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F01 Dynamic Driving Systems

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Dynamic Driving Systems

Model: F01/F02

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Understand Integrated Chassis Management on the new 7-series
- Understand “Higher Level” driving dynamics control
- Understand the interaction between various chassis dynamics systems

Introduction

Integrated Chassis Management (ICM)

History

A central, higher-level driving dynamics control system was first introduced in BMW vehicles several years ago.

The introduction of the longitudinal dynamics management system in the BMW 3 Series (E9x) was the first step in this direction. The longitudinal dynamics control functions, Dynamic Cruise Control and Active Cruise Control, were integrated into one control unit, the LDM control unit. These integrated functions considerably enhanced the harmony and coordination of drive and brake actuation.

The Vertical Dynamics Management made its debut in the BMW X5 (E70) with the VDM control unit: the integrated Vertical Dynamics Control (VDC) function controls the adjustable dampers. In contrast to the earlier system, not only ride-level heights and vertical acceleration are used as the input signals. Instead, the higher-level control strategy of the Vertical Dynamics Control takes all signals relevant to driving dynamics into account, including, for example, road speed, and longitudinal and lateral acceleration.

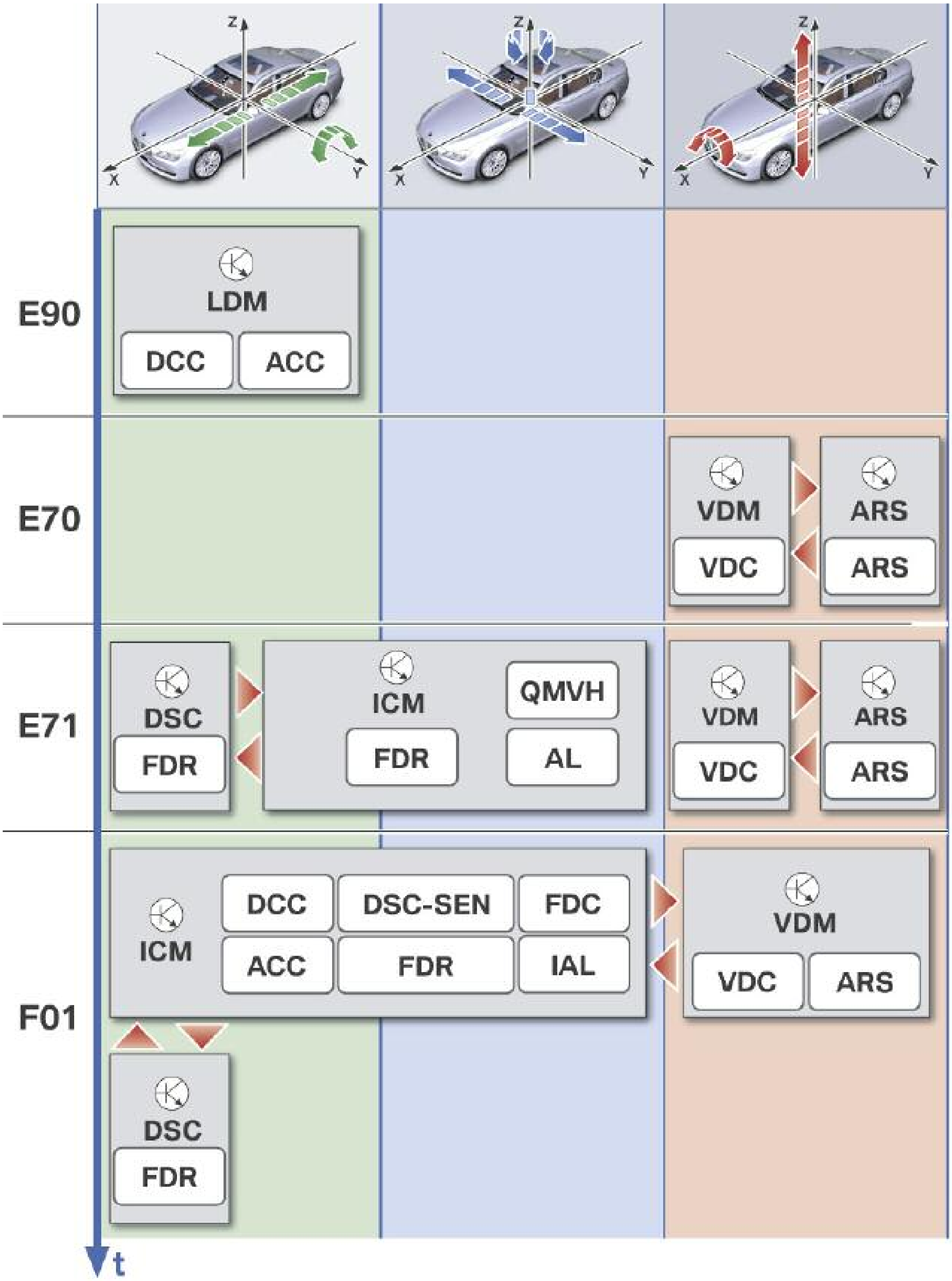
The VDM control unit also coordinates the Vertical Dynamic Control and Active Roll Stabilization (ARS) functions. Overall, this meant that wheel contact with the road surface was improved and the vertical movement of the body reduced for a wider variety of road situations.

In addition to the VDM control unit, the BMW X6 (E71) was also equipped with an ICM control unit that for the first time incorporates both the longitudinal and lateral dynamics control functions. The longitudinal and lateral motion of the vehicle is evaluated centrally in the ICM control unit.

Following on from this development, the dynamic driving systems Active Steering and Dynamic Performance Control are now used and their interaction is of course also coordinated by the ICM control unit.

Significant at this stage is the definition of the ICM as the main control unit for the control functions. The actuators on the other hand are activated by control units specially intended for this purpose.

Evolution stages of Integrated Chassis Management



Index	Explanation
LDM	Control unit, Longitudinal Dynamics Management
DCC	Dynamic Cruise Control function (cruise control with braking function)
ACC	Active Cruise Control function
VDM	Control unit, Vertical Dynamics Management
VDC	Vertical Dynamics Control function
ARS	Control unit or function, Active Roll Stabilization (Dynamic Drive)
DSC	Control unit, Dynamic Stability Control
FDR	Driving dynamics control function
ICM	Control unit, Integrated Chassis Management
QMVH	Lateral torque distribution at rear axle (Dynamic Performance Control)
AL	Active Steering function
DSC-SEN	DSC sensor in the ICM control unit
FDC	Driving dynamics control switch
IAL	Integral Active Steering function

The red triangles denote interaction between the control units and functions. This is not always purely be an exchange of sensor signals. Control signals and reference values may be also used (for example) to influence the driving dynamics control in the ICM control unit or the Active Roll Stabilization in the VDM control unit.

New Control Units

Two newly developed control units for dynamic driving systems will also be used in the F01/F02:

- Integrated Chassis Management (ICM) and
- Vertical Dynamics Management (VDM).

Although their names are already familiar from the E70/E71, they differ considerably in their functional range and design.

A multitude of driving dynamics functions is concentrated in these control units.

In addition to central signal provision, the essential functions of the ICM control unit are concerned with longitudinal and lateral dynamics. These include the control function for the new Integral Active Steering, for example.

The vertical dynamics functions on the other hand are incorporated in the VDM control unit: Vertical Dynamics Control in the 2nd generation and Active Roll Stabilization (also: Dynamic Drive).

Although both control units are standard equipment, two expansion stages are available in each case, depending on the options fitted to the vehicle.

■ ICM control unit expansion stages

The basic version of the ICM control unit is fitted as standard in the F01/F02. In this case, the vehicle is provided with the Servotronic steering system and cruise control driver assistance function with braking function.

The high-performance version of the ICM control unit is used if one or both of the following options are ordered by the customer:

- Integral Active Steering
- Active Cruise Control with Stop & Go function

■ Expansion stages of VDM control unit

The basic version of the VDM control unit contains the Vertical Dynamics Control function. This is included in the standard equipment of the F01/F02.

The high-performance version of the VDM control unit is fitted if the customer also orders the option Active Roll Stabilization (ARS). The high-performance version also incorporates the output stages required for activation of the hydraulic valves in the ARS.

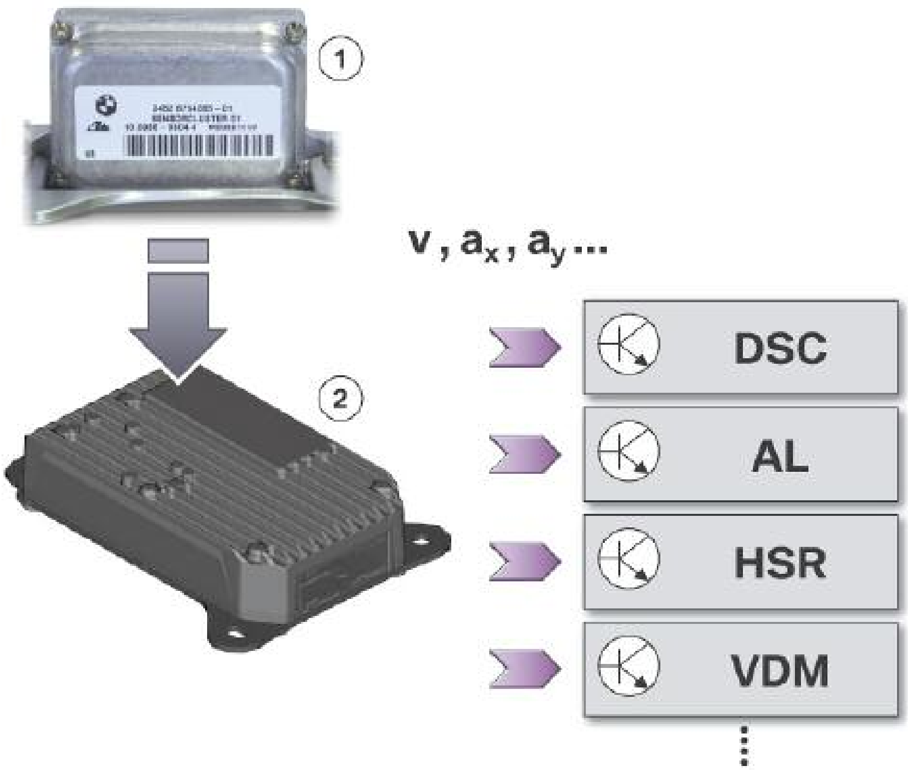
New Evolution Stage in Driving Dynamics Control

The notion of “Integrated Chassis Management” is significantly developed further in the F01/F02. The two main objectives were to improve the performance and interaction of the individual dynamic driving systems. In order to achieve the desired dynamic effect in each road situation, the most suitable actuator can now be selected and activated. It may of course be useful to operate several actuators in tandem. Examples of this are activating the brakes for individual wheels or superimposing a steering angle using Integral Active Steering.

A further task of the ICM control unit is to make the driving dynamics condition available throughout the entire vehicle through in the form of signals. This is why the DSC sensor in the F01/F02, which was previously fitted separately, has now been integrated into the ICM control unit.

This means that all systems have access to the same information provided by the ICM control unit. As a consequence, the potential for errors, particularly in networked systems, is reduced and the system reliability of systems is increased. Further, this simplifies the diagnosis of the interconnected system as the fault code memory entries for the driving dynamics signals are now stored centrally in the ICM control unit and are no longer distributed between many control units.

Driving dynamics signals provided by the ICM control unit



Index	Explanation	Index	Explanation
1	DSC sensor integrated into the ICM control unit	DSC	Dynamic Stability Control
2	ICM control unit	AL	Active Steering
v	Road speed	HSR	Rear axle slip angle control
ax	Longitudinal acceleration	VDM	Vertical Dynamics Management
ay	Lateral acceleration		

The result for the customer is perfect harmony in terms of vehicle handling - irrespective of the equipment specification and road situation. This uses the possibilities for maximizing convenience, agility and stability to the full.

The customer's experience of this harmony in terms of vehicle handling is especially enhanced by the new **Driving Dynamics Control** function. This offers several particularly distinctive vehicle characteristics that determine how the vehicle handling as a whole is perceived by the driver and passengers. The driver can use the driving dynamics switch to select a characteristic that perfectly matches the specific driving requirement or section of road.

Standard Equipment and Options

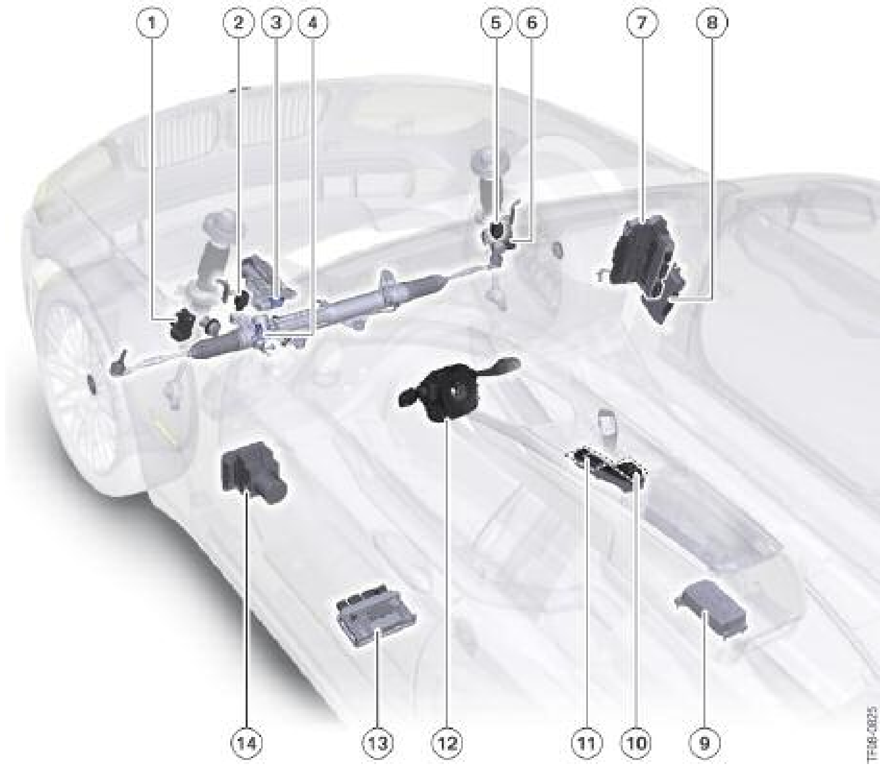
The following table shows the standard equipment and options available for dynamic driving systems. A specific model (750i) has been selected in order to compare the functions and equipment levels of the E65 and F01.

Dynamic Driving System	E65/E66		F01/F02	
	Standard	**Optional**	**Standard**	**Optional**
Higher Level Driving Dynamics Systems				
Integrated Chassis Management			●	
Driving Dynamics Control			●	
Longitudinal Dynamics				
Dynamic Stability Control	●		●	
Electro-Mechanical Parking Brake (EMF)	●		●	
Lateral Dynamics				
Servotronic	●		●	
Integrated Active Steering (IAL)				●
Vertical Dynamics				
Electronic Damping Control (continuous) EDC-K		●		
Vertical Dynamics Control 2 (VDC 2)			●	
Active Roll Stabilization	●			●
Electronic Height Control		● (E65/66)	● (F02)	
Driver Assistance				
Cruise Control (FGR)	●			
Cruise Control with braking function (DCC)			●	
Active Cruise Control (ACC)		●		
Active Cruise Control with Stop and Go (ACC Stop and Go)				●

System Overview

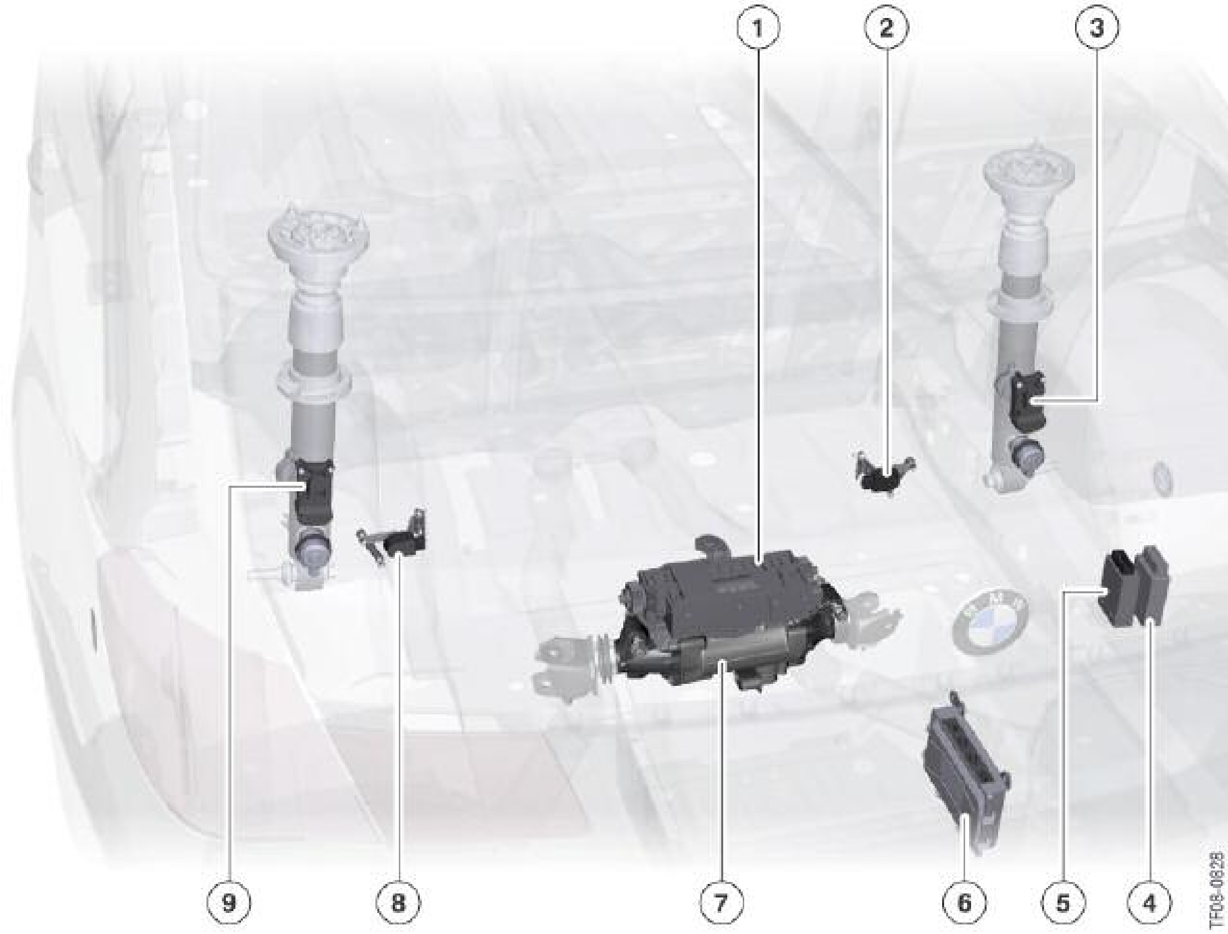
Installation Locations in the Vehicle

Control units, sensors and actuators of the dynamic driving systems in the F01/F02



Index	Explanation
1	Electronic Damping Control satellite, front left
2	Ride-height sensor, front left
3	Valve for electronic flow rate adjustment of power steering pump (EVV)
4	Servotronic valve
5	Ride-height sensor, front right
6	Electronic Damping Control satellite, front right
7	Junction box electronics and fuse carrier, front
8	Control unit for Vertical Dynamics Management
9	Control unit for Integrated Chassis Management
10	Buttons for electromechanical parking brake and Automatic Hold
11	Driving dynamics switch and DTC button
12	Steering column switch cluster with steering angle sensor
13	Control unit for Active Steering
14	Control unit and hydraulic unit for Dynamic Stability Control

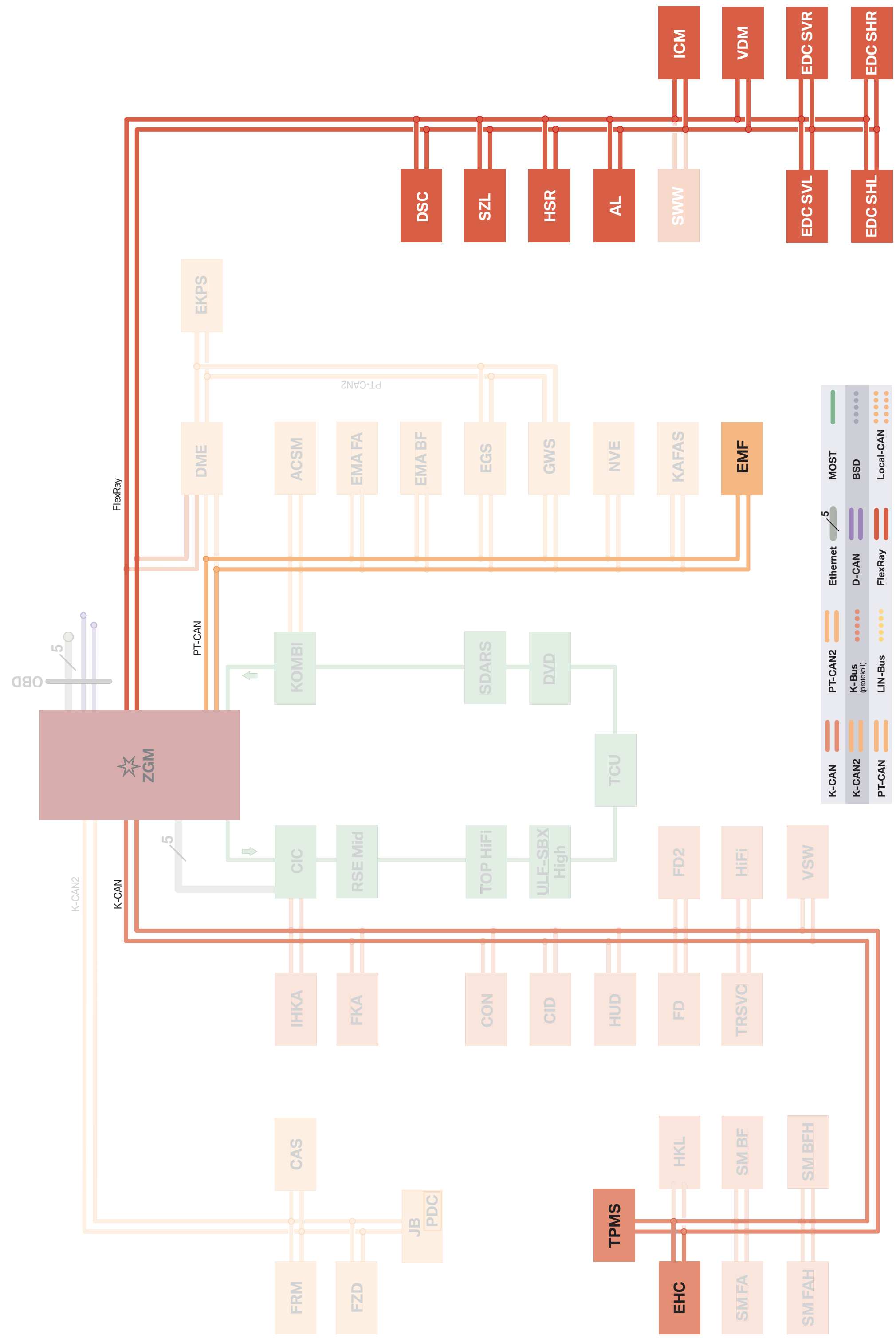
Control units, sensors and actuators of the dynamic driving systems in the F01/F02 (2)



Index	Explanation
1	Control unit and actuating unit for electromechanical parking brake
2	Ride-height sensor, rear right
3	Electronic Damping Control satellite, rear right
4	Control unit for TPMS
5	Control unit for electronic ride-height control
6	Control unit for rear axle slip angle control
7	Actuating unit for rear axle slip angle control
8	Ride-height sensor, rear left
9	Electronic Damping Control satellite, rear left

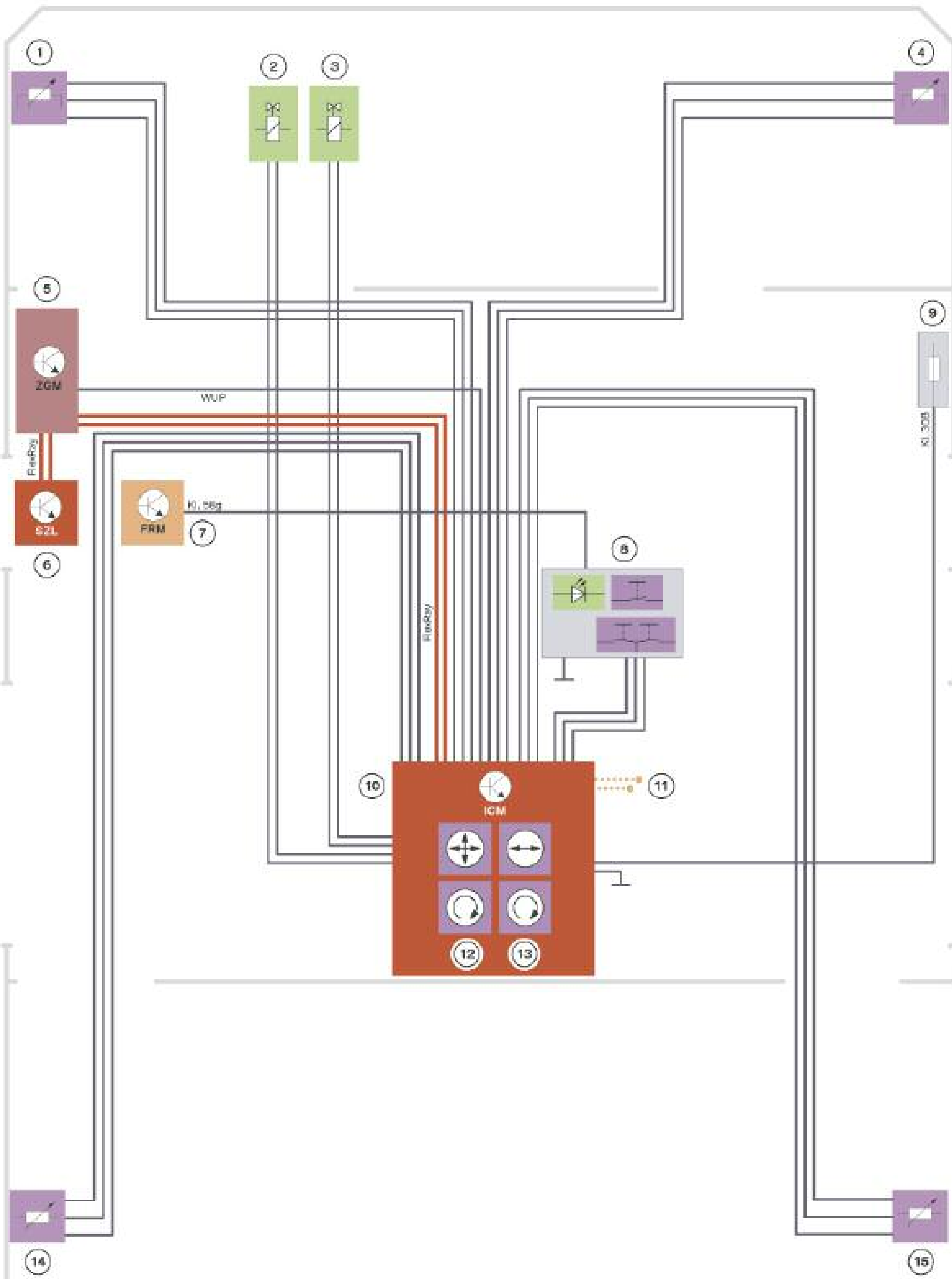
Both graphics show the installation locations of the most important control units, sensors and actuators of the dynamic driving systems in the F01/F02. These have been split into two graphics to maintain clarity of overview and not for functional reasons.

Bus System Overview for Dynamic Driving Systems



Index	Explanation
AL	Active Steering
DSC	Dynamic Stability Control
EHC	Electronic ride-height control
EDC SHL	Electronic Damping Control satellite, rear left
EDC SHR	Electronic Damping Control satellite, rear right
EDC SVL	Electronic Damping Control satellite, front left
EDC SVR	Electronic Damping Control satellite, front right
EMF	Electromechanical parking brake
ICM	Integrated Chassis Management
HSR	Rear axle slip angle control
TPMS	Tire Pressure Monitoring System
SZL	Steering column switch cluster with steering angle sensor
VDM	Vertical Dynamics Management
ZGM	Central gateway module

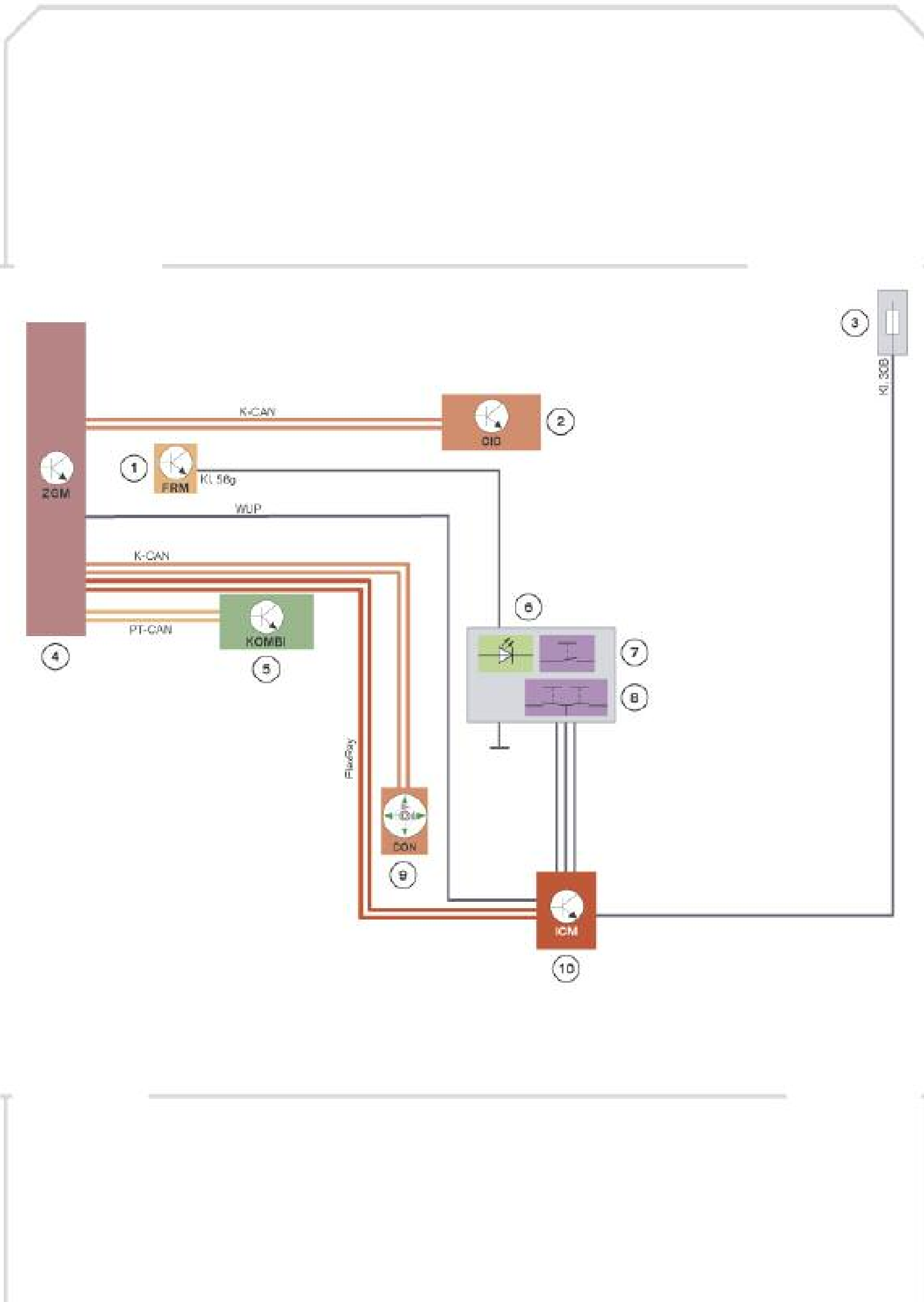
Integrated Chassis Management System Circuit Diagram



Index	Explanation
1	Ride-height sensor, front left
2	Servotronic valve
3	EVV valve
4	Ride-height sensor, front right
5	Central gateway module
6	Steering column switch cluster with steering angle sensor
7	Footwell module
8	Driving dynamics switch and DTC button
9	Fuse for ICM control unit (fuse carrier at front, junction box electronics)
10	Integrated Chassis Management
11	Local CAN
12	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)
13	Redundant DSC sensor in the ICM control unit (lateral acceleration, yaw rate)
14	Ride-height sensor, rear left
15	Ride-height sensor, rear right

The purpose of the local CAN is to connect the ICM control unit to the radar sensors for the Active Cruise Control with Stop & Go function.

Driving Dynamics Control System Circuit Diagram



Index	Explanation
1	Footwell module
2	Central Information Display
3	Fuse for ICM control unit (fuse carrier at front, junction box electronics)
4	Central gateway module
5	Instrument cluster
6	Operating unit for center console with locating lamp
7	DTC button
8	Driving dynamics switch
9	Controller
10	Integrated Chassis Management

This system circuit diagram shows the operator control and display elements for the driving dynamics control function. For clarity of overview, the drive and dynamic driving systems upon which the driving dynamics control acts have been omitted. These are described in the Functions section instead.

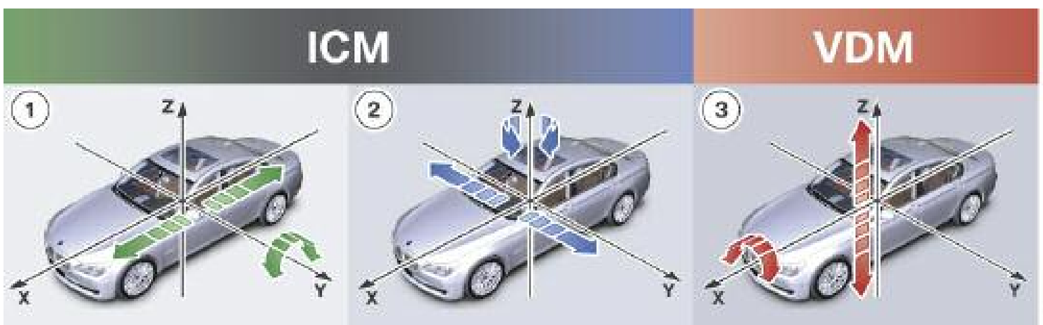
Functions

Integrated Chassis Management

Overview
With the E71, the notion of a higher-level driving dynamics control system was implemented for the first time in a standard model. This central function is also referred to as "Integrated Chassis Management" ("ICM" for short) and is integrated in the control unit of the same name in the E71.

The previous strategy was to use one control unit to perform the control tasks for each main movement direction. This approach was not employed in the E71 or the F01/F02.

Control units and main movement directions of vehicle



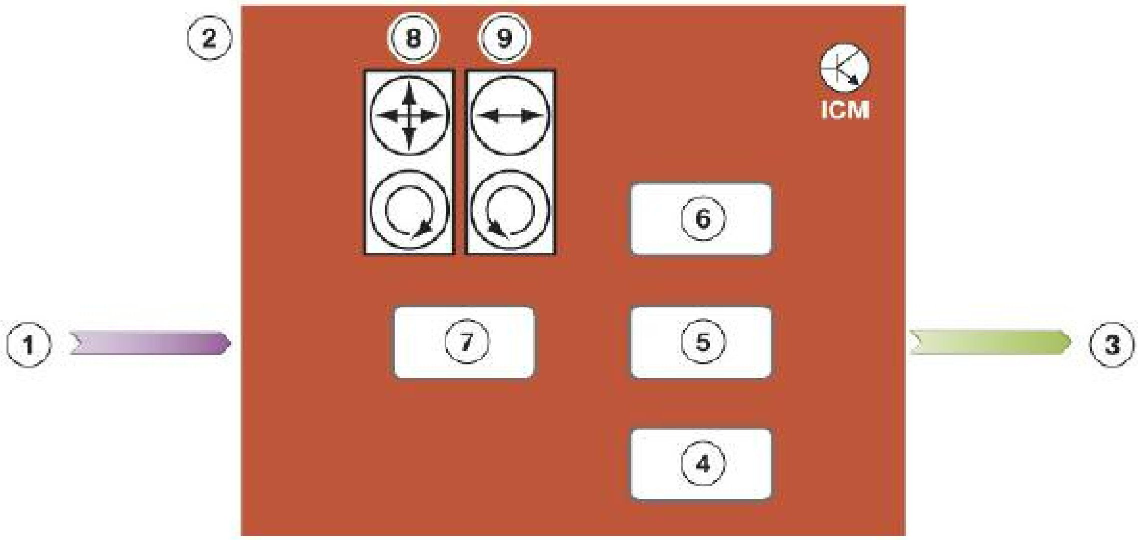
Index	Explanation	Index	Explanation
1	Longitudinal dynamics	ICM	Integrated Chassis Management
2	Lateral dynamics	VDM	Vertical Dynamics Management
3	Vertical dynamics		

As is the case in the E71, the new ICM control unit in the F01/F02 essentially performs the calculations for the control functions that influence the longitudinal and lateral dynamics. The actuators are activated by separate control units (e.g. AS control unit). The functional range of the ICM control unit in the F01/F02 has grown considerably when compared to the E71.

The Vertical Dynamics Management (VDM) is still responsible for controlling the vertical dynamics. The vertical dynamic control and dynamic drive functions are therefore accommodated in the VDM control unit. Signals that provide information on the current driving situation are obviously exchanged between the ICM and VDM.

The main focus of this section is to describe the functions of the ICM control unit. An introductory overview of these functions is provided in the following illustration and explanation. The functions are dealt with in more depth in the following chapters.

Functions in the ICM control unit



Index	Explanation
1	Input signals from external sensors
2	Integrated Chassis Management
3	Output signals (target values at actuators and actuator control units)
4	Driver assistance functions
5	"Central driving dynamics and steering control" function
6	"Sensor signal processing and signal provision" function
7	"Driving dynamics control" function
8	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)
9	Redundant DSC sensor in the ICM control unit (lateral acceleration, yaw rate)

Signal Provision

The ICM control unit reads signals from external and also internal sensors. These sensor signals are processed and converted into physical signals that describe the driving dynamics of the vehicle, and are subsequently made available to a large number of systems in the vehicle. Examples of these signals are road speed and lateral acceleration.

The central driving dynamics control system in the ICM firstly evaluates the current driving condition and driver's command, also taking the dynamic driving systems installed in the vehicle into account.

On the basis of this information, the system decides whether or not to intervene in the driving dynamics, and also the extent the intervention. The highly intelligent dynamic driving systems permit slight and barely noticeable interventions as soon as e.g. a tendency towards understeering is detected.

A coordinator ensures that the most suitable actuator is activated in each case. Where several actuators are used simultaneously, a great deal of importance has been placed on ensuring that these interventions are in perfect harmony.

The driving dynamics control provides the driver with the choice of one of four driving dynamics settings (Normal, Comfort, Sport and Sport+). By making this choice, the driver influences the central driving dynamics control system and therefore all dynamic driving systems and drive train systems. All systems are matched appropriately to every setting and, most importantly, their interaction with each other within one specific setting is also perfectly coordinated. The status of the Dynamic Stability Control is also taken into account thus ensuring that two additional driving dynamics specifications are possible.

The ICM control unit is also responsible for the Servotronic function including valve actuation. This steering control function is also influenced by the driving dynamics control.

Driver Assistance Functions

The ICM control unit incorporates the “Cruise control with braking” and “Active Cruise Control with Stop & Go” control functions. In addition, the ICM coordinates activation of the vibration actuator in the steering wheel for the “Lane Departure Warning” and “Active Blind Spot Detection” driver assistance functions.

Signal Provision

Signals from integrated sensor system

The sensors that were previously accommodated separately in the DSC sensor are now installed in the ICM control unit. The following variables can be recorded with these sensors.

- Longitudinal acceleration and pitch of the road or vehicle in the longitudinal direction
- Lateral acceleration and pitch of road or vehicle in lateral direction
- Rotational speed around vertical axis (yaw rate)

The sensor signals are initially referenced to the sensor housing. However, to be useful to the dynamic driving systems, these variables must be referenced to the vehicle coordinate system. The ICM control unit performs the necessary conversion. A synchronization process is carried out when the ICM control unit is started up during which appropriate correction values are determined and saved.

Note: Calibration of the sensors integrated into the ICM control unit is necessary in the following cases:

- **the ICM control unit has been replaced or**
- **if requested by the test schedule in the diagnostic system due to a fault code memory entry.**

The calibration must be performed with the vehicle standing on a level surface in the longitudinal and lateral direction. Terminal 15 must be switched on.

Signals from External Sensors

The ICM control unit imports the following signals that are important for dynamic driving systems from external sources:

- Wheel speeds, four signals transmitted via FlexRay from DSC.
- Ride-level heights, four signals, wired directly to ICM control unit.
- Steering wheel angle, transmitted via FlexRay from steering column switch cluster.
- Position of actuators for Active Steering and rear axle slip angle control, transmitted via FlexRay.

The ICM calculates the actual **speed** at which the vehicle moves along the driving axis on the road based on the four **wheel-speed signals**. If dynamic driving systems intervene and affect the wheel speeds, this is taken into account in the calculation. The status of the ABS control (for example) is also imported in this instance.

The road speed thus determined for the first time in the F01/F02 is now used as the reference for practically all systems in the vehicle. This means that a multiple calculation no longer needs to be performed in many other control units.

The ICM control unit also derives the following information from the wheel-speed signals:

- **Distance** travelled
- **Wheel tolerance check:** The marginal differences in wheel speeds (e.g. due to differences in tire diameter) are identified and adjusted by the ICM.
- **Snow chain detection:** If snow chains are fitted, the driver can enter this information manually via the Central Information Display. The wheel speeds are also used by the HSR control unit to automatically determine whether snow chains are mounted on the rear wheels. The result of this identification is transmitted to the ICM control unit via the FlexRay.

Although, from a theoretical standpoint, it may be more appropriate to assign the **ride-height sensors** to the Vertical Dynamics Management, the four ride-height sensors are directly connected to the ICM control unit.

The ICM control unit imports the analog voltage signals of the ride-height sensors. These are converted into the actual ride-level heights in millimeters. To perform this conversion, the ICM control unit must be able to map the voltage signals it receives to reference values as otherwise it will not be able to determine the actual ride-level heights. These reference values are determined by means of a synchronization procedure.

The harmonized ride-level heights are made available by the ICM control unit as bus signals. They are imported from:

- the Vertical Dynamics Management system for the Vertical Dynamics Control and Active Roll Stabilization and also from the
- footwell module for the headlight-range adjustment function.

The ride-level heights are not transmitted as bus signals for the purposes of electronic ride-height control (EHC). Instead, an additional direct line connection exists between the ride-height sensors of the rear axle and the EHC control unit.

The ICM control unit determines the resulting steering lock angle of the front wheels based on the steering wheel angle and location of the Active Steering actuator motor.

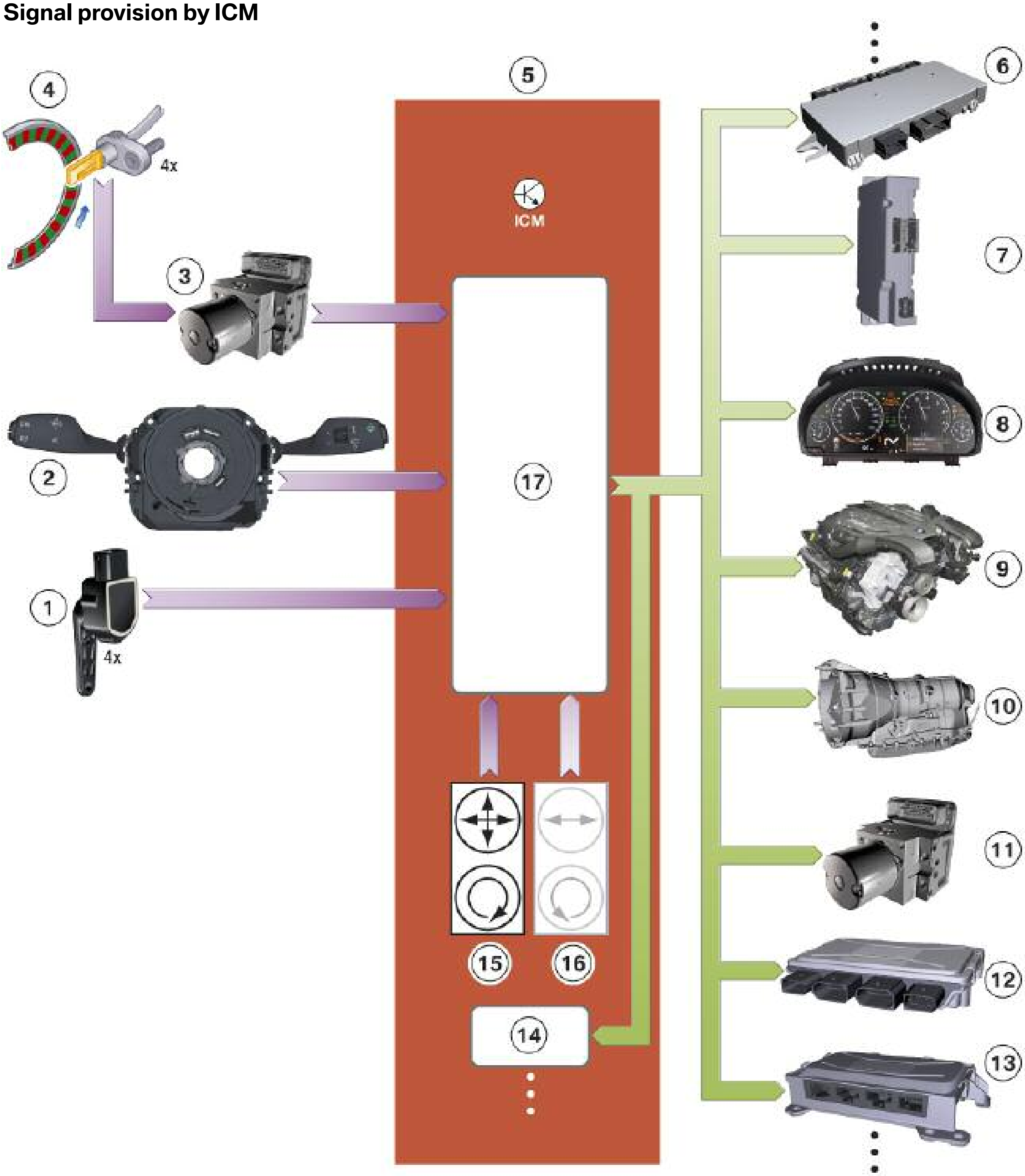
As the rear axle can also be steered, a reliable conclusion regarding the driving dynamics cannot be obtained purely on the basis of the steering angle of the front wheels. This is why the ICM control unit also takes the steering angle of the rear wheels into account. The **effective steering angle** (of the front and rear wheels) is then determined using both steering angles.

This is a purely theoretical computing value that indicates the steering lock of the vehicle's front wheels that would be required to achieve the same vehicle motion if the rear axle could not be steered. The easiest way for all systems in the vehicle to evaluate the data on the steering wheel movement is to use this effective steering angle.

NOTES PAGE

Processing and distribution of signals

Signal provision by ICM



Index	Explanation	Index	Explanation
1	Ride-height sensors	10	Electronic transmission control unit
2	Steering column switch cluster with steering angle sensor	11	Dynamic Stability Control
3	Dynamic Stability Control	12	AS control unit
4	Wheel-speed sensors	13	HSR control unit
5	Integrated Chassis Management	14	Driving dynamics functions in the ICM control unit
6	Footwell module	15	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)
7	KAFAS control unit	16	Redundant DSC sensor in the ICM control unit (lateral acceleration, yaw rate)
8	Instrument cluster	17	"Signal processing" function in the ICM control unit
9	Engine control system		

The signals from the sensors are processed before being made available in the vehicle via the FlexRay bus system. Specific examples of this have already been referred to above. To formulate this in more general terms, the ICM control unit uses all available sensor signals and several computing models to improve the quality of the signals provided. This means that they contain fewer errors and therefore allow the signal “users” (e.g. the dynamic driving systems) to operate with a greater degree of precision.

A new aspect of the F01/F02 is that the signals are not available to just a few systems in the vehicle.

In the F01/F02, the signals provided by the ICM are not used exclusively by the dynamic driving systems. The drive control units, driver assistance systems, information systems and body electrical system share the signals, instead of recording or preparing these separately.

Note: This has a distinct advantage when it comes to the diagnosis of signal faults: Faults in all signals described here are stored centrally in the fault memory of the ICM control unit.

In previous vehicles, it was possible for one signal fault to produce a large number of branches in the test schedule trees. The ICM architecture in the F01/F02 means that the test schedule can quickly pinpoint the ICM control unit in the event of a signal fault.
The test schedule then shows the effective repair measure in each case.

Higher-level Driving Dynamics Control

Observation of the Driving Condition

The Integrated Chassis Management (ICM) control unit calculates the current driving situation from the signals listed below. This essentially means the longitudinal and lateral dynamic driving condition.

- Wheel speed signals from all four wheels
- Longitudinal acceleration
- Lateral acceleration
- Yaw rate

The ICM control unit therefore knows how the vehicle is actually moving at this point.

To be able to optimize the vehicle behavior, the dynamic driving systems require information about how the driver wishes the vehicle to move. The driver's command is determined from the following signals:

- Accelerator pedal angle and current engine torque and gear ratio
- Application of the brake pedal and current brake pressure
- Effective steering angle and steering-angle speed.

The driving condition and driver's command are provided both internally and externally by the ICM control unit. The central driving dynamics control acts as a receiver internally in the ICM control unit. The control units of the dynamic driving systems (e.g. DSC) are the external receivers. They receive the driving condition and the driver's command from the ICM control unit via the FlexRay bus system.

Central Driving Dynamics Control

The aim of the interventions by the dynamic driving system is to improve agility and traction. If required, they can of course also restore the stability of the vehicle. In previous vehicles, separate systems existed that were designed to do this and although they in fact communicated with each other, they tended to have a more restricted range of tasks. The interaction of all systems that ultimately determines the overall driving characteristics was therefore difficult to coordinate.

The Integrated Chassis Management of the F01/F02 incorporates the central driving dynamics control. This compares the command given by the driver with the actual movement of the vehicle at that point and therefore determines whether intervention of the dynamic driving system is required, and also the extent of the intervention.

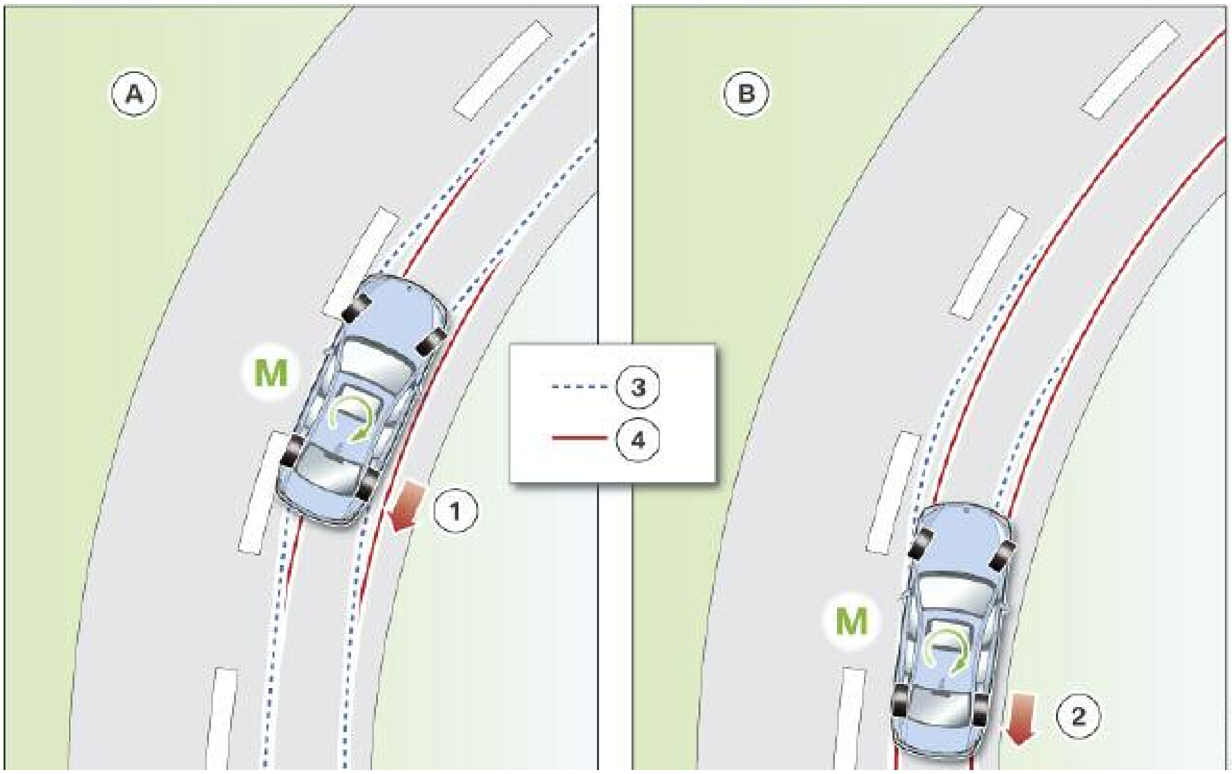
The yawing force is an output variable of the central driving dynamics control system. This produces a rotation of the vehicle that is superimposed on the existing movement of the vehicle.

This can be used to “readjust” the driving characteristics if the result identified does not match the driver’s command. Classic examples of this are understeering or oversteering driving characteristics.

A new feature of the ICM installed in the F01/ F02, however, is that the dynamic driving systems are already deliberately activated before a deviation of this nature is identified. The interventions of the dynamic driving systems therefore take place long before the driving characteristics become unstable.

This produces a far more harmonious effect in the vehicle than would be possible from a conventional chassis design. The vehicle reacts neutrally in many more situations and does not even begin to understeer or oversteer. This new function is possible through the use of extremely precise computing models and new control strategies that can be used to evaluate and influence the driving characteristics.

Influencing the driving characteristics using the driving dynamics control system



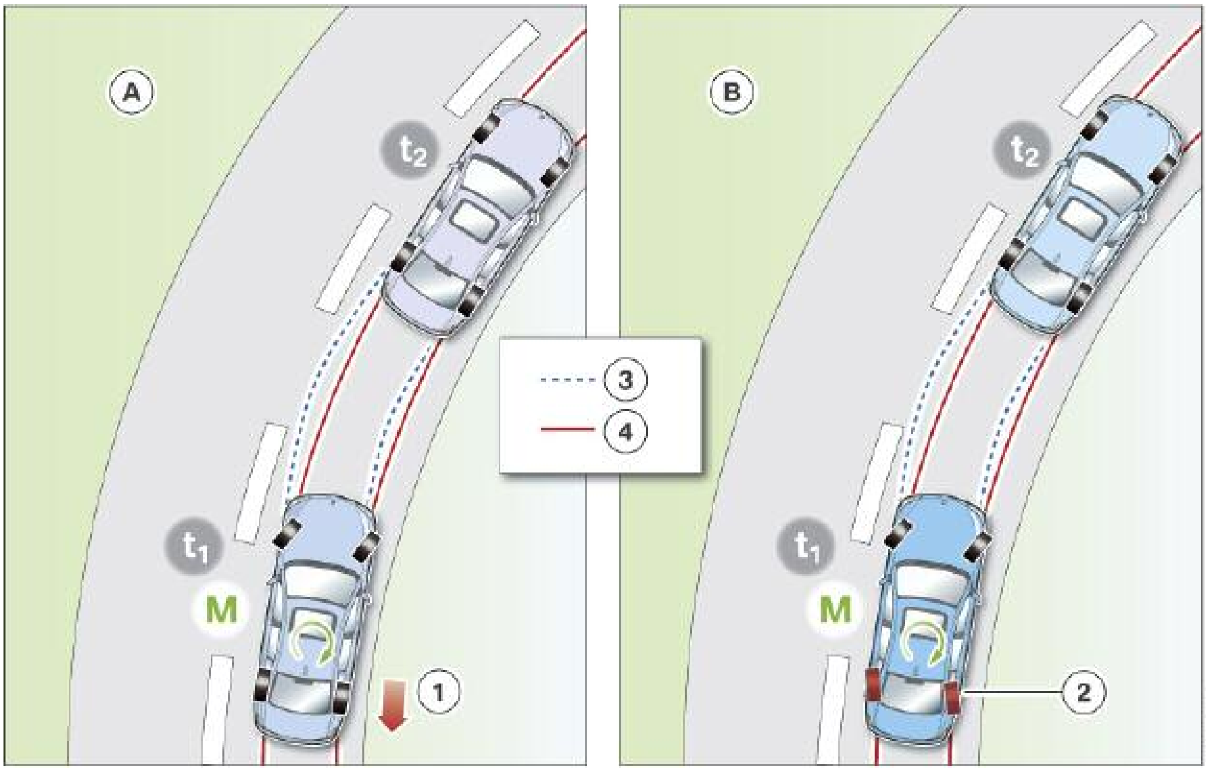
Index	Explanation
A	Correction of unstable driving characteristics
B	Intervention at an early stage to achieve neutral driving characteristics
1	Braking intervention at individual wheels in order to correct understeering
2	Braking intervention at individual wheels in order to prevent understeering
3	Course of an understeered vehicle
4	Course of a vehicle with neutral driving characteristics
M	Yawing force that acts on the vehicle due to braking intervention (at individual wheels)

Coordinated Intervention by the Dynamic Driving Systems

The following intervention options for producing the yawing force calculated by the central driving dynamics control system have been available up till now (and will of course remain available) -the corresponding dynamic driving systems are shown in brackets:

- Individual activation of the wheel brake (DSC)
- Adjustment of the current engine torque (ASC+T, DSC, MSR)
- Adjustment of the steering angle of the front wheels, regardless of the driver's input (Active Steering).

Possible driving dynamics interventions during understeering



Index	Explanation
A	Prevention of understeering by means of braking at individual wheels
B	Prevention of understeering by means of steering intervention at rear axle
1	Braking intervention at individual wheels
2	Steering intervention at the rear axle
3	Course of an understeered vehicle
4	Course of a vehicle with neutral driving characteristics
M	Yawing force that acts on the vehicle due to braking intervention (at individual wheels)

The option of influencing the lateral dynamics of the vehicle - the rear axle slip angle control (HSR) - was available for the first time in the F01/F02. The customer only receives this innovative dynamic driving system in combination with the established Active Steering feature. This option is referred to as “Integral Active Steering”.

A function referred to as “Actuator coordination” follows the central driving dynamics control. This decides which dynamic driving system should be used to produce the yawing force in the specific road situation.

For example, if the vehicle has a tendency to sharply understeer this can be counteracted by means of selective braking intervention at the back wheel on the inside of the curve. If the vehicle is equipped with Integral Active Steering, the same objective can be achieved more harmoniously by applying an appropriate steering angle at the rear axle.

As both actuating options are limited, it may also be beneficial to apply both at once. If understeering is avoided the driver becomes aware of this due to the considerable increase in agility.

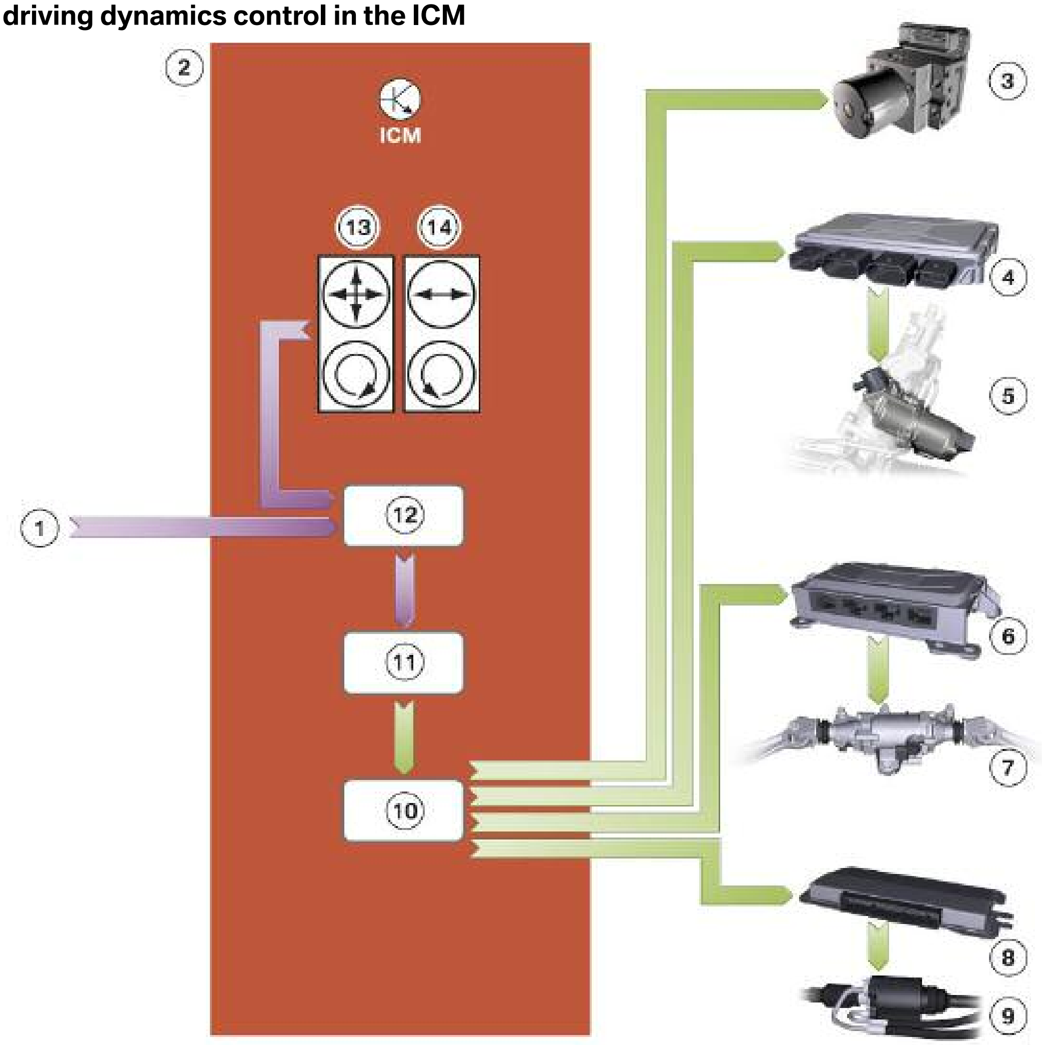
The F01/F02 is the first instance where genuine functional networking between the integrated chassis management and Vertical Dynamics Management functions also takes place. This does not simply mean that the ICM records and processes ride-height information and then delivers it to the VDM.

The ICM also actively controls the Active Roll Stabilization as an integral part of central driving dynamics control in order to influence the self-steering characteristics. As the conventional chassis design already demonstrates, a more rigid anti-roll bar on one axle means that the overall achievable cornering stability on the same axle is lower. The effects of more or less rigid anti-roll bars can be emulated with the aid of the hydraulic motors in the anti-roll bars of the Dynamic Drive. This means that the central driving dynamics control of the ICM can selectively influence the degree of available lateral force on one axle via the active anti-roll bars of Dynamic Drive.

If the vehicle is currently oversteering, the cornering force at the rear axle is insufficient. The roll stabilizing torque at the rear axle tends to reduce in this case. This loss of torque is compensated for by additional cornering stability at the rear axle which helps stabilize the vehicle.

The activity of the central driving dynamics control in the ICM control unit is summarized in the input/output graphic on the following page.

Central driving dynamics control in the ICM

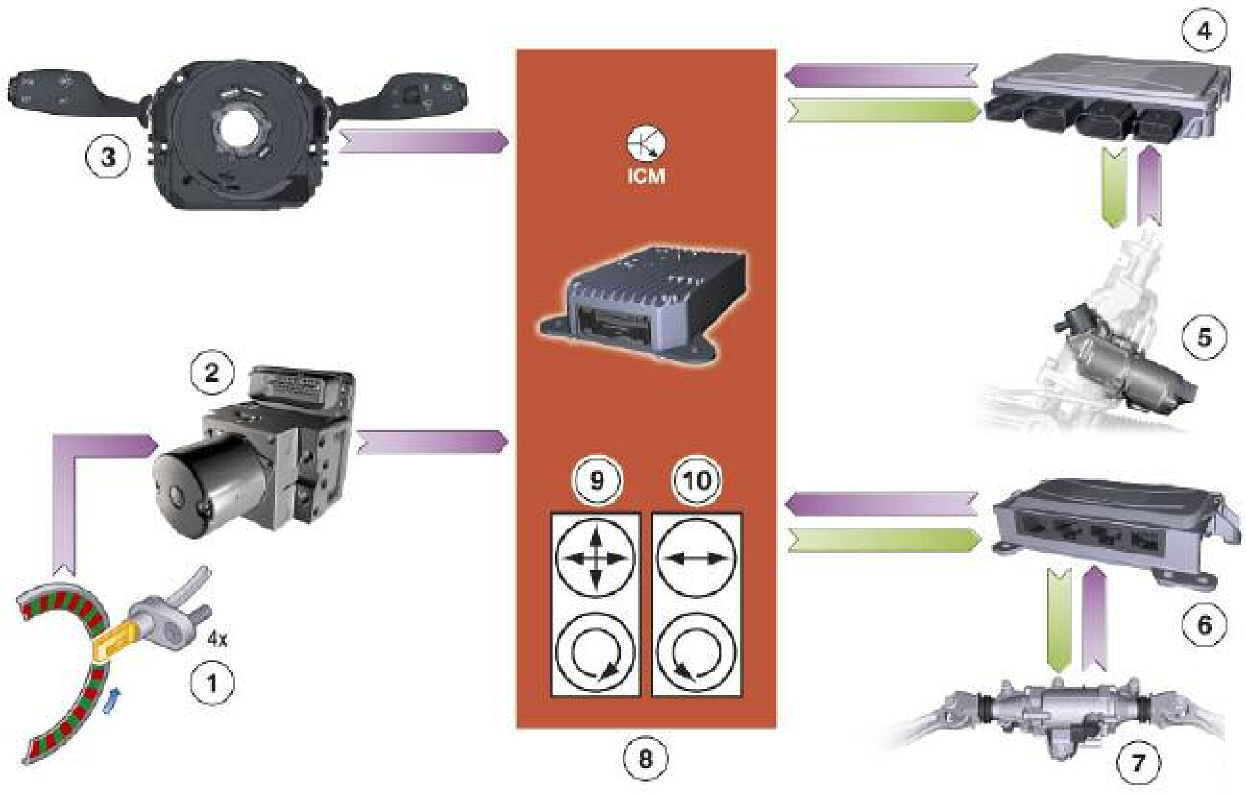


Index	Explanation	Index	Explanation
1	Input signals from external sensors	8	VDM control unit
2	Integrated Chassis Management	9	Active anti-roll bar
3	Dynamic Stability Control	10	"Actuator coordination" function
4	AS control unit	11	"Central driving dynamics control" function
5	AS actuating unit	12	"Sensor signal preparation" function
6	HSR control unit	13	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)
7	HSR actuating unit	14	Redundant DSC sensor in the ICM control unit (lateral acceleration, yaw rate)

Distributed functions: ICM and actuator control units

A description of the distribution of tasks between the ICM and the other driving dynamics control units follows using Integral Active Steering as an example.

ICM and actuator control units AS and HSR



Index	Explanation	Index	Explanation
1	Wheel-speed sensors	6	HSR control unit
2	Dynamic Stability Control	7	HSR actuating unit
3	Steering column switch cluster with steering angle sensor	8	Integrated Chassis Management
4	AS control unit	9	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)
5	AS actuating unit	10	Redundant DSC sensor in the ICM control unit (lateral acceleration, yaw rate)

The Integrated Chassis Management (ICM) is the control unit that performs the calculations for higher-level driving dynamics functions of the Integral Active Steering.

The Integrated Chassis Management uses the current driving situation and the driver's directional input to calculate the individual setpoint values for the variable steering-transmission ratio and the Yaw-Rate Control Plus. Once these have been prioritized, the ICM produces a reference value for the AS and HSR control unit respectively. This is a reference angle that should be set at the front or rear wheels.

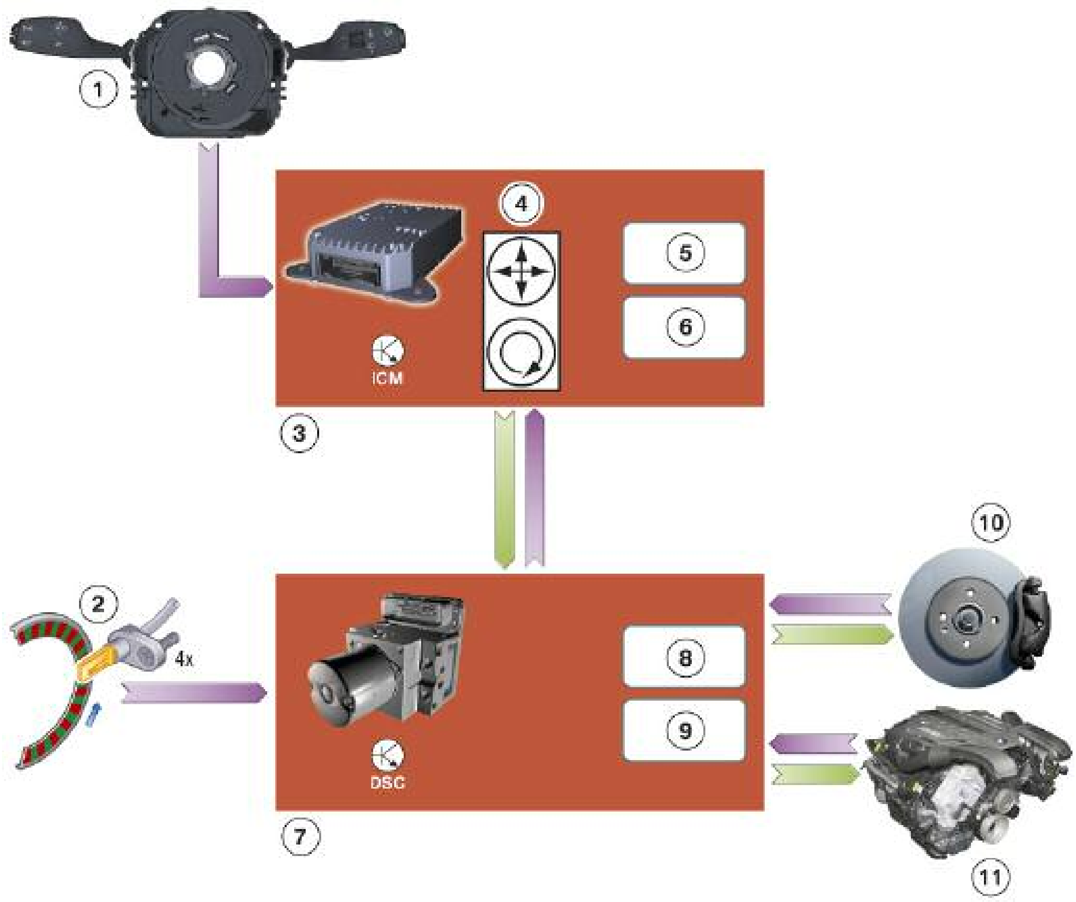
The AS control unit receives this reference value and has the principal task of controlling the actuating elements in order to achieve the reference value. The AS control unit is therefore purely an actuator control unit. The same applies for the HSR control unit: this is also an actuator control unit. As with the AS control unit, this control unit is purely responsible for implementing the reference steering angle requested by the ICM.

This type of task distribution was implemented for the first time with the introduction of the ICM in the E71. The expansions in the F01/F02 mean that

- the ICM now controls all longitudinal and lateral dynamics systems centrally (AS, HSR and also DSC) and that
- ICM is the master control unit both in the linear range and also in unstable driving conditions.

However, the interface between the Integrated Chassis Management and Dynamic Stability Control is a special case.

Input/Output: interaction of ICM and DSC



Index	Explanation	Index	Explanation
1	Steering column switch cluster with steering angle sensor	7	Dynamic Stability Control
2	Wheel-speed sensors	8	"Driving dynamics control" function in DSC control unit
3	Integrated Chassis Management	9	"Actuator control" function
4	DSC sensor in the ICM control unit (longitudinal acceleration, lateral acceleration, yaw rate)	10	Wheel brake
5	"Driving dynamics control" function in the ICM control unit	11	Drive
6	"Actuator coordination" function		

The Dynamic Stability Control also has its own internal driving dynamics controller that normally implements the reference value (reference yawing force) sent from the ICM control unit in the F01/F02. This is achieved through braking intervention at individual wheels and also by influencing the input torque.

The DSC driving dynamics controller is also able to detect an unstable road situation itself using corresponding signals on the driving condition provided by the ICM in which case the stabilizing braking or engine interventions are implemented automatically by DSC. Corresponding feedback is of course also sent to the ICM. In this case, the interventions of the driving dynamics control in the ICM are cancelled.

Control and Adjustment of Steering

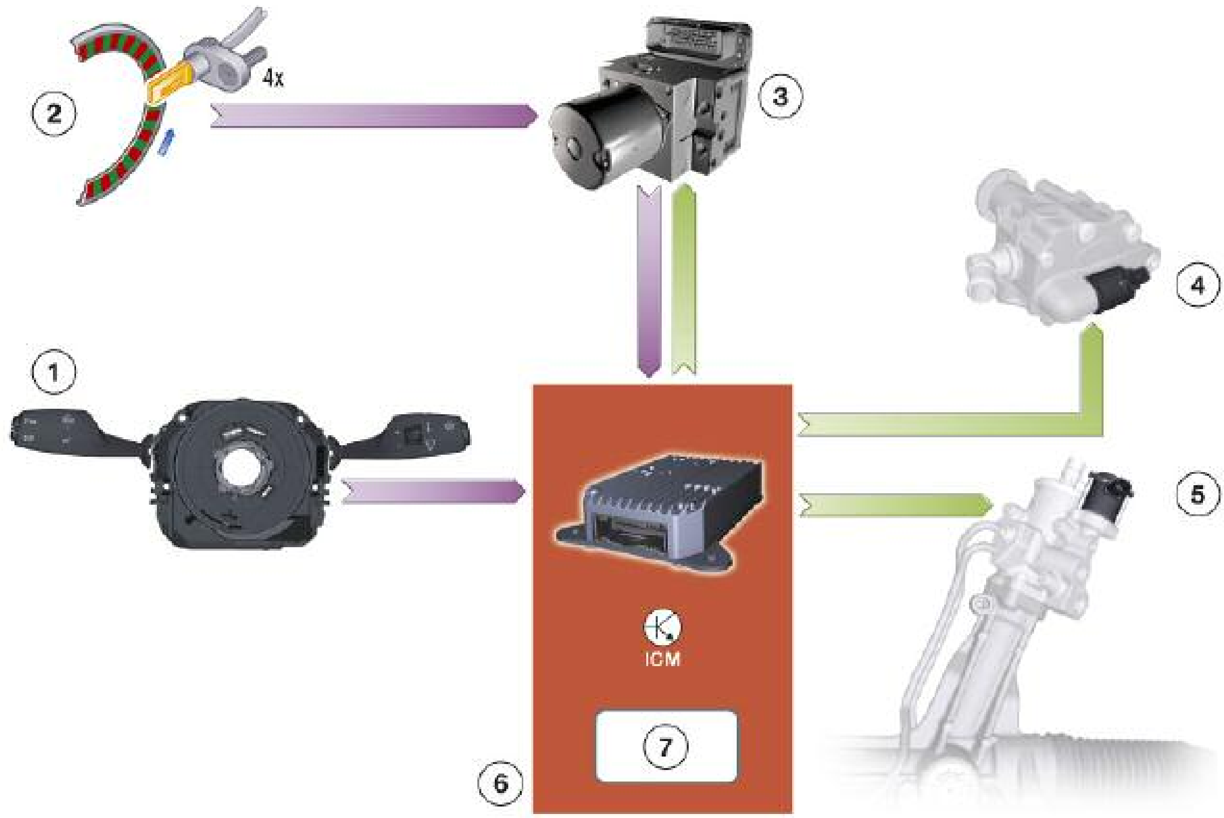
The **Servotronic** function in the F01/F02 is included in the basic steering and Integral Active Steering (option). This speed-dependent power steering assistance function is implemented by the Servotronic valve at the steering gear.

The Servotronic valve is always activated from the ICM control unit irrespective of the equipment specification. It follows that the ICM control unit also incorporates the logic of the Servotronic function.

Again, regardless of the options fitted, the steering system also contains a proportional valve that is also controlled by the ICM control unit. The volumetric flow in the steering hydraulic circuit can be adjusted electronically assisted by this valve which is why it is also referred to as an “electronic volumetric flow adjustment” valve, or EVV valve for short.

This valve is also controlled by the ICM control unit. The volumetric flow generated by the power steering pump is distributed between a circuit to the steering valve and a bypass circuit according to the level of power steering assistance required. This distribution is infinitely variable. The less power steering assistance is required, the more hydraulic oil is diverted to the bypass circuit. Because the hydraulic oil in the bypass circuit has no task to perform, this means that the power steering pump consumes less power. In this way, the EVV valve contributes to **reducing** fuel consumption and **CO_2 emissions**.

Input/Output: 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
4	EVV valve		

Driver Assistance Functions

Depending on the equipment specification, two driver assistance functions that act on the longitudinal dynamics of the vehicle can be integrated in the ICM control unit:

- **Cruise control with braking function** (Dynamic Cruise Control, DCC) and
- **Active cruise control with stop & go function** (ACC Stop&Go).

The Adaptive Brake Assistant function is included in the same equipment package as ACC Stop&Go.

The ACC Stop&Go function has been integrated into the ICM control unit in the F01/F02. This dispenses with the need for a separate LDM control unit. The DCC function that is calculated in the Dynamic Stability Control in the E70, for example, has been accommodated in the ICM control unit of the F01/F02.

Input/Output, driver assistance systems - longitudinal dynamics

Index	Explanation	Index	Explanation
1	Short range radar sensors (SRR)	7	Integrated Chassis Management
2	Long range radar sensors (LRR)	8	Drive
3	Footwell module	9	Dynamic Stability Control
4	Control panel for driver assistance functions	10	Instrument cluster
5	Steering column switch cluster	11	"DCC" function
6	Control panel for DCC or ACC Stop & Go on multi-function steering wheel	12	"ACC Stop & Go and Adaptive Brake Assistant" functions

The ICM control unit performs an additional important function for the **Lane Departure Warning** and **Active Blind Spot Detection** driver assistance systems. As both systems warn the driver via a vibration in the steering wheel, a coordinator function is required. This is integrated in the ICM control unit.

The ICM control unit generates a reference value for the vibration based on the warning requirements for the lane departure warning (KAFAS control unit) and the lane change warning (SWW sensor). The amplitude of the vibration varies depending on what triggered the warning.

The reference value is transmitted to the steering column switching cluster via the FlexRay bus system then put into effect via the steering wheel module (LRE) or the vibration actuator in the steering wheel.

The Input/Output graphic below is intended as an overview only.

Input/Output, coordination of steering wheel vibration

Index	Explanation	Index	Explanation
1	Radar sensor, lane change warning	7	Steering column switch cluster
2	KAFAS control unit	8	Steering wheel electronics (LRE) and vibration actuator in steering wheel
3	Camera for lane departure warning	9	Lane change warning display in door mirror
4	Footwell module	10	Instrument cluster
5	Control panel for driver assistance functions	11	Coordination function for steering wheel vibration
6	Integrated Chassis Management		

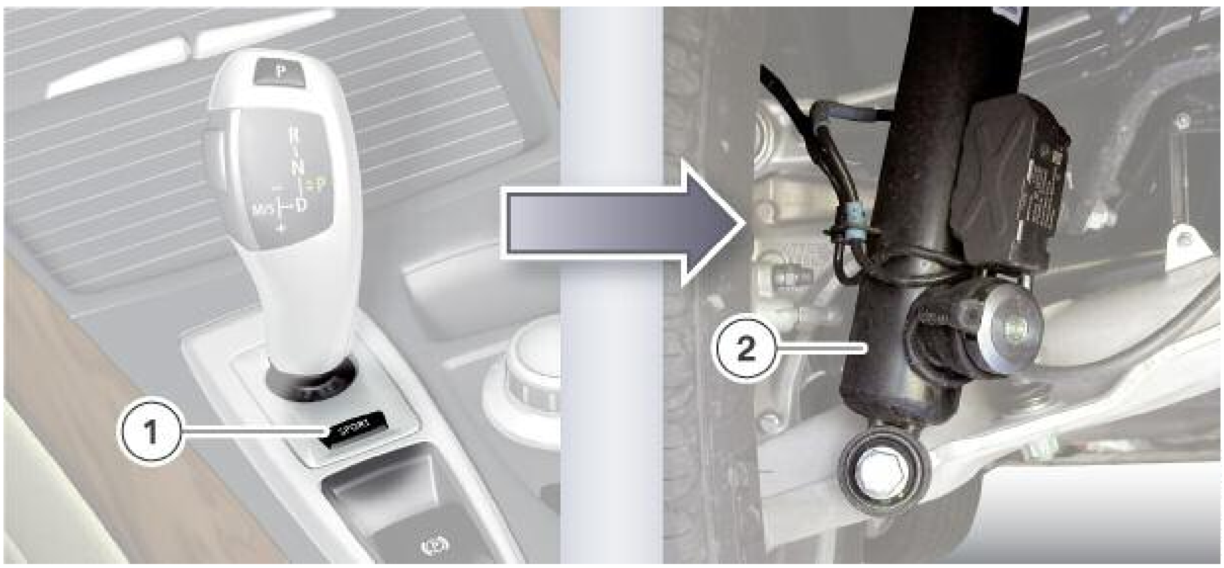
Driving Dynamics Control

History

Control elements are already installed in a number of BMW vehicles that the driver can use to switch individual systems to a sporting mode. This includes the sports setting of the automatic selector lever. In this case, only the shift characteristics of the automatic gearbox are influenced.

The system behaves in a similar manner when the SPORT button for the Electronic Damping Control or Vertical Dynamics Control (shown below) is used. This only changes the characteristic (hardness) of the shock absorber.

SPORT button in E70/ E71

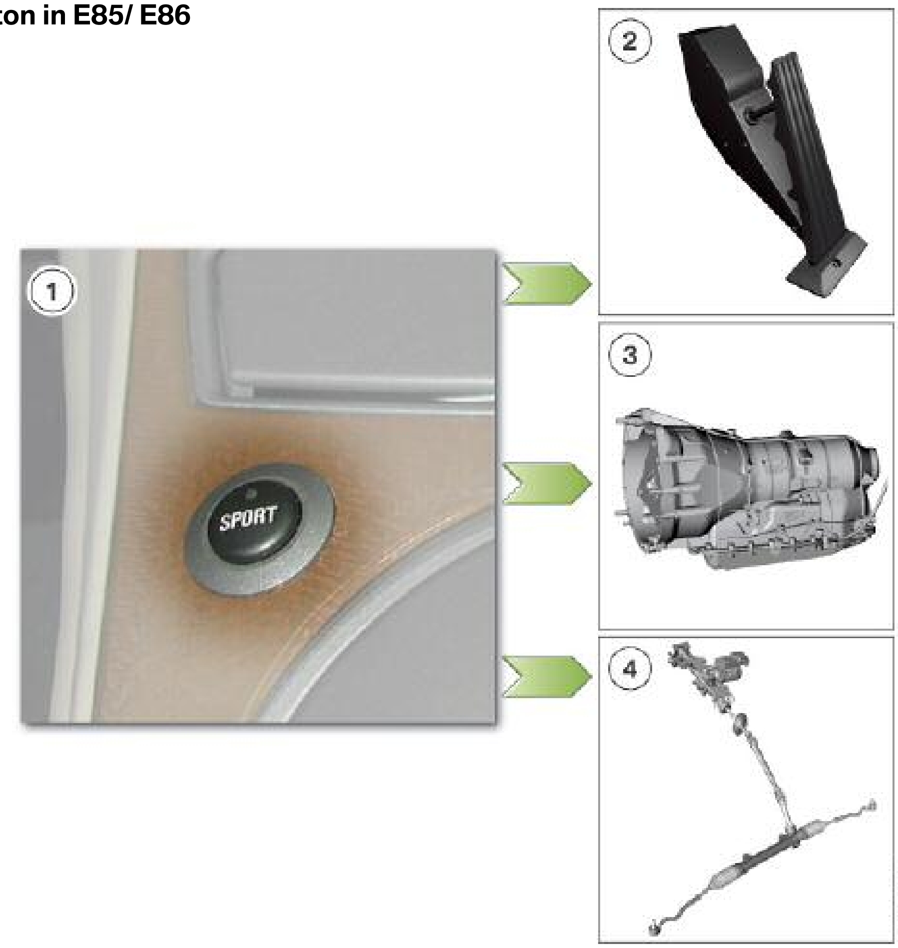


Index	Explanation	Index	Explanation
1	SPORT button	2	Vertical Dynamics Control with electronically adjustable shock absorbers

All other drive and dynamic driving systems therefore be found as it would need to remain in their basic setting. A suitable harmonize the damping action in both sporting compromise for this basic setting must mode and standard mode.

A SPORT button that influences several systems was introduced for the first time in the E85/E86. The corresponding “driving dynamics control” function effects a changeover between a standard mode and a sporting mode in the steering, automatic gearbox and accelerator pedal. This meant it was now possible to coordinate these three systems far more effectively in both modes with the result that the customer now experiences a car that is uncompromisingly tailored to “Sport” in every sense.

SPORT button in E85/ E86



Index	Explanation	Index	Explanation
1	SPORT button	3	Automatic transmission
2	Accelerator pedal	4	Steering

The new driving dynamics control in the F01/ F02 contains two groundbreaking new features when compared to the E85/E86:

1. All drive and dynamic driving systems installed in the vehicle are comprehensively switched over.
2. Four settings are available. The status of the Dynamic Stability Control is also taken into account thus ensuring that two additional settings are possible.

The driving dynamics control is operated via a new driving dynamics switch and the DTC button positioned directly in front of it.

The changeover operations for many drive and driving dynamics functions are therefore bundled in the driving dynamics control of the F01/F02. The vehicle as a whole then behaves as the driver would expect in accordance with his/her chosen setting.
This bundling can make the handling characteristics of the vehicle considerably more distinctive and less compromising.

Conversely, many individual, and also sometimes meaningless, combinations are avoided (example: sports steering combined with comfort-oriented damping).

DTC button and driving dynamics switch

Index	Explanation	Index	Explanation
1	DTC button	2	Driving dynamics switch

Mode of Action of Driving Dynamics Control in F01/F02

Networking of Systems

The systems involved in the "driving dynamics control" function are shown in the following Input/Output illustration.

Input/Output, driving dynamics control

Index	Explanation	Index	Explanation
1	Controller	7	Vertical Dynamics Control with electronically adjustable shock absorbers
2	Driving dynamics switch and DTC button	8	Active anti-roll bar
3	Integrated Chassis Management	9	Dynamic Stability Control
4	Accelerator pedal	10	Instrument cluster
5	Automatic transmission	11	Central information display
6	Steering		

The driver operates the driving dynamics control using the driving dynamics switch and the DTC button. The ICM control unit imports the control signals then determines on the basis of this which new mode the driving dynamics control should adopt. The mode thus determined is transmitted to the relevant drive and dynamic driving systems for implementation. These are:

- The engine control system for the accelerator pedal characteristic.
- The electronic gearbox control for driving programs and shift speed.
- The Vertical Dynamics Management system for the Vertical Dynamics Control and Active Roll Stabilization.
- The Dynamic Stability Control .
- The ICM control unit itself that controls the power steering assistance (Servotronic) and the steering-transmission ratio (Active Steering).

The ICM control unit also prompts the display of the relevant mode in the instrument cluster and also in the Central Information Display. In addition to selecting a mode, the driver can use the controller to make further settings.

Operation and display

The driver can select the four main modes using the driving dynamics switch. These main modes are designated as follows:

- Comfort
- Normal
- Sport
- Sport+

After the vehicle is started, the driving dynamics control is always in “Normal” mode. When the driving dynamics switch is moved to the “Sport” position, the driving dynamics control initially changes to “Sport” mode and then to “Sport+” mode if this button is pressed again. If the driver moves the driving dynamics switch to the “Comfort” position, the mode changes in the opposite direction, i.e. from “Sport” to “Normal” mode.

The DTC button provides the driver with two additional modes:

- Traction
- DSC off

The “Traction” mode can be activated by briefly pressing the DTC button. This works irrespective of which driving dynamics control mode was previously active. “DSC off” is activated by holding the DTC button pressed for longer. The “Traction” and “DSC off” modes can be switched off by pressing the DTC button again. The driving dynamics control subsequently returns to “Normal” mode. If the driver instead presses one of the two rocker switches at the driving dynamics switch to deactivate the “Traction” or “DSC off” modes, the driving dynamics control subsequently enters “Sport” or “Comfort” mode (depending on which rocker switch is pressed).

Each time the driving dynamics switch or DTC button is pressed this immediately prompts a reaction in the instrument cluster display. The changeover to “Sport” mode is shown below.

Display of "Sport" mode directly following operation

After some time, unless the driving dynamics switch is pressed, a more compact version of the display for the driving dynamics control appears.

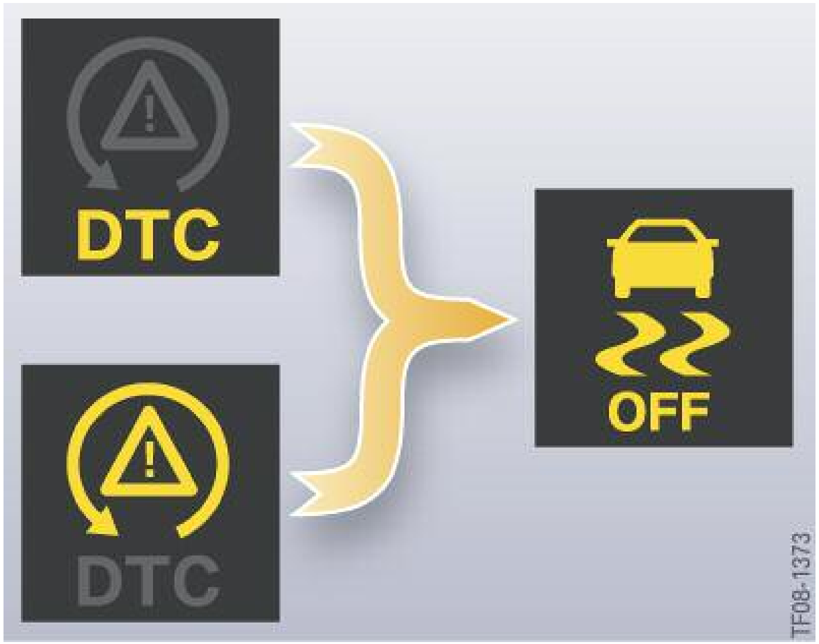
"Sport" display mode

The two modes “Traction” and “DSC off” present a special case in terms of their display requirements. In addition to the text entry, the yellow DSC indicator and warning lamps must be activated.

"Traction" display mode

”DSC off” display mode

Note: New symbols are now used for the yellow DSC indicator and warning lamp and the DTC button. The new DSC symbols used for the first time in the F01/F02 replace the symbols previously used.



DSC and DTC symbolic representation

Two different symbols were formerly used for the two states “DTC mode” and “DSC off” and were displayed in the instrument cluster. Since the launch of the F01/F02, only one symbol has been used for both states.

The new symbols are being gradually introduced in all newly developed vehicles. The reason for this are changes to legislation that require automobile manufacturers to produce a uniform display format.

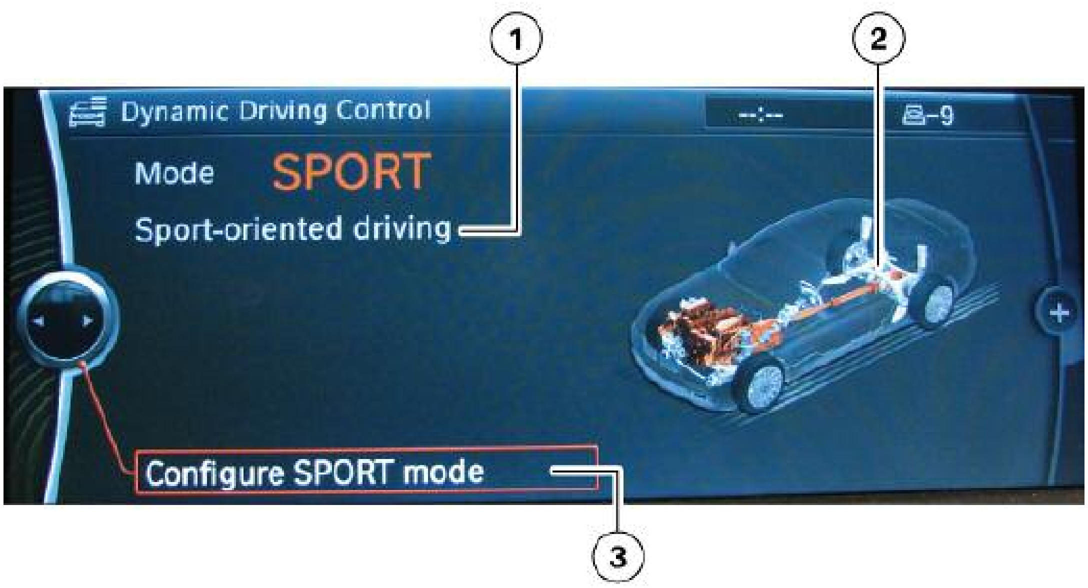
This legislation also specifies that the text message “off” must be displayed as soon as the DSC function is restricted, as is the case in the “Traction” and “Sport+” modes.

When the DTC button or the driving dynamics switch is pressed, an assistance window appears at the same time as the instrument cluster display in the Central Information Display. The name of the newly selected mode appears there together with an explanatory text.

In the “Sport” mode the driver also has the option of configuring this. Assisted by the controller, the driver can choose whether to apply the “Sport” mode to the drive systems, or the dynamic driving systems or both.

Configuration of the "Sport" mode	Drive systems	Chassis and dynamic driving systems
Drive and chassis (factory setting)	Sports	Sports
Drive only	Sports	Normal
Chassis only	Normal	Sports

Assistance window, “Sport” mode



Index	Explanation
1	Text description of the area(s) in which "Sport" mode is applied (shown here: chassis only and/or dynamic driving systems)
2	Visual description of the area(s) in which "Sport" mode is applied
3	Menu for configuration of "Sport" mode

Modes and their effects

This chapter describes the effects of the individual modes in the drive and dynamic driving systems. As the individual systems are switched over together in a coordinated manner, this lends coherence to the overall behavior of the vehicle. This of course also means that meaningless combinations, such as a sports accelerator pedal characteristic combined with a highly comfort-oriented automatic gearbox shift program, are avoided and meaningful combinations for the mode are integrated instead.

This is why when compared to earlier vehicles, the configuration of individual systems can to a great extent now be uncompromisingly tailored to one mode. The driver therefore not only experiences coherent vehicle response characteristics in all modes, he/she will also sense the differences between the individual modes far more acutely.

The table below demonstrates this, particularly through the comparison between the "Normal" and "Sport" modes.

	Comfort	Normal	Sport	Sport+
Drive systems				
Accelerator pedal characteristic	Normal	Normal	Sports	Sports
Shift program, automatic gearbox	Normal	Normal	Sports	Sports
Shift speed, automatic gearbox	Normal	Normal	Sports	Sports
Chassis and dynamic driving systems				
Power steering assistance	Normal	Normal	Sports	Sports
Integral Active Steering	Normal	Normal	Sports	Sports
Dynamic Stability Control	DSC on	DSC on	DSC on	DTC (sports)
Vertical Dynamics Control	Comfortable	Normal	Sports	Sports
Active anti-roll bar	Normal	Normal	Sports	Sports
The configuration shown here in "Sport" mode applies for both drive and dynamic driving systems.				

If the "Comfort" and "Normal" modes are compared instead, it is evident that the configuration differs in one dynamic driving system only: the Vertical Dynamics Control. This characteristic of the "Comfort" mode does not happen by chance and takes several peripheral factors into account:

- Most drive and dynamic driving systems ensure that driving is sufficiently comfortable in the "Normal" configuration; this is something that BMW 7 Series customers would expect. The Servotronic already offers requirement-based power steering assistance with maximum comfort, for example.

- The “Normal” configuration does not necessarily mean adherence to a single, defined system characteristic. The shift program of the automatic gearbox is only one example of how the current driving condition and driver’s command are taken into account in order to bring the behavior of the relevant system into line with these requirements.
- Most drivers relate a desire for greater comfort with the suspension and damping characteristics. This requirement is particularly relevant when driving on poor or uneven roads.

This means that the “Comfort” mode also embraces the philosophy of driving dynamics control which is to achieve a coherent vehicle response characteristic that meets the expectations of the driver.

The “Sport” and “Sport+” modes also differ in terms of the coordination of one specific dynamic driving system: the Dynamic Stability Control. In the “Sport” mode, a decidedly sports-oriented overall vehicle behavior is available to the driver.

Although it is assumed that many drivers would like to use this “Sport” mode, the DSC remains in normal operating mode and stabilizes the vehicle in a timely manner as required. The familiar intervention thresholds (slip, sideslip angle) that the driver has become accustomed to in the “Comfort” and “Normal” modes remain unchanged. This ensures that less proficient drivers are not taken by surprise when the DTC subsequently intervenes in the sportier DTC mode.

Only once a proficient driver deliberately selects the second sports mode “Sport+” will gentle drifts also become available due to the higher wheel slip and sideslip angle.

The two additional modes that the driver can select using the DTC button produce the effects on the drive and dynamic driving systems shown below.

	Normal	**Traction**	**DSC off**
Drive systems			
Accelerator pedal characteristic	Normal	Normal	Normal
Shift program, automatic gearbox	Normal	Normal	Sports
Shift speed, automatic gearbox	Normal	Normal	Sports
Chassis and dynamic driving systems			
Power steering assistance	Normal	Normal	Sports
Integral Active Steering	Normal	Normal	Sports
Dynamic Stability Control	DSC on	DTC	DSC off
Vertical Dynamics Control	Normal	Normal	Sports
Active anti-roll bar	Normal	Normal	Sports

The "Traction" mode is similar to the familiar DTC mode of the DSC in former BMW vehicles. All other drive and dynamic driving systems remain in their normal configuration which makes its main application clear: the purpose of "Traction" mode is to improve traction, e.g. when driving off on a loose subsurface. Sports driving takes a background role instead as the "Sport+" and "Sport" modes are available for this.

The stabilizing DSC interventions are switched off in the "DSC off" mode. Only the braking interventions that support traction are performed i.e. Electronic Differential Lock Control.

In this case, most other drive and dynamic driving systems are in the sports configuration. This means that the aim of "DSC off" mode is to support pure driving; a direct bond between the driver, vehicle and road.

Although initially it may seem astonishing that the accelerator pedal characteristic remains in the normal configuration in both "Traction" and "DSC off" modes, this setting is deliberate. When driving off on a loose subsurface and also when driving in a highly sports-oriented manner with the DSC switched off, it is especially important that the driver can apply engine torque extremely sensitively. This is much easier to do using a normal rather than a more sports-oriented accelerator pedal characteristic.

The sports-oriented accelerator pedal characteristic translates the accelerator pedal angle into a higher torque requirement at the engine. This torque requirement is then also put into effect more quickly by the engine control system.

As a result, the driver perceives the response characteristics of the drive, and therefore the vehicle, as more sports-oriented. However, the driver cannot use this to apply engine torque sensitively.

System Components

ICM Control Unit

Only the system components that are linked to the new architecture of the dynamic driving systems in the F01/F02 are described in this Product Information. In essence, this is the new ICM control unit and the periphery equipment directly connected to this control unit.

Three other Product Information packages are available in which descriptions of the system components for the individual dynamic driving systems are provided:

- Longitudinal dynamics systems
- Lateral dynamics systems
- Vertical dynamics systems

Design of the Two Control Unit Versions

An ICM control unit is installed in every F01/ F02. Each ICM control unit contains the following, irrespective of the equipment installed in the vehicle:

- Two microprocessors
- A FlexRay controller
- Output stages for activating valves in the steering system
- Integrated sensor system for driving dynamics variables (previously: DSC sensor)

The essential tasks of one of the microprocessors are the calculation of control functions, communication processing and activation of the output stages. The main task of the second processor is to monitor safety-relevant functions and bring about a system shut down in the event of a fault.

The other components of the ICM control unit listed above are described in the following chapters.

Two versions of the ICM control unit exist. The version installed in the vehicle depends on the equipment.

If the vehicle is equipped with one or both of the following options

- Integral Active Steering (IAL, SA 2VH) or
- Active Cruise Control with Stop & Go function,

the high-performance version of the ICM control unit is installed.

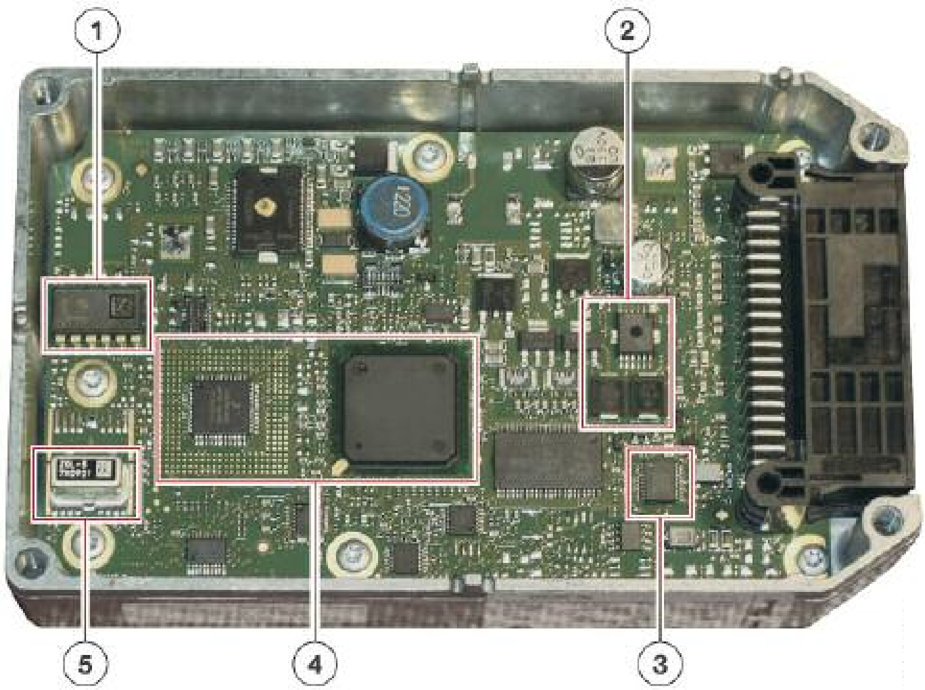
If neither of these options are installed in the vehicle, the basic version of the ICM control unit is used. The two versions of the ICM control unit are differentiated externally by their part numbers.

The internal layout of the high-performance version differs from the internal layout of the basic version in the following ways:

- Larger microprocessor (required to calculate the Integral Active Steering control and active speed control)
- Redundant sensor system for lateral acceleration and yaw rate (safety requirement for Integral Active Steering).

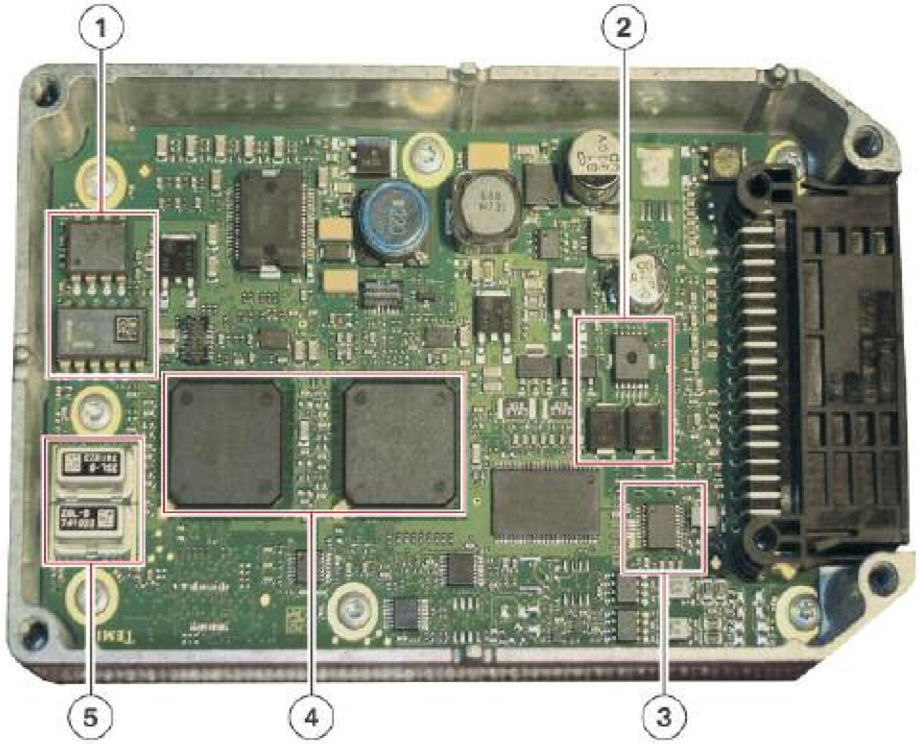
The following graphics make these differences clear.

ICM control unit, basic version



Index	Explanation
1	Acceleration sensor (longitudinal and lateral acceleration)
2	Output stages for Servotronic and EVV valves
3	Controller for FlexRay connection
4	Two microprocessors (basic version)
5	Yaw rate sensor

ICM control unit, high-performance version



Index	Explanation
1	Acceleration sensors (1 for longitudinal acceleration, 2 for lateral acceleration)
2	Output stages for Servotronic and EVV valves
3	Controller for FlexRay connection
4	Two microprocessors (high-performance version)
5	Yaw rate sensors (2x)

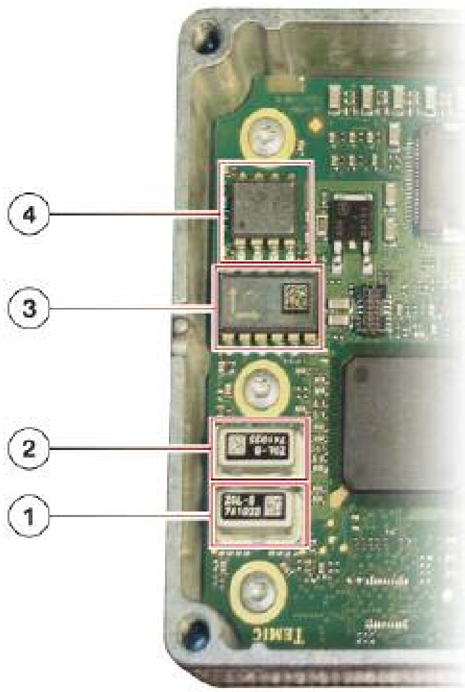
Integrated sensor system

The sensors that were previously accommodated separately in the DSC sensor are now installed in the ICM control unit.

The ICM control unit uses these sensors to calculate variables that provide key information on the vehicle's dynamic state:

- Longitudinal acceleration and pitch of the vehicle in the longitudinal direction
- Lateral acceleration and pitch of the vehicle in the lateral direction
- Yaw rate.

DSC sensor integrated into the ICM control unit



Index	Explanation
1	Yaw rate sensor
2	Second redundant yaw rate sensor
3	Longitudinal and lateral acceleration sensor
4	Second redundant lateral acceleration sensor

All sensors integrated into the ICM control unit are known as micromechanical sensors. By applying this principle, the dimensions of these sensors can be reduced to the extent that they can be accommodated in housings that are similar in size to microprocessor housings. The sensors are of course designed on the basis of prevailing stresses in the vehicle (thermal, mechanical). However, when servicing the vehicle, the ICM control unit must be handled with the same degree of care as the familiar DSC sensor.

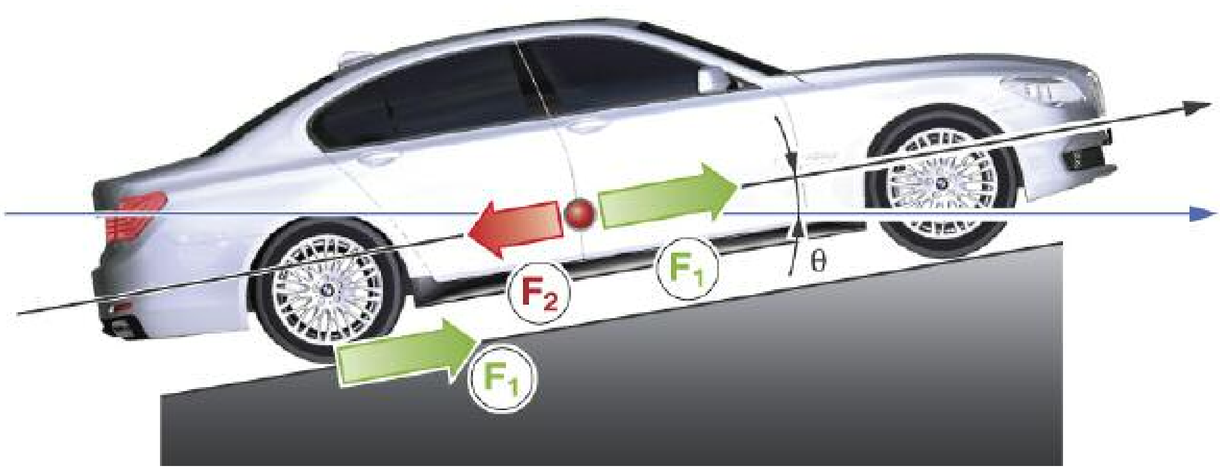
Note: The ICM control unit must not be exposed to strong vibrations. The integrated sensor system will be destroyed if the housing is struck by hard objects, or if the control unit is dropped. The control unit must not be installed in the vehicle in this case.

The **longitudinal and lateral acceleration** sensors operate according to the capacitive principle. They consist of two electrodes, that mesh in a comb-like form. One of the electrodes has a unidirectional moving bearing which means that if a force acts on the sensor, the electrode is displaced. This changes the gap between the two electrodes and in turn changes the capacitance which is calculated back to the size of the force applied by means of evaluating circuits.

Instead of recording the acceleration directly, the sensors record it indirectly by **measuring the force** on the sensor element. The force applied may have several causes and the sensor cannot differentiate between these:

- Inclination of the vehicle or road (e.g. gradient accelerating force)
- Change in speed (drive or braking force)
- Cornering (centrifugal force).

Longitudinal forces acting on the vehicle



Index	Explanation	Index	Explanation
F_1	Motive force	θ	Inclination of road
F_2	Gradient accelerating force		

In the graphic two longitudinal forces are shown acting on the vehicle: a motive force and a gradient accelerating force. These forces are produced due to the inclination of the road. As a result, a force acts on the vehicle and can be calculated as follows:

$F_{resulting} = F_1 - F_2$

Only the resulting force can be measured by the sensor. The measured force is processed in the control unit. The change in road speed is taken into account. The actual acceleration of the vehicle and the gradient of the road are the only calculation results provided.

A similar calculating process is used for the lateral direction. The calculation results produced in this case are the lateral tilt and lateral acceleration of the vehicle.

The sensor that determines the **yaw rate** also employs the principle of force measurement, a principle also used by the acceleration sensors. The yaw rate sensor measures the force that acts on a sensor element oscillating across the direction of rotation.

The sensor signals are initially referenced to the sensor housing. However, in order to be useful to the dynamic driving systems, these variables must be referenced to the vehicle coordinate system. The ICM control unit performs the necessary conversion. A synchronization process is carried out when the ICM control unit is started up during which corresponding correction values are determined and saved.

Note: Calibration of the sensors integrated into the ICM control unit is necessary in the following cases

- **the ICM control unit has been replaced or**
- **if requested by the test schedule in the diagnostic system due to a fault code memory entry.**

The calibration must be performed with the vehicle standing on a level surface in the longitudinal and lateral direction. Terminal 15 must also be switched on.

■ **Connector**
The control unit has a 54-pin plug via which the power supply, sensors, actuators and bus systems are connected.

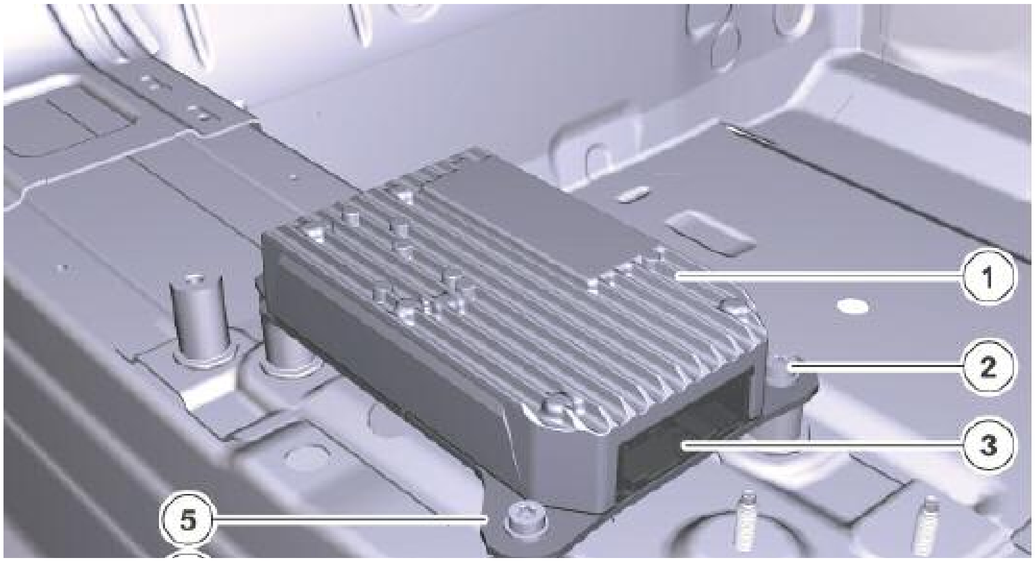
As is the case with the controller housing, the plug does not have a watertight design. This is The control unit has a 54-pin plug via which not necessary as it is installed on the inside of the vehicle.

Installation location of the ICM control unit overview

Installation Location
The ICM control unit is installed in the center console behind the sensor for the crash safety module. This means that the position of the control unit and its integrated sensor system in the vehicle, near to its center of gravity, is ideal from the point of view of driving dynamics. The mounting points on the body are precisely determined and are measured when the vehicle is manufactured and must not be replaced with any other mounting points.

The housing of the control unit is connected to the metal body of the transmission tunnel with four screws and spacer sleeves made of aluminum. The control unit must be mounted on the vehicle body free of play as otherwise vibrations may be induced in the control unit housing which would severely impair the operation of the integrated sensor system. A secondary task of this mounting is to conduct heat away from the control unit to the body.

Installation location of the ICM control unit - detail



Index	Explanation	Index	Explanation
1	Upper section of housing	4	Spacer sleeve
2	Mounting bolt	5	Lower section of housing
3	Connector		

For the mounting to be able to perform these tasks, the following points must be observed when mounting and replacing the ICM control unit:

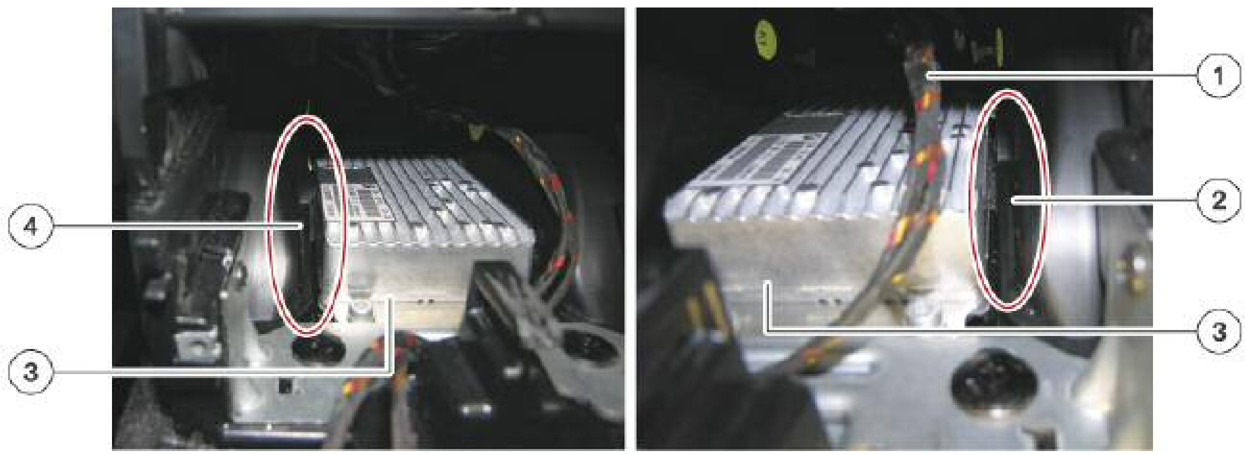
Note: Only screws and spacer sleeves that are in perfect condition may be used. Deformed or damaged fixing elements must not be used.

The mounting screws in the reamed holes must be tightened first, followed by the other two screws. The tightening torque specified in the repair instructions must be observed without fail.

A check must then be carried out to make sure the control unit is mounted securely and free of play.

To ensure sufficient heat dissipation and to avoid vibrations, the sides and top of the control unit housing must not come into contact with other vehicle components. Instead, the spaces provided around the control unit as part of the engineering design must always remain free of other components.

Installation situation of the ICM control unit - detail



Index	Explanation
1	Wiring harness, e.g. for rear display
2	The compartment on the right next to the ICM control unit must remain unoccupied
3	ICM control unit
4	The compartment on the left next to the ICM control unit must remain unoccupied

The wiring harness that runs in the center console in particular must never be routed in, or even pushed into, the spaces on either side of the ICM control unit.

Replacement and Start-up

Removing and installing the ICM control unit
The ICM control unit performs tasks that are important for many vehicle functions, e.g. provision of sensor signals. If the vehicle were operated without the ICM control unit installed, a large number of vehicle functions would not be available. In the area of dynamic driving systems, for example, the Servotronic and stabilization functions would no longer be available. In addition, fault code memory entries would inevitably also be generated in many control units.

Note: If the ICM control unit needs to be replaced, the repair instructions must be observed without fail.

For example, the vehicle battery must be disconnected before removing the control unit and reconnected following the installation. This is the only way to ensure synchronized restarting of the control unit assembly.

Note: Once the new ICM control unit has been installed, it must be started up with the assistance of the diagnostic system. To do this, the following steps must be carried out (depending on the equipment specification):

- **Calibration of the sensors integrated into the ICM**
- **Calibration of the ride-height sensors**
- **Initialization of the Integral Active Steering.**

Calibration of the sensors integrated into the ICM
The signals from the acceleration and yaw rate sensors integrated into the ICM are referenced to their housing. However, in order to be useful to the dynamic driving systems, these variables must be referenced to the vehicle coordinate system. In order for the ICM control unit to be able to carry out the necessary conversion, it requires corresponding correction values. These are determined during the one-off calibration procedure and stored in the ICM control unit.

Note: The instructions of the diagnostic system must be followed precisely during calibration of the sensors integrated into the ICM. It is particularly important for the vehicle to be standing on a surface that is level in both the longitudinal and lateral directions. If this is not the case, incorrect correction values will be determined that may cause the dynamic driving system to malfunction.

Calibration of the ride-height sensors

The measurement signals from the ride-height sensors are evaluated by means of voltage measurement in the ICM control unit. The ICM control unit cannot calculate the actual ride-level heights in millimeters on the basis of this information alone. To perform this calculation, the ICM control unit must be able to map the voltage signals it receives to reference values. This is the only way to establish a relationship between the measurement signals and the actual ride-level heights at the wheels. These reference values are determined during a synchronization procedure.

Note: The ride-height signals in the ICM must be synchronized in the following cases

- **following replacement of the ICM control unit,**
- **following replacement of a ride-height sensor or**
- **if prompted to do so by the test schedule of the diagnostic system (due to a fault code memory entry in the ICM).**

The synchronization does not have to be carried out if a wheel has been changed.

Note: The following points must be observed in order to perform the synchronization using the diagnostic system

- **the air suspension control operations must be blocked (remove fuse for EHC control unit)**
- **the ride-level heights must be measured using a tape measure and**
- **the rim size must be determined.**

The diagnostic system also refers to the ride-level height reference values (design position). These values are used by the diagnostic system and ICM to calculate the reference values for the conversion that are ultimately saved in the ICM control unit.

The ride-height signals in the EHC control unit (if installed) and the ride-height signals in the ICM control unit must be synchronized together.

Initialization of the Integral Active Steering

The ICM control unit calculates the higher-level control functions for the Integral Active Steering. The output signals of this control function are the reference steering angles, that should be set at the front and rear axle.

This is performed by the AS and HSR actuator control units together with the actuators. The actual angle set at the front and rear axle is sent to the ICM control unit as acknowledgement. The control circuit of the driving dynamics control system closes once this information has been received.

To determine this information correctly, the Integral Active Steering must be initialized. During this initialization procedure, the center of the steering gear at the front axle is determined and the corresponding signal values are stored (for example).

Note: The Integral Active Steering must be initialized under the following circumstances:

- **the ICM, AS or steering column switch cluster control unit has been replaced or**
- **the steering angle sensor in the steering column switch cluster has been calibrated or**
- **the steering gear has been replaced or**
- **if requested by the diagnostic system due to a fault code memory entry in the test schedule.**

During the calibration the diagnostic system issues several prompts to steer from one limit position to the other. The internal combustion engine should be running and the vehicle should be standing on the ground of the workshop when calibration is in progress. These marginal conditions most closely resemble the conditions under which the customer operates the vehicle and deliver the best initialization results. If the front wheels are resting on revolving and sliding supports, or are suspended in mid air if the vehicle is raised, this may lead to unsatisfactory results.

Calibration of the steering angle sensor in the steering column switch cluster
In addition to the signals from the motor-position sensors of the Integral Active Steering, the ICM control unit also imports the signal from the steering angle sensor in the steering column switch cluster. This is used by the ICM to determine the effective steering angle (see "Functions" section).

This is why it is important that the ICM receives a correctly mapped value from the steering angle sensor.

Note: The steering angle sensor must be calibrated if the steering column switch cluster is replaced or reprogrammed. A calibration must also be performed if this is requested in the test schedule of the diagnostic system as the result of a fault code memory entry.

The steering angle sensor must be calibrated before the ICM can calculate a correct effective steering angle and make this available via the bus system.

Note: Once the steering angle sensor has been calibrated, the instructions of the diagnostic system must be precisely followed.

The vehicle must be standing on even ground during calibration. The steering wheel must be in the straight-ahead position (visually).

Start-up, short range radar sensors
If the option "Active speed control with stop & go function" is installed in the vehicle, this will include the necessary radar sensors.

Although short range radar sensors are intelligent sensors that perform the functions of a control unit they cannot be accessed directly via the diagnostic system. The ICM control unit acts as a "go-between" between the short range radar sensors and the diagnostic system which is why the ICM also controls the start-up process for the short range radar sensors.

Note: The short range radar sensors for ACC Stop & Go must be started up if one (or both) short range radar sensor(s) is/are replaced. In this instance, the diagnostic system communicates with the ICM control unit. The ICM in turn controls the corresponding functions in the short range radar sensors.

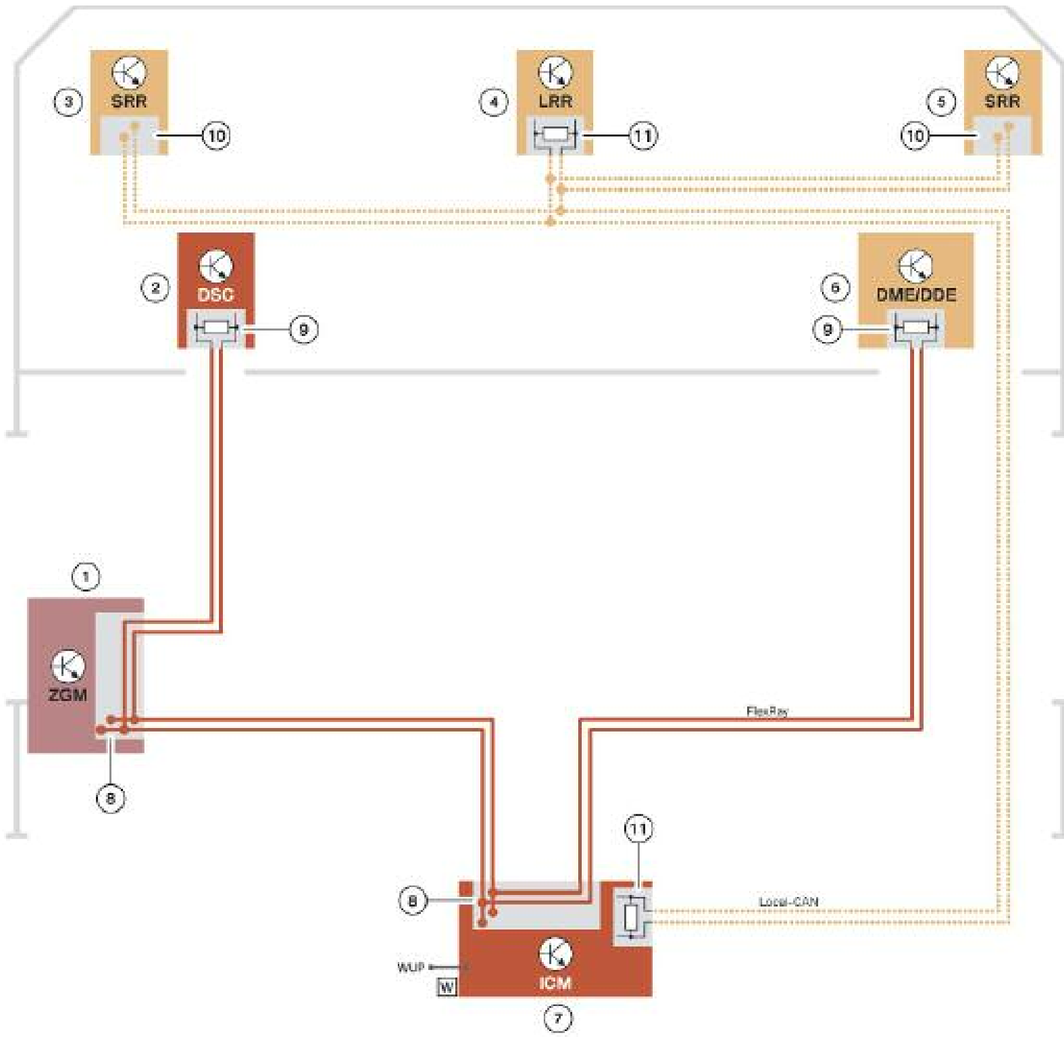
The installation position and, most importantly, the angle at which they are installed relative to the vehicle's longitudinal axis, are entered in the newly installed short range radar sensors during start-up. A measurement does not need to be carried out in this case. The angle entered is the angle predetermined by the construction and the form of the bumper support.

NOTES PAGE

Periphery of ICM Control Unit

Bus Systems

ICM control unit with FlexRay, local CAN and wake-up line



Index	Explanation	Index	Explanation
1	Central gateway module	8	FlexRay routing and continuation without terminating resistor
2	Dynamic Stability Control	9	Routing of FlexRay with terminating resistor
3	Short range radar sensor (SRR), left	10	Routing of local CAN without terminating resistor
4	Long range radar sensor (LRR)	11	Routing of local CAN with terminating resistor
5	Short range radar sensor (SRR), right	W	ICM control unit can be woken up
6	DME/DDE control unit	WUP	Wake-up line
7	ICM control unit		

FlexRay

The ICM control unit is connected to the FlexRay controller via the FlexRay bus system. The communication with virtually all partner control units is handled by the microprocessors in the ICM.

The FlexRay is routed to the ICM control unit (from the central gateway module) and continues from there (to the DME/DDE). The ICM control unit is related to the FlexRay, i.e. not an end node. This is why it does not have a terminating resistor for the FlexRay.

Local CAN

A further bus system, a local CAN, is connected to the ICM control unit in addition to the FlexRay. This serves the ICM exclusively for the purposes of communication with the active speed control radar sensors. This local CAN therefore performs the same tasks as the sensor CAN in the E6x LCI that connects the LDM control unit to the radar sensors. It transmits information on road users that has been recorded by the radar sensors.

The local CAN operates in the same way as the PT-CAN with a data transfer rate of 500 kBit/s. There are two terminating resistors for the local CAN, each with 120 .. One of these is in the ICM control unit, the second is integrated in the long range radar sensor (LRR). The close range sensors (SRR) are routed to the local CAN via short lines.

The pins for the local CAN are only connected at the plug of the ICM control unit if it is a high-performance version.

Wake-up line

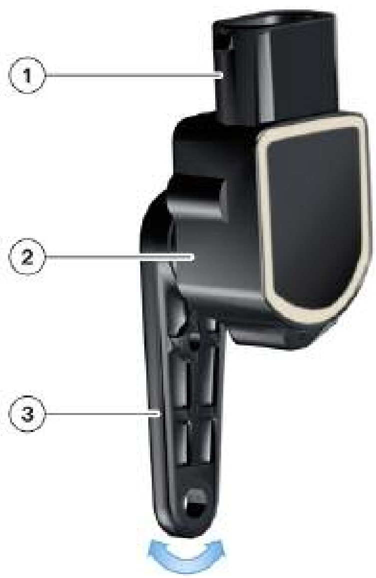
The ICM control unit is also connected to the wake-up line. The ICM control unit can be woken up via the wake-up line.

Power Supply

The only external power supply to the ICM control unit is with terminal 30B. This is made available by the junction box electrical system and the fuse carrier at the front.

The electronics and integrated sensor system are therefore supplied inside the ICM control unit. Additionally, the ride-height sensors connected to the ICM control unit and the output stages for activation of the valves for the steering unit are also supplied.

Ride-height Sensors



Index	Explanation
1	Connector
2	Housing
3	Arm (pivoting)

Design and principle of operation

The angle of a pivoting arm is converted to a voltage signal via the ride-height sensors. The greater the angle (with reference to a defined starting position), the greater the output voltage generated by a Hall sensor element.

Versions

Four ride-height sensors are installed in every F01/F02 as standard equipment.

However, the ride-height sensors installed in the vehicle are available in different versions. Different ride-height sensors are used on the left and right of the front axle. Different ride-height sensors are also used on the rear axle. The reasons for this in both cases are the available installation space and the starting position.

Double or single-type ride-height sensors are used at the rear axle, depending on whether the vehicle is equipped with electronic ride-height control (EHC). Single-type ride-height sensors are always used at the front axle.

Type of ride-height sensors at the ...	Front axle	Rear axle
Without electronic ride-height control	single	single
With electronic ride-height control	single	double

Interface with ICM control unit

As shown in the system circuit diagram, each ride-height sensor (irrespective of the version) is connected to the ICM control unit by three lines. The double-type ride-height sensors at the rear axle are also connected to the EHC control unit according to the same principle via three additional lines.

Power is supplied by the ICM control unit to the ride-height sensor via one of the lines. The sensor uses the second line to deliver its measurement signal (0-5 V DC voltage). The third line is connected to a common ground inside the ICM control unit.

The measurement signal is evaluated by means of voltage measurement in the ICM control unit. The ICM control unit cannot calculate the actual ride-level heights in millimeters on the basis of this information alone. To perform this calculation, the ICM control unit must be able to map the voltage signals it receives to reference values. This is the only way to establish a relationship between the measurement signals and the actual ride-level heights. These reference values are determined during a synchronization procedure.

Note: The ride-height signals in the ICM must be synchronized in the following cases

- **following replacement of the ICM control unit,**
- **following replacement of a ride-height sensor or**
- **if prompted to do so by the test schedule of the diagnostic system (due to a fault code memory entry in the ICM).**

The synchronization does not have to be carried out if a wheel has been changed.

Driving Dynamics Switch

The driving dynamics switch and DTC button are integral components of the center console operator control unit.

Installation location of the driving dynamics switch and DTC button

Index	Explanation
1	DTC button
2	Driving dynamics switch, "SPORT" rocker switch
3	Driving dynamics switch, "COMFORT" rocker switch

The new driving dynamics switch consists of two buttons labeled “COMFORT” and “SPORT”. This is a rocker switch that returns automatically to the center position after it is pressed. The center position corresponds to the “no button pressed” status.

Both buttons of the driving dynamics driving switch are connected directly to the ICM control unit via two lines. The ICM control unit applies a voltage at these lines. Both buttons are connected to the ground via a resistance network. The ICM control unit can determine the following by back-scanning the voltage obtained:

- whether a button has been pressed and, if so, which of the two buttons,
- whether breaks in the wiring exist and
- whether a short to ground has occurred.

In previous vehicles, the familiar DTC button is connected electrically, e.g. to the IHKA control unit (E70/E71). In the F01/F02 on the other hand, the DTC button is connected to the ICM control unit via an electrical wire. A voltage is applied to this wire by the ICM control unit. The DTC button connects to the ground. The ICM control unit can determine by means of voltage measurement whether the DTC button is operated.

The “Driving dynamics control” function in the ICM control unit evaluates the operation of the driving dynamics switch and DTC button and uses this as the basis for determining the corresponding mode (see “Functions” section). The ICM control unit sends signals via the bus system to inform the driver at the instrument cluster which mode has been set.

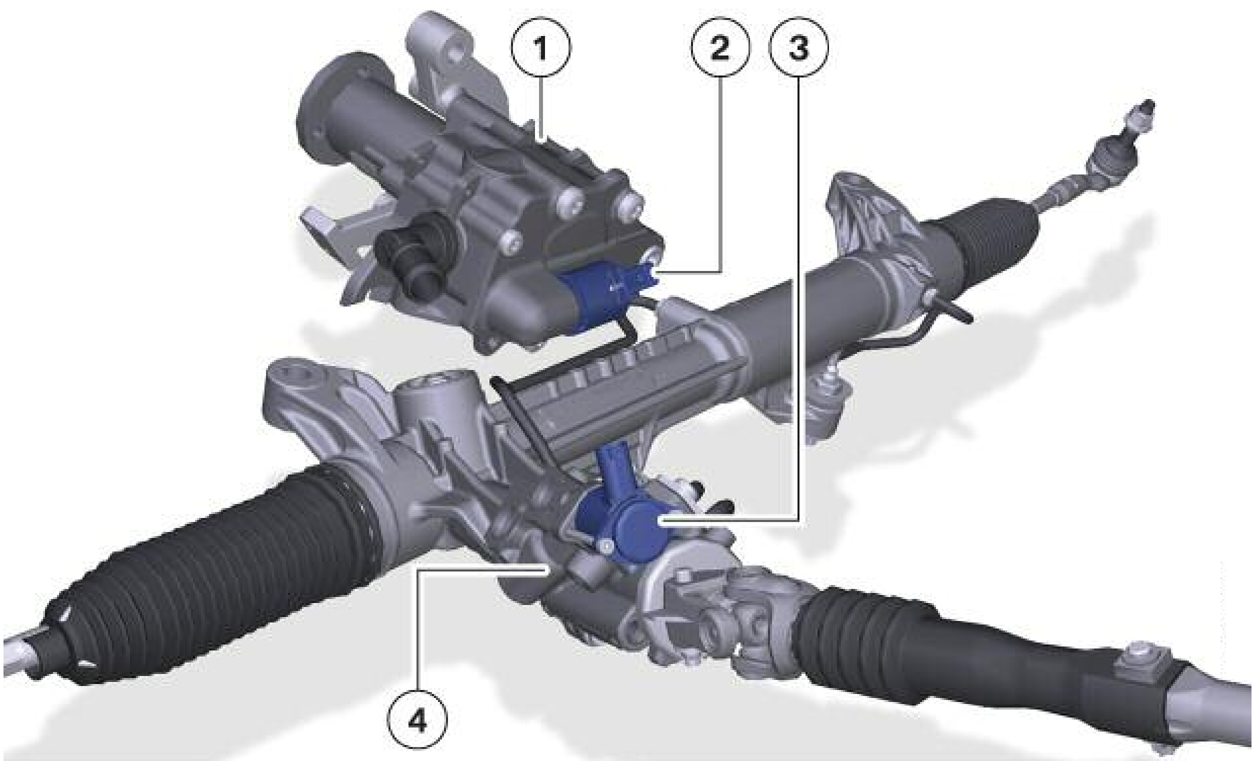
The footwell module supplies power to the center console operator control unit via terminal 58g for the locating lamp.

Valves of Steering Unit

The proportional valve that adjusts the electronic flow (EVV valve) and the Servotronic valve is activated directly from the ICM control unit. The ICM control unit contains the necessary output stages that are built up using power semiconductors.

Each valve is connected by two lines to the ICM control unit. The ICM control unit calculates the reference values for the aperture of both valves based on the road speed, steering angle and steering-angle speed input signals. These reference values are converted to a pulse-width-modulated signal that is applied at the lines leading to the valves. This means that the ICM control unit can change the aperture of the valves at any time.

Valves of the steering unit



Index	Explanation
1	Power steering pump
2	Valve for electronic flow rate adjustment (EVV valve)
3	Servotronic valve
4	Housing of control valve for hydraulic power steering

Service Information

What Points must be Observed During Servicing

ICM Control Unit

Note: If the ICM control unit needs to be replaced, the repair instructions must be observed without fail.

For example, the vehicle battery must be disconnected before removing the control unit and reconnected following the installation. This is the only way to ensure synchronized restarting of the control unit assembly.

Note: The ICM control unit must not be exposed to strong vibrations. The integrated sensor system will be destroyed if the housing is struck by hard objects, or if the control unit is dropped. The control unit must not be installed in the vehicle in this case.

Note: Only screws and spacer sleeves that are in perfect condition may be used to mount the ICM control unit. Deformed or damaged fixing elements must not be used.

The mounting screws in the reamed holes must be tightened first, followed by the other two screws. The tightening torque specified in the repair instructions must be observed without fail.

A check must then be carried out to make sure the control unit is mounted securely and free of play.

Note: Once the new ICM control unit has been installed, it must be started up with the assistance of the diagnostic system. To do this, the following steps must be carried out (depending on the equipment specification):

- **Calibration of the sensors integrated into the ICM**
- **Calibration of the ride-height sensors**
- **Initialization of the Integral Active Steering.**

Diagnosis in the Event of Signal Faults

Note: The ICM control unit itself contains sensors that provide the following signals:

- **longitudinal acceleration**
- **lateral acceleration**
- **yaw rate.**

The wheel-speed signals are recorded and made available by the DSC control unit. The steering wheel angle is determined by the steering angle sensor in the steering column switch cluster.

The ICM control unit processes all the sensor signals and makes these available in the form of bus signals to other systems in the vehicle.

If fault code memory entries for these signals exist, the following procedure is recommended when working through the test schedules:

Start with the test schedule for the control unit that is providing the signals. The most important signal sources for dynamic driving systems are the ICM, DSC and steering column switch cluster. You will be able to get to the root of the fault and eliminate it more quickly using this procedure.

Instead, the test schedules for the control units that receive these signals only contain references to the transmitter control units which means they do not lead directly to the ultimate cause/solution of the fault.

Sensors in the ICM

Note: Calibration of the sensors integrated into the ICM control unit is necessary in the following cases

- **the ICM control unit has been replaced or**
- **if requested by the test schedule in the diagnostic system due to a fault code memory entry.**

The calibration must be performed with the vehicle standing on a level surface in the longitudinal and lateral direction. Terminal 15 must also be switched on.

Note: The instructions of the diagnostic system must be followed precisely during calibration of the sensors integrated into the ICM. It is particularly important for the vehicle to be standing on a surface that is level in both the longitudinal and lateral directions.

If this is not the case, incorrect correction values will be determined that may cause the dynamic driving system to malfunction.

Ride-height Sensors

Note: The ride-height signals in the ICM must be synchronized in the following cases:

- **following replacement of the ICM control unit,**
- **following replacement of a ride-height sensor or**
- **if prompted to do so by the test schedule of the diagnostic system (due to a fault code memory entry in the ICM).**

The synchronization does not have to be carried out if a wheel has been changed.

Note: The following points must be observed in order to perform the synchronization using the diagnostic system

- **the air suspension control operations must be blocked (remove fuse for EHC control unit)**
- **the ride-level heights must be measured using a tape measure and**
- **the rim size must be determined.**

The diagnostic system also refers to the ride-level height reference values (design position).

These values are used by the diagnostic system and ICM to calculate the reference values for the conversion that are ultimately saved in the ICM control unit.

The ride-height signals in the EHC control unit (if installed) and the ride-height signals in the ICM control unit must be synchronized together.

Steering Column Switch Cluster with Ssteering Angle Sensor

Note: The steering angle sensor must be calibrated if the steering column switch cluster is replaced or reprogrammed. A calibration must also be performed if this is requested in the test schedule of the diagnostic system as the result of a fault code memory entry.

The steering angle sensor must be calibrated before the ICM can calculate a correct effective steering angle and make this available via the bus system.

Note: Once the steering angle sensor has been calibrated, the instructions of the diagnostic system must be precisely followed. The vehicle must be standing on even ground during calibration. The steering wheel must be in the straight-ahead position (visually).

Integral Active Steering

Note: The Integral Active Steering must be initialized under the following circumstances

- **the ICM, AS or steering column switch cluster control unit has been replaced or**
- **the steering angle sensor in the steering 1 column switch cluster has been calibrated or**
- **the steering gear has been replaced or**
- **if requested by the diagnostic system due to a fault code memory entry in the test schedule.**

Displays and Operation

Note: New symbols are now used for the yellow DSC indicator and warning lamp and the DTC button. The new DSC symbols used for the first time in the F01/F02 replace the symbols previously used.