Reference Manual

DSCi

Technical Training

Technical training.
Product information.

DSCi

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BMW Service

General information

Symbols used

The following symbol is used in this document to facilitate better comprehension or to draw attention to very important information:

Contains important safety information and information that needs to be observed strictly in order to guarantee the smooth operation of the system.

Information status: May 2018

BMW Group vehicles meet the requirements of the highest safety and quality standards. Changes in requirements for environmental protection, customer benefits and design render necessary continuous development of systems and components. Consequently, there may be discrepancies between the contents of this document and the vehicles available in the training course.

The information contained in the training course materials is solely intended for participants in this training course conducted by BMW Group Technical Training Centers, or BMW Group Contract Training Facilities.

This training manual or any attached publication is not intended to be a complete and all inclusive source for repair and maintenance data. It is only part of a training information system designed to assure that uniform procedures and information are presented to all participants.

For changes/additions to the technical data, repair procedures, please refer to the current information issued by BMW of North America, LLC, Technical Service Department.

This information is available by accessing TIS at www.bmwcenternet.com.

Additional sources of information

Further information on the individual topics can be found in the following:

- Owner's Handbook
- Integrated Service Technical Application
- Aftersales Information Research (AIR)

DSCi

Contents

Contents

DSCi

1. Introduction

This Product Information is intended for the Technical Qualification of BMW Group employees in the retail outlets worldwide. The descriptions are confined to the fundamental innovations which present themselves with the introduction of Dynamic Stability Control integrated (DSCi). Participants are required to have a basic knowledge of the design and function of current brake systems.

For further information on the subject of brakes, please refer to the Product Information "Service Brake Systems".

1.1. Dynamic Stability Control integrated (DSCi)

Dynamic Stability Control integrated (DSCi) has its first series introduction in the BMW X5 with the development code G05. Further models are to follow. In this way, this new brake system design with reduced components will define the new standard of future BMW brake systems. The brake systems of these vehicles are also called integrated brake systems. The core of the integrated brake system is DSCi, which will be described in greater detail in the following.

The system supplier of DSCi introduced in the G05 is Continental®. The official supplier name for DSCi is C1®. In the current expansion stage DSCi at BMW is equipped exclusively with diagonal brake circuit split.

DSCi

1. Introduction

DSCi unit design

Index	Explanation
1	Brake linkage with ball head
2	Expansion tank
3	Brake fluid level sensor
4	Plug connection, voltage supply (DC)
5	Plug connection, vehicle electrical system
6	DSCi control unit

DSCi

1. Introduction

Index	Explanation
7	DSCi hydraulic control unit
8	Brake pedal force simulator
9	Linear actuator electric motor (AC)
10	DSCi unit

The technical highlight of DSCi is the separation of the driver from the brake hydraulics of the wheel brakes. Brake systems with this attribute are called electro-hydraulic brake-by-wire brakes. Electro-hydraulic brake-by-wire brake systems have been in use at the BMW Group since 2009. However, their range of use was limited to a very small number of models with hybrid drives. With the introduction of DSCi, vehicle models with conventional drive concepts are now also switching to electro-hydraulic brake-by- wire technology.

1.1.1. Wheel slip control

Wheel slip control is effected along similar lines to the conventional DSC brake system. It comprises the familiar BMW stabilization and safety functions (ABS, DSC, DTC, etc.).

Wheel slip control is effected by a linear actuator in conjunction with the pressure retaining and pressure reducing valves.

1.1.2. Additional functions

The established additional functions such as reading in of the brake pad wear sensor or monitoring of the tire pressures continue to be supported by the DSCi control unit.

1.2. Terms

1.2.1. Mild Hybrid vehicle

Classic Mild Hybrid systems are for the most part defined by the following attributes:

- High voltages of approximately 42 - 160 V
- Electric-only driving not possible
- Energy recovery and boost function by means of high-voltage electrical machine
- External charging of the high-voltage battery not possible.

1.2.2. Full Hybrid vehicle

Classic Full Hybrid systems are for the most part defined by the following attributes:

- High voltages currently of approximately 200 - 400 V
- Electric-only driving possible for short ranges
- Energy recovery and boost function by means of high-voltage electrical machine
- External charging of the high-voltage battery not possible.

1.2.3. Plug-in Hybrid Electric Vehicle

Classic Plug-in Hybrid Electric Vehicles (PHEV) are for the most part defined by the following attributes:

- High voltages currently of approximately 200 - 400 V
- Electric-only driving possible for medium ranges
- Energy recovery and boost function by means of high-voltage electrical machine
- External charging of the high-voltage battery possible.

1.2.4. Energy recovery

In electric or hybrid vehicles, an electrical machine decelerates the vehicle in addition to the existing service brake system. It is activated as a generator and thus generates electric current. A high-voltage battery saves the generated current and makes it available to the electrical machine during acceleration. Regenerative braking can be performed entirely by the electrical machine or can be divided between the electrical machine and the hydraulic service brake system. An anticipatory driving style with a high regenerative braking share increases vehicle efficiency and reduces brake wear.

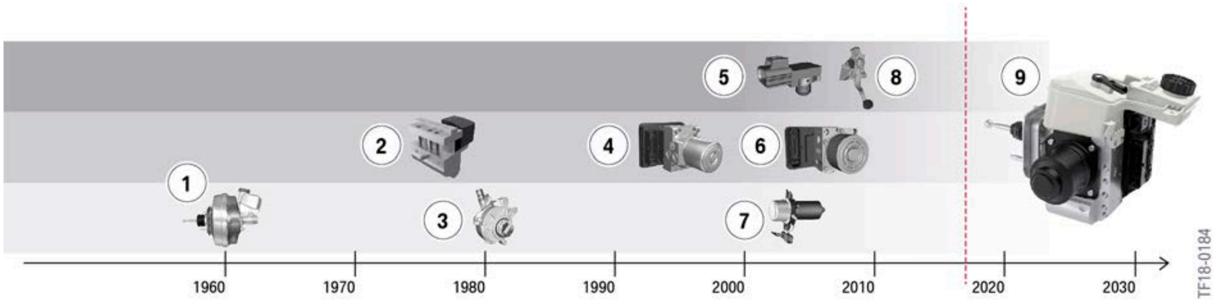
1.2.5. Brake-by-wire

Brake-by-wire literally means braking via the power cable. This term describes a brake system in which the activation and transmission components are separate from each other. This means that the driver does not have a direct connection to the hydraulic brake circuits of the vehicle. One advantage of this technology is that the necessary hydraulic pressures can be built up or reduced in the brake system without a perceptible effect on the brake pedal.

1.3. History

Brakes are among the most important safety features of a vehicle. For this reason, particular importance is attached to their continued further development. The demands imposed on the brake system result on the one hand from the constantly increasing engine performance and vehicle weight figures and on the other hand from the ever-increasing number of new driver assistance systems. Rising customer expectations additionally intensify the conflict between the targets of comfort and sportiness.

The graphic below provides a general overview of important stages of development and of the components used in BMW brake systems.



Historical overview of brake system components

Index	Explanation
1	Vacuum brake servo
2	Anti-lock braking system ABS
3	Mechanical vacuum pump
4	Dynamic Stability Control (DSC)
5	Brake vacuum pressure sensor
6	Hybrid brake system (brake-by-wire)
7	Electrical vacuum pump
8	Brake pedal travel sensor
9	Dynamic Stability Control integrated (DSCi)

1.3.1. Brake servo 1960

BMW was one of the first vehicle manufacturers to introduce the brake servo, back in the year 1960. The brake-servo assistance of earlier brake systems was delivered above all by the self- energization of the drum brakes and accordingly high brake pedal lever travel.

1.3.2. Antilock braking system (ABS) 1979

The foundation for the suspension control systems used today was laid by Bosch®at the end of the 1970s with the development of the anti-lock brake system (ABS). At BMW this system was used in the E23 from 1979.

1.3.3. Mechanical vacuum pump 1983

In petrol engines (without Valvetronic) a pressure drop prevails upstream and downstream of the throttle valve. The vacuum applied in the process downstream of the throttle valve was used in older vehicles for brake- servo assistance. With the introduction of a mechanical vacuum pump, it also become possible to fit diesel vehicles with a vacuum brake servo. This was necessary since load control in diesel vehicles is not regulated via a throttle valve.

1.3.4. Dynamic Stability Control (DSC) 1995

A significant milestone for the driving dynamics and driving safety of BMW customers was the introduction in 1995 of Dynamic Stability Control in the BMW 7 Series E38. Dynamic Stability Control (DSC) is a further development of the Antilock Braking System (ABS). This was necessary to be able to cope with the dramatic increase of new brake system functions.

1.3.5. Automatic engine start-stop function (MSA) 2006

With the introduction of the automatic engine start-stop function (MSA 1.0) in 2006 the vacuum in the brake servo was sensed by means of a brake vacuum sensor. When the vacuum in the brake servo is too low, e.g. due to frequent brake pedal pressing when the vehicle is stationary during an engine stop, the engine is automatically started.

1.3.6. Hybrid brake system 2009

Hybrid brake systems can be designed as an electro-hydraulic brake-by- wire brake system (disconnected) or as a conventional brake system (connected). The difficulty when using a conventional brake system (connected) in an electric or hybrid vehicle lies in the ability to recover as much energy as possible (recuperation). The response travel to be overcome between the brake pedal and the tandem brake master cylinder in every brake system is used to convert a small amount of the kinetic energy when braking into electric current. However, the proportion of regenerative braking operations can be increased significantly with the aid of a electro-hydraulic brake-by- wire brake system (disconnected).

Already in 2009 BMW had begun, with the introduction of the BMW ActiveHybrid X6 (development code E72), to introduce a electro-hydraulic brake-by-wire hybrid brake system. A particularity of this brake system is that the activation and transmission components are separate from each other. Consequently, the driver has no direct contact with the brake hydraulics. The driver's brake request is sensed via a brake pedal travel sensor and processed by a control unit. The braking computed in the process can be performed via the energy recovery of the electrical machine. The wheel brakes are also used if the braking power of the electrical machine is not sufficient. It was thus possible to improve the overall efficiency.

Hybrid vehicles which can drive 100 % electrically also require an electrified vacuum supply for these operating situations. These vehicles therefore have an electrical vacuum pump in addition to the mechanical vacuum pump. The electrical vacuum pump is activated solely for electric-only driving. The electrical vacuum pump is controlled via a brake vacuum sensor on the brake servo.

1. Introduction

The table below provides an overview of current hybrid vehicles and associated brake systems:

Development code	Figure	Concept	Brake system	Vacuum supply
E72		Full hybrid	Disconnected brake system	Mechanical and electrical vacuum pumps
F04		Mild hybrid	Connected brake system	Mechanical vacuum pump
F01H/F02H		Full hybrid	Connected brake system	Mechanical and electrical vacuum pumps
F10H		Full hybrid	Connected brake system	Mechanical and electrical vacuum pumps
F15 PHEV		Plug-in Hybrid Electric Vehicle	Partly connected brake system (disconnected at the rear axle, connected at the front axle)	Mechanical and electrical vacuum pumps
F30H		Full hybrid	Connected brake system	Mechanical and electrical vacuum pumps
F30 PHEV		Plug-in Hybrid Electric Vehicle	Connected brake system	Mechanical and electrical vacuum pumps
G12 PHEV		Plug-in Hybrid Electric Vehicle	Connected brake system	Mechanical and electrical vacuum pumps
G30 PHEV		Plug-in Hybrid Electric Vehicle	Connected brake system	Mechanical and electrical vacuum pumps

1.4. Motivation for introduction

1.4.1. Requirements

DSCi

1. Introduction

The demands imposed on older brake systems are confined primarily to:

- high braking performance (active safety)
- comfort and sportiness
- high efficiency
- high robustness.

Current brake systems are exposed to ever greater challenges by the continuous further development of the driver assistance systems and the electrification of the drivetrain. To reduce the complexity while simultaneously enhancing functionality a completely new brake system with the designation Dynamic Stability Control integrated (DSCi) is introduced in the BMW Group in the new BMW X5 with the development code G05.

DSCi will in due course be introduced in many other BMW models.

Wide range of demands imposed on future brake systems

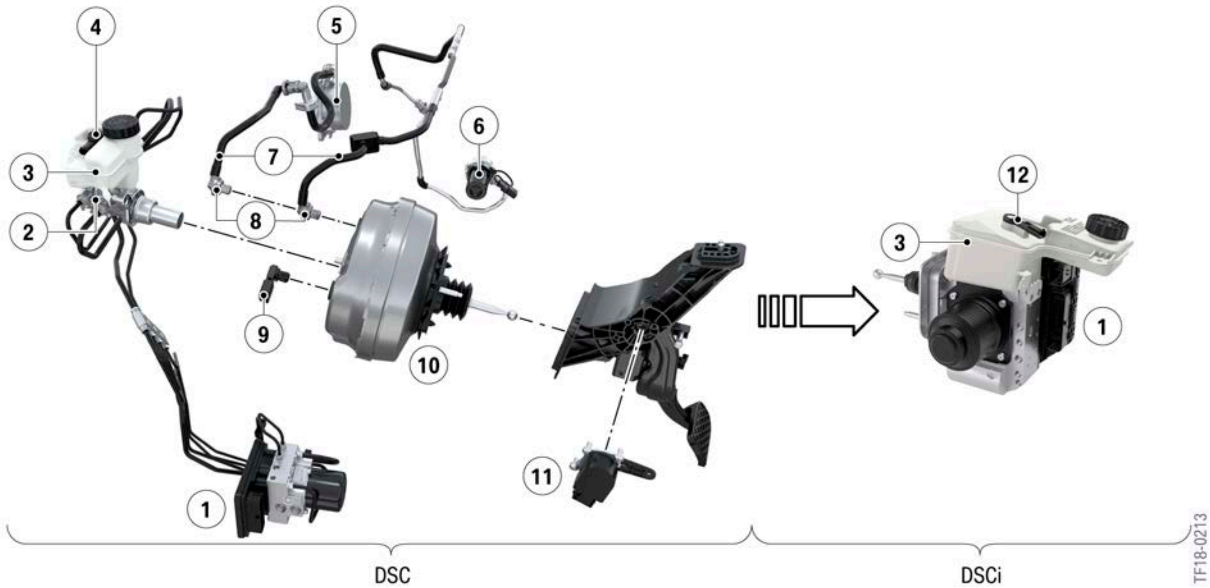
Index	Explanation
1	High braking performance (active safety)
2	Driver assistance systems
3	Comfort and sportiness
4	Electromobility
5	Efficiency
6	High robustness
7	Dynamic Stability Control integrated (DSCi)

DSCi

2. Design and Description

2.1. System comparison, DSC brake and DSCi brake

A comparison of the previous system structure of the brake reveals a clear reduction in the required components. Furthermore, the DSCi brake is designed in all models as a electro-hydraulic brake-by-wire brake.



System overview of DSC brake and DSCi brake

Index	Explanation
DSC	Dynamic Stability Control
DSCi	Dynamic Stability Control integrated
1	DSC unit
2	Tandem brake master cylinder
3	Expansion tank
4	Brake fluid level switch
5	Mechanical vacuum pump
6	Electrical vacuum pump*
7	Vacuum line
8	Non-return valve
9	Brake vacuum sensor *
10	Brake servo
11	Brake pedal travel sensor *
12	Brake fluid level sensor

*Additional components may, depending on the vehicle, feature in the DSC brake system.

2. Design and Description

2.1.1. Additional components of the DSC brake

Electrical vacuum pump:

- in electric or hybrid vehicles
- as a technical retrofit in vehicles with suction jet pump.

Brake vacuum sensor:

- in vehicles with automatic engine start-stop function (MSA)
- in electric or hybrid vehicles
- as a retrofit as part of Technical Campaigns.

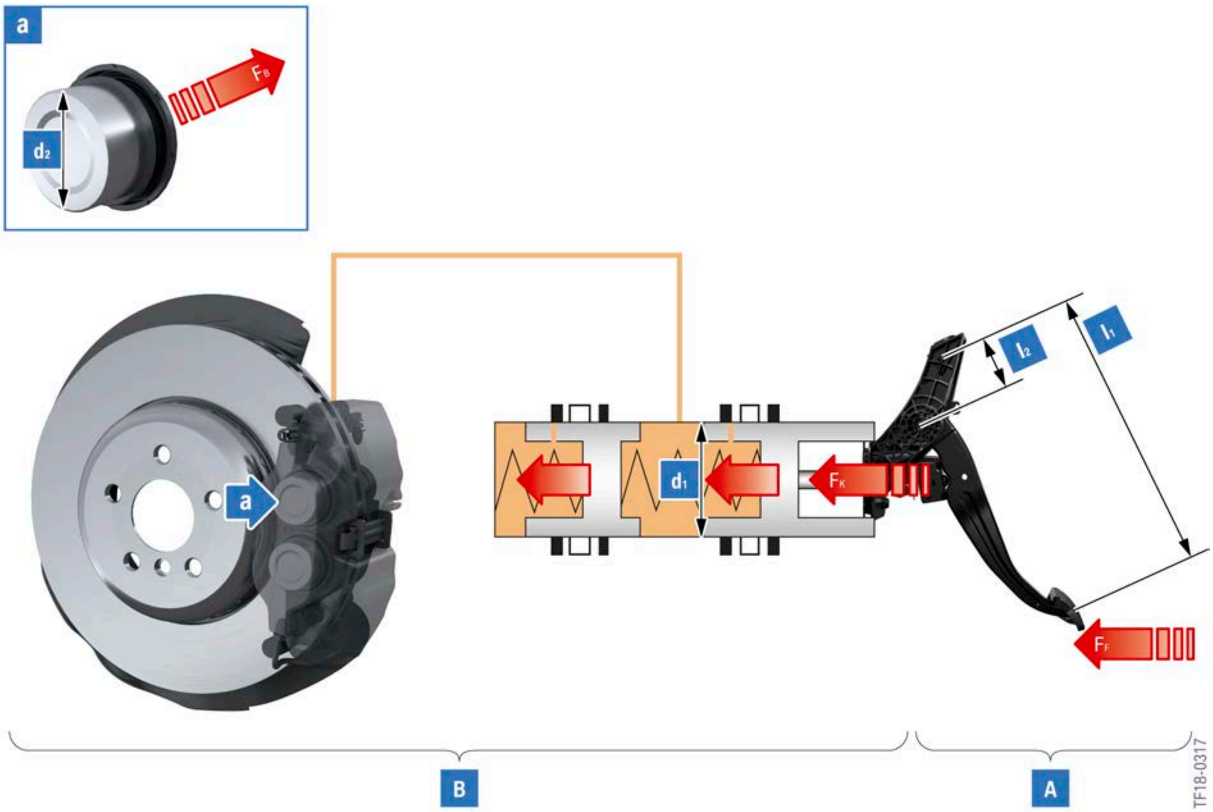
Brake pedal travel sensor:

- in electric or hybrid vehicles.

2.1.2. Brake power assistance

A comparison of the two brake systems shows up clear differences in the area of vacuum brake-servo assistance. The absence of vacuum brake-servo assistance from the DSCi brake reduces the complexity while simultaneously increasing failure safety.

Brake power assistance of DSC brake	Brake power assistance of DSCi brake
Transmission ratio at the pedal mechanism	Increased transmission at the pedal mechanism
Hydraulic transmission ratio	Hydraulic transmission ratio
Vacuum brake servo	None
DSC return pump (DC)	Linear actuator (AC)



Transmission ratio at the pedal mechanism and in the brake hydraulics

Index	Explanation
A	Transmission ratio at the pedal mechanism
B	Hydraulic transmission ratio
d_1	Push rod piston diameter
d_2	Brake piston diameter
F_F	Foot force
F_B	Brake piston force
F_K	Push rod force
l_1	Lever arm (foot force)
l_2	Lever arm (piston)

Calculation of lever force:

$F_F \cdot l_1 = F_K \cdot l_2$

$F_K = F_F \cdot l_1 : l_2$

Calculation of hydraulic transmission ratio (i):

$i = d_1 : d_2$

$i = F_K : F_B$

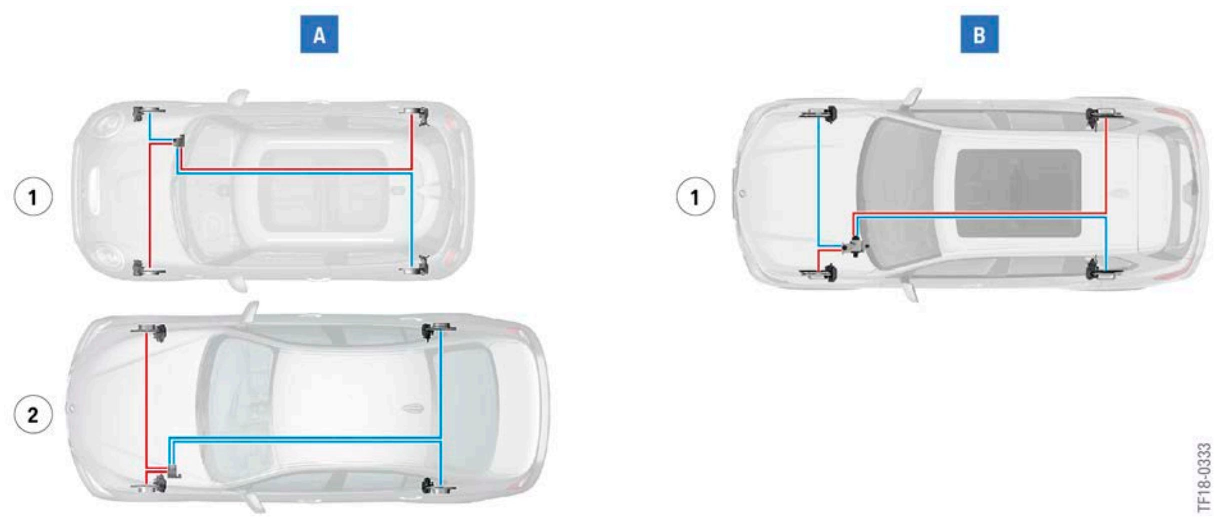
Calculation of brake piston force:

$F_B = F_K \cdot i$

2.1.3. Split braking system

Current BMW vehicles with a DSC brake are, depending on the drive concept (front-wheel drive/rear-wheel drive) and the associated vehicle platform equipped with front/rear split or diagonal brake circuit split.

With the introduction of the DSCi brake, the corresponding vehicles are equipped in all models with diagonal brake circuit split.



BMW brake circuit split

Index	Explanation
A	Vehicles with DSC brake
B	Vehicles with DSCi brake
1	Brake circuit split: Diagonal
2	Brake circuit split: Front/rear split

2.1.4. Safeguarding of the brake circuits

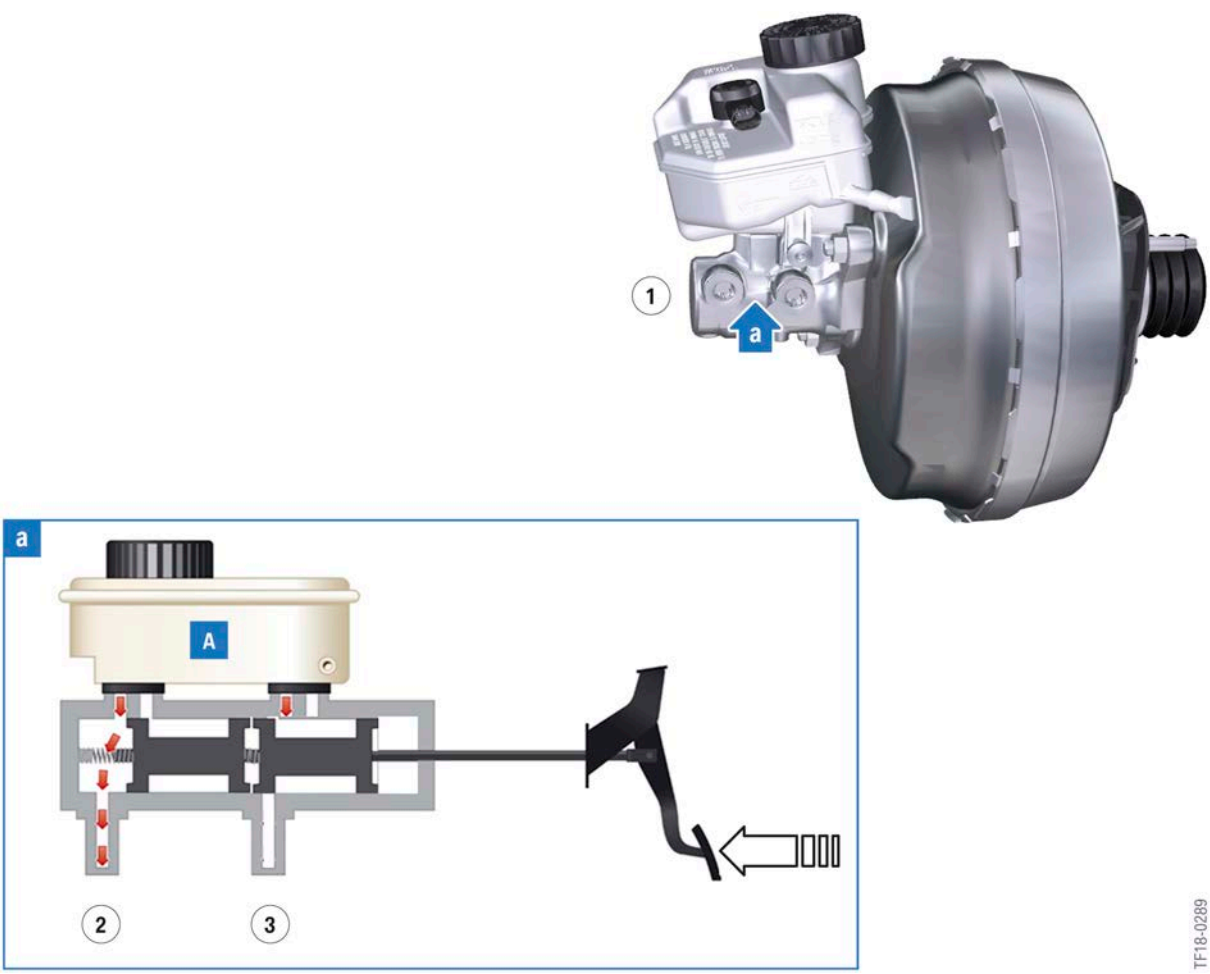
The DSCi brake can use the leakage detection software function to detect a leak in brake-by-wire mode and deactivate the corresponding brake circuit.

In the fallback level the brake circuits are safeguard along similar lines to the DSC brake with the aid of a tandem brake master cylinder. The two brake systems differ, however, in where the tandem brake master cylinder is installed.

Depending on the status (brake-by-wire mode or fallback level), the motor vehicle is decelerated in the event of a leak in one of the two brake circuits with reduced effect via the brake circuit that is still intact.

Safeguarding of the DSC brake circuits	Safeguarding of the DSCi brake circuits
- - -	In brake-by-wire mode via channel deactivation by means of leakage detection
Generally via a separate tandem brake master cylinder	In the fallback level via an integrated tandem brake master cylinder

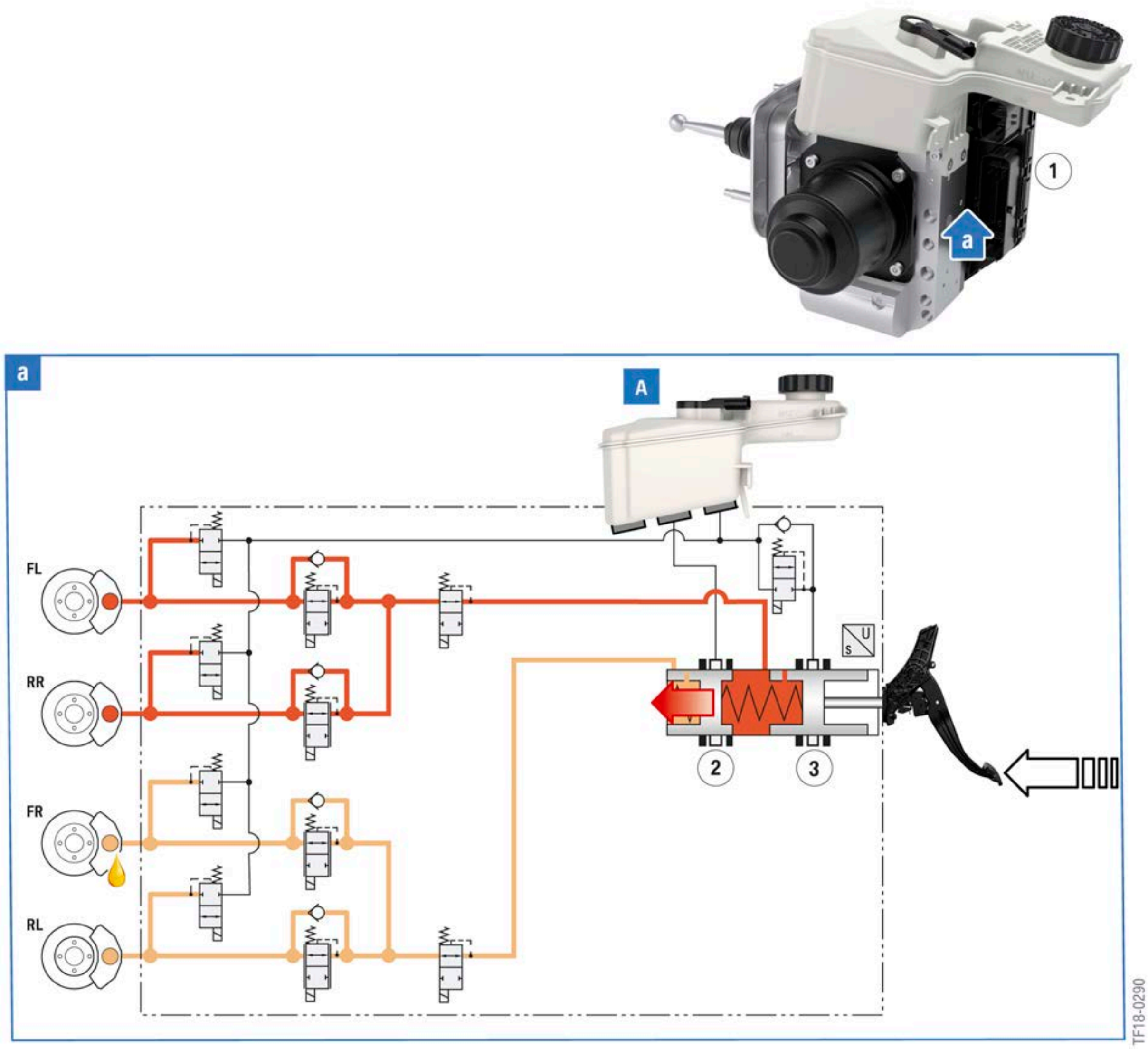
DSC brake



Separate tandem brake master cylinder to safeguard the brake circuits in the DSC brake

Index	Explanation
A	Leak in brake circuit 1
1	Tandem brake master cylinder
2	Brake circuit 2
3	Brake circuit 1

DSCi brake



Integrated tandem brake master cylinder to safeguard the brake circuits in the DSCi brake

Index	Explanation
A	Leak in brake circuit 2
1	Integrated tandem brake master cylinder
2	Brake circuit 2
3	Brake circuit 1
FL	Front left
RR	Rear right
FR	Front right
RL	Rear left

2.1.5. Expansion tank

Another difference between the two brake system is the increased brake fluid volume and the monitoring of the brake fluid level in the expansion tank.

DSC brake	DSCi brake
0.2 l volume in the expansion tank	0.6 l volume in the expansion tank
Brake fluid level switch	Brake fluid level sensor

Monitoring of brake fluid level in the expansion tank

Index	Explanation
A	DSC brake
B	DSCi brake
1	Float with ring magnet
2	4 Hall effect elements

2. Design and Description

2.1.6. Brake fluid level sensor

Brake fluid level sensor with Hall effect sensor

Index	Explanation
1	Connector connection
2	Float with ring magnet
3	Warning level 1 (Hall effect element 1, 2)
4	Warning level 2 (Hall effect element 3, 4)

A minimum volume of brake fluid is required in the expansion tank to ensure safe functioning of the DSCi brake. The DSCi control unit therefore permanently monitors the brake fluid level to ensure that this is above the minimum level. If the brake fluid level in the expansion tank is too low, there is a risk of air being drawn into the linear actuator pressure cylinder.

An excessively low brake fluid level is detected with the aid of a float with ring magnet and 4 Hall effect sensors. If the brake fluid level drops to the level of Hall effect elements 1 and 2, warning level 1 is activated. If the brake fluid level drops to the level of Hall effect elements 3 and 4, warning level 2 is activated.

Warning level 1

The customer receives the following message:

- Brake malfunction, stop carefully and do not continue driving.

Warning level 2

If the brake fluid level drops to the level of Hall effect elements 3 and 4, the following effect is to be expected:

- Activation of the fallback level.

The fallback level will be activated if the fill level is too low or the plug is pulled.

Brake fluid level in the expansion tank

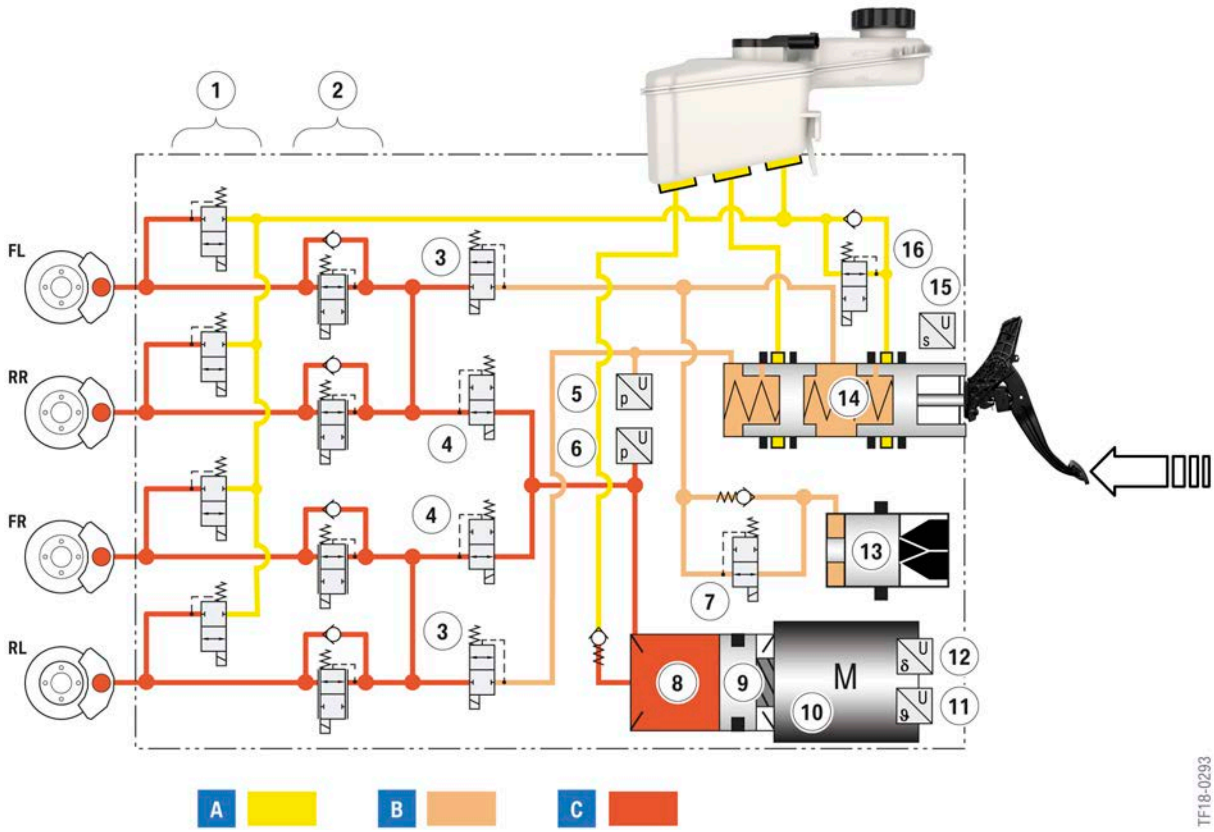
Index	Explanation
A	Brake fluid level too low
B	Maximum brake fluid level

An excessively low brake fluid level in the expansion tank must be corrected without delay. Furthermore, if further abnormalities are evident, the leak-tightness of the entire brake hydraulics must be checked. Failure to comply with this requirement may cause the brake system to fail.

2.2. System description

Because DSCi is a disconnected brake system, the brake request must be sensed and the brake force generated in accordance with the driver's request and including the corresponding driving dynamics values from a power servo source. This requires adjustments in the area of the sensor and actuator systems.

2. Design and Description



Hydraulic circuit diagram of DSCi unit

Index	Explanation
A	Return and supply, expansion tank
B	Simulation pressure
C	Operating pressure (brake pressure)
FL	Front left
RR	Rear right
FR	Front right
RL	Rear left
1	Pressure reducing valves
2	Pressure retaining valves
3	Driver separator valves
4	Linear actuator changeover valves
5	Brake pressure sensor simulator circuit
6	Brake pressure sensor working circuit
7	Simulator valve
8	Linear actuator pressure cylinder

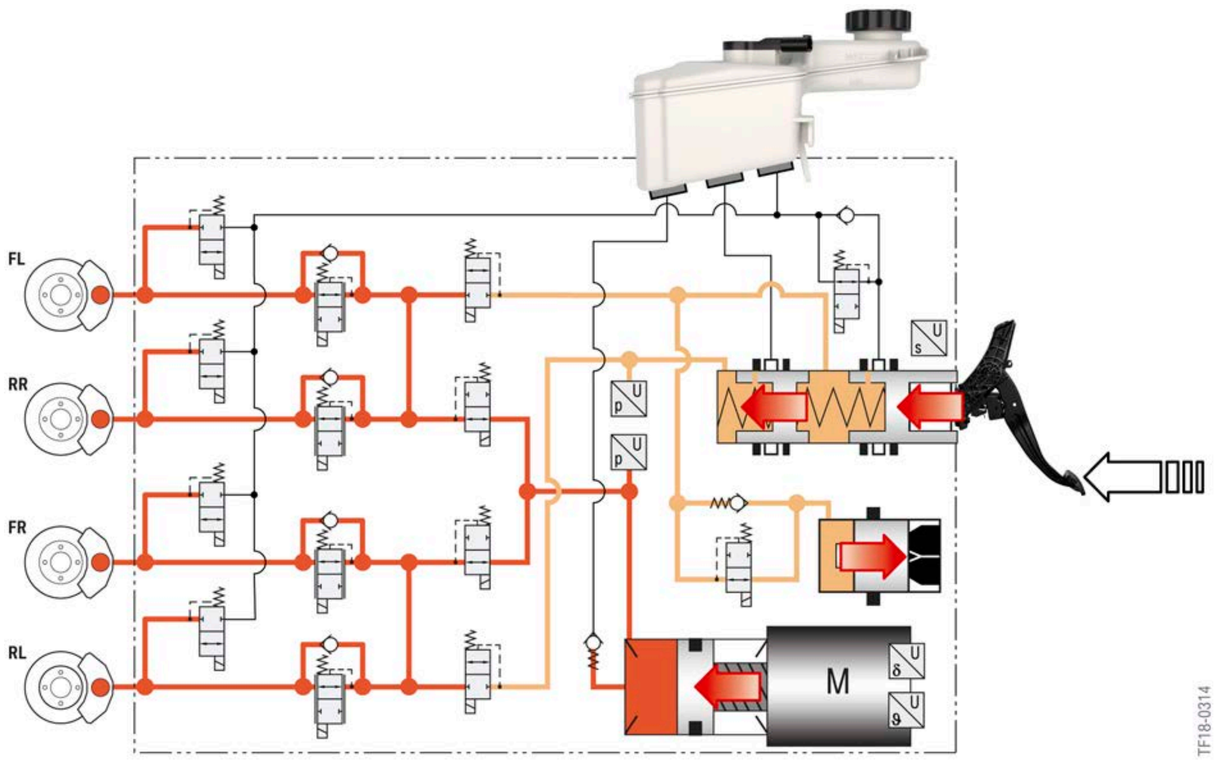
Index	Explanation
9	Linear actuator
10	Linear actuator electric motor (AC)
11	Position sensor, electric motor
12	Linear travel sensor
13	Brake pedal force simulator
14	Tandem brake master cylinder
15	Brake pedal travel sensor
16	Diagnosis valve

2.2.1. Electro-hydraulic brake-by-wire mode

When the driver presses the brake pedal in brake-by-wire mode, the brake request is sensed via a brake pedal travel sensor. 2 driver separator valves prevent the hydraulic pressure generated from being able to act in the direction of the wheel brake. Instead, the hydraulic pressure passes through the opened simulator valve to the brake pedal force simulator. An elastomer inside the brake pedal force simulator generates the customary counterforce.

The sensor signal from the brake pedal travel sensor is processed by the DSCi control unit and the linear actuator is activated in accordance with the driver's brake request. The generated brake pressure is routed through the opened linear actuator changeover valves in the direction of the wheel brakes.

2. Design and Description



Electro-hydraulic brake-by-wire mode of DSCi brake

Brake pedal activated

When the brake pedal is pressed the corresponding solenoid valves are energized and thereby switched to brake-by-wire mode.

Valves with brake pedal pressed	Open	Closed
Driver separator valves		●
Simulator valve	●	
Linear actuator changeover valves	●	

Brake pedal not activated

When the brake pedal is not pressed the solenoid valves are in the rest position (de-energized).

Valves with brake pedal not pressed	Open	Closed
Driver separator valves	●	
Simulator valve		●
Linear actuator changeover valves		●

2. Design and Description

Special features

Familiar feedback from the brake hydraulics towards the brake pedal can, when compared with previous brake systems, now no longer be perceived by the driver. Such feedback can be, for example:

- pulsing of the brake pedal during an ABS or DSC control operation
- pulsing of the brake pedal due to high brake disc lateral runout
- pulsing of the brake pedal due to high brake disc thickness tolerance
- an indirect brake pedal feel due to old brake fluid
- a changed pressure point due to worn brake pads

Signal processing

The DSCi control unit processes the brake requests and performs a pressure build-up via the linear actuator.

The signals from the following sensors are continuously checked for plausibility:

- Brake pedal travel sensor
- Brake pressure
- Linear travel sensor
- Wheel speed sensor.

System fault

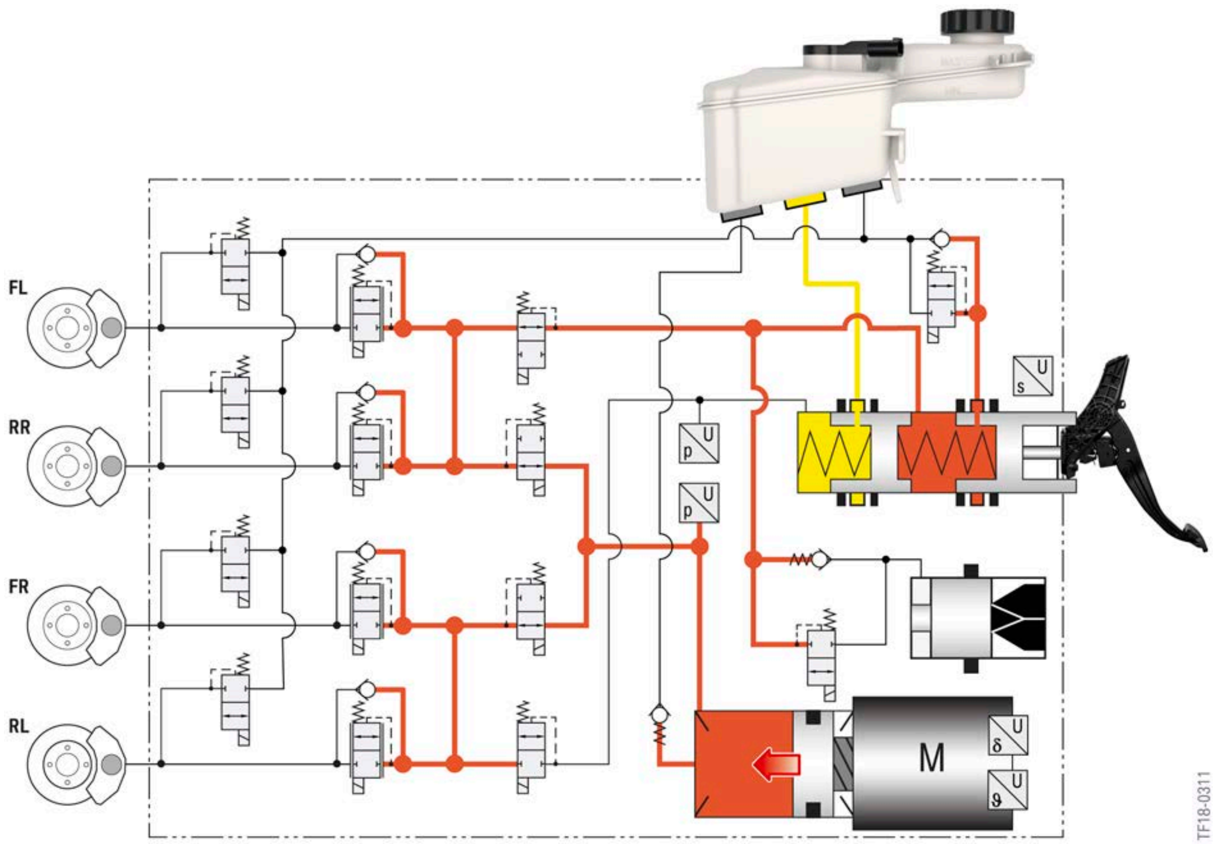
The values of the brake pressure sensor and the linear travel sensor are permanently checked for plausibility. In the event of deviation from the stored maximal threshold values, the following effects are to be expected:

- Selective hydraulic deactivation of individual brake circuits
- Activation of the fallback level.

2.2.2. Pre-drive check

When the data bus wakes up, e.g. through detection of the ID transmitter or opening of the doors, the DSCi control unit starts a pre-drive check.

Step 1A:



Step 1A of pre-drive check

One driver separator valve remains open while the second is closed.

The diagnosis valve closes to prevent the brake fluid from flowing back into the expansion tank.

The linear actuator begins with a slight pressure build-up.

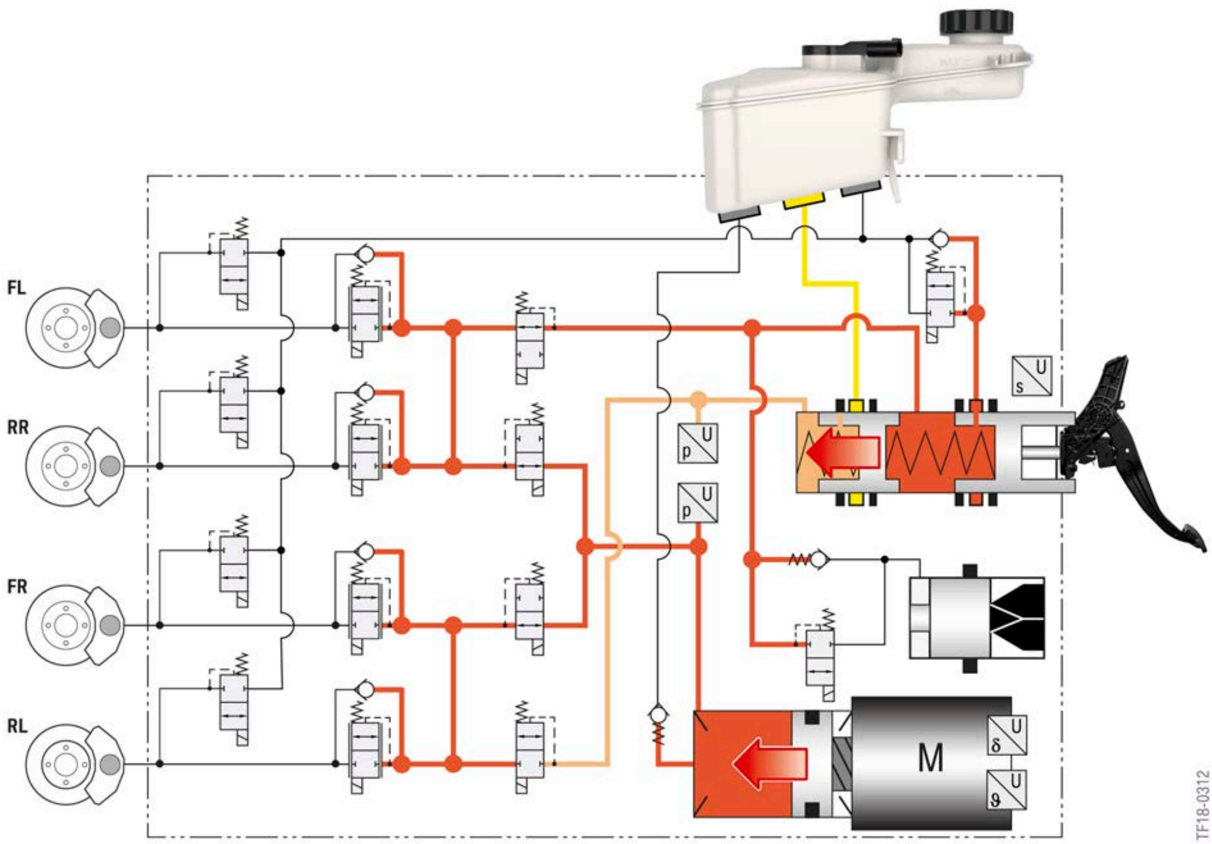
The brake pressure sensor in the working circuit and the linear travel sensor are checked for plausibility.

Step 1B:

The linear actuator increases the brake pressure.

The intermediate piston in the tandem brake master cylinder is displaced to the left in response to the pressure increase.

The brake pressure sensor in the simulator circuit is checked for plausibility.

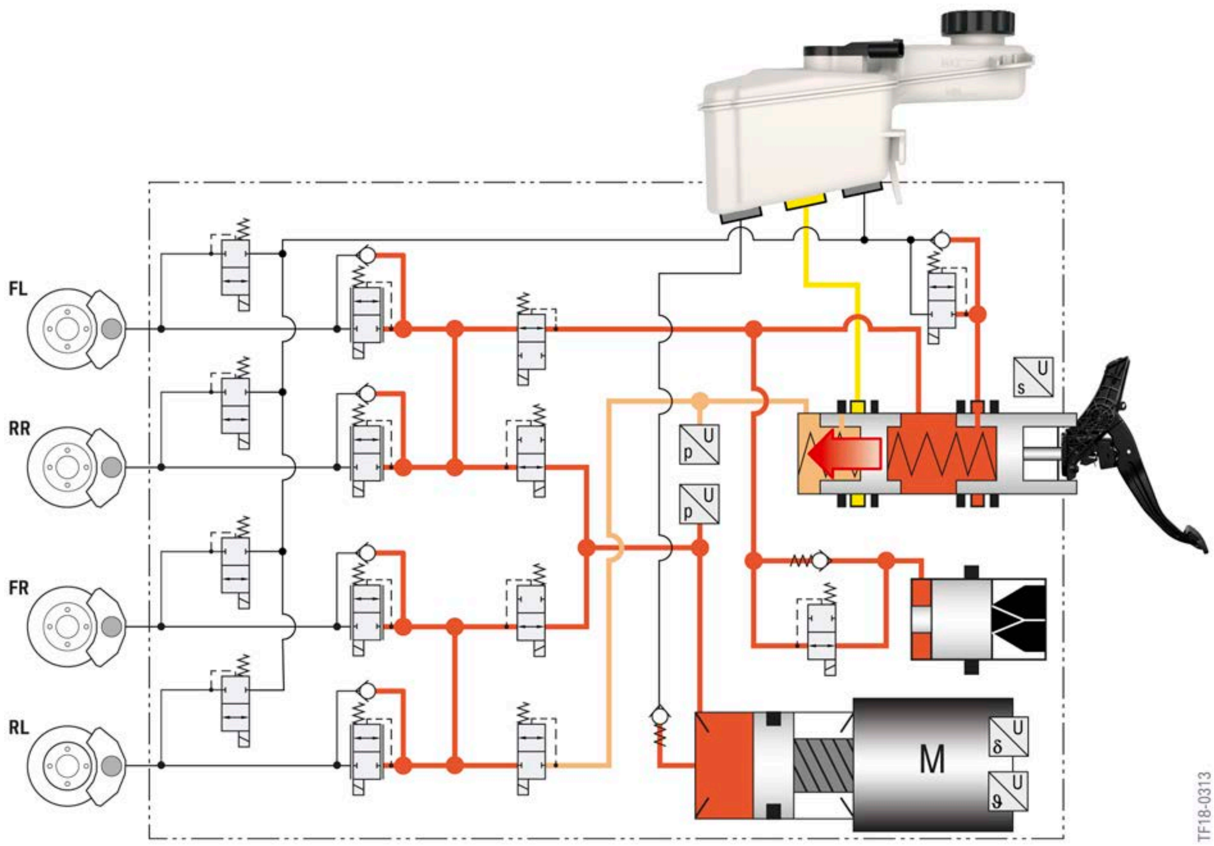


Step 1B of pre-drive check

Step 2:

The simulator valve is opened and the pressure in the direction of the brake pedal force simulator is reduced.

The signals from the different sensors are checked for plausibility in the process.



Step 2 of pre-drive check

Overview of valve positions

Status	Driver separator valve 1	Driver separator valve 2	Diagnosis valve	Simulator valve	Linear actuator changeover valves	Pressure retaining valves
1A	■	▲	▲	▲	■	▲
1B	■	▲	▲	▲	■	▲
2	■	▲	▲	■	■	▲

■ = open

▲ = closed

The pressure retaining valves are permanently closed during the test phase. This ensures that no hydraulic brake pressure acts on the wheel brakes. Employees who are carrying out servicing work on the brake system are not put at risk.

The fallback level is activated in the event of an incorrect pre-drive check.

2.2.3. DSCi control

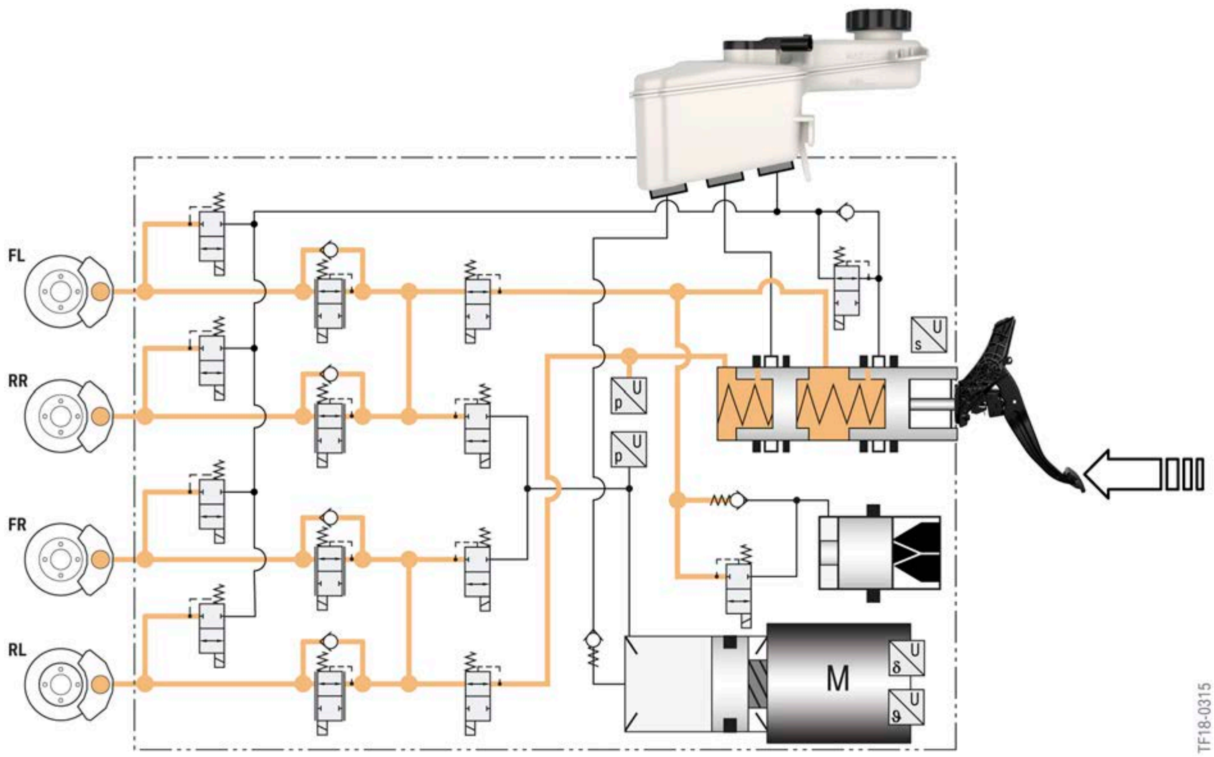
During ABS or DSCi pressure control phases the brake fluid volume in the pressure chamber is displaced via the pressure retaining and pressure reducing valves in the direction of the expansion tank. To maintain the necessary brake pressure, the linear actuator thereby moves further into the pressure chamber. During very long pressure control phases this results in the linear actuator extending to the maximum limit position.

To continue to make sufficient brake pressure available in these cases, the linear actuator moves back to the retracted position and in so doing draws in fresh brake fluid from the expansion tank. The brake fluid volume obtained as a result is then used again to build up the pressure. This process takes place within a few milliseconds and is unnoticeable to the driver.

Pulsations at the brake pedal, as occur in DSC brake systems during the pressure control phases, are not discernible due to the disconnection of the driver in the case of the DSCi brake. The driver receives appropriate feedback on pressure control phases exclusively via the flashing DSC indicator and warning light.

2.2.4. Fallback level

The fallback level is activated if signals are implausible. The linear actuator changeover valves are closed and the driver separator valves opened for this purpose. In addition, the function of the brake pedal force simulator is deactivated by the simulator valve being closed. The simulator circuit is now used actively for braking and thus becomes the working circuit.



Fallback level of DSCi brake

Valves	Open	Closed
Driver separator valves	●	
Simulator valve		●
Linear actuator changeover valves		●

In the de-energized fallback level a service brake effect of approximately 6.4 m/s² is achieved with a pedal force of 500 N. The customer however obtains a significantly changed braking feel. The background is the absence of brake-servo assistance by an power servo source.

The driver's foot force is amplified slightly by an adjusted transmission ratio of the lever travel on the brake pedal mounting and by the active activation of the actuators of the electromechanical holding brake on the rear axle. The braking power does not however reach the level of a braking operation in brake-by-wire mode.

To avoid dangerous driving situations due to an overbraking of the rear wheels, the actuators of the electromechanical holding brake are permanently slip-controlled in braking operations in the fallback level.

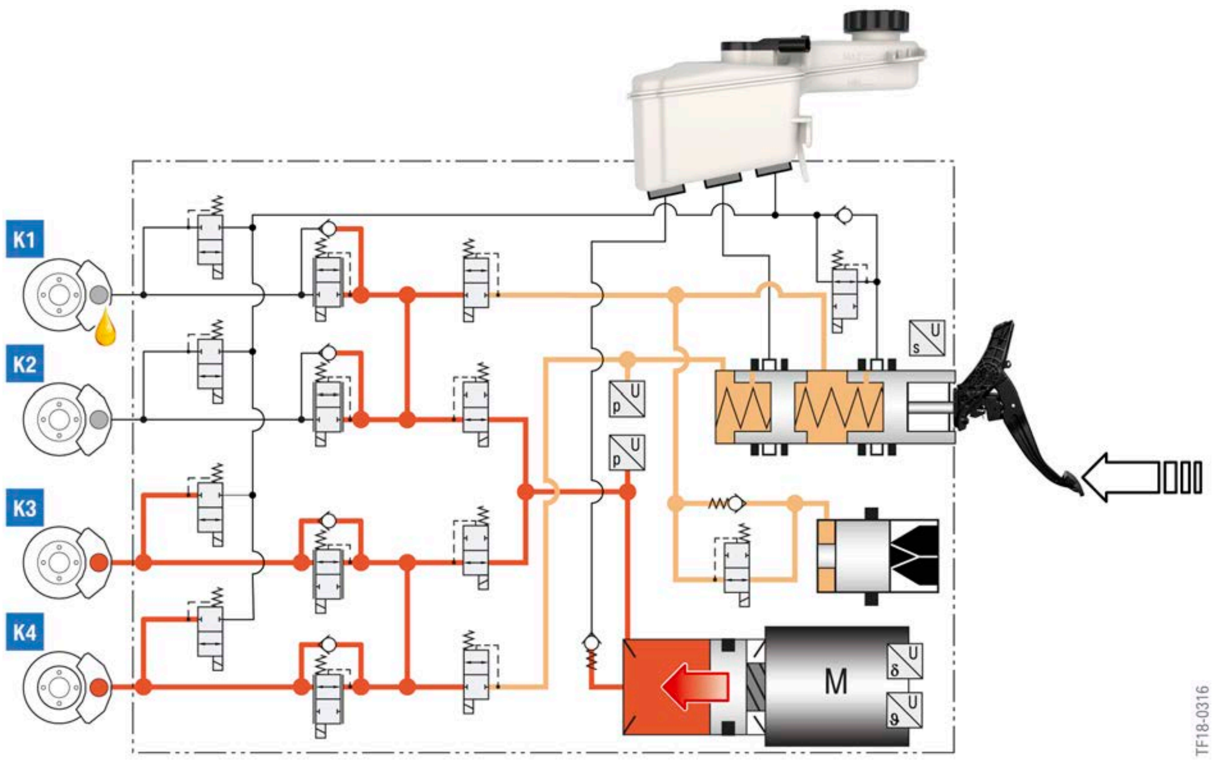
2.2.5. Leakage detection

Plausibility check

A leakage can be detected by checking the plausibility of the following sensor signals:

- Brake pedal travel sensor
- Brake pressure sensor in the working circuit
- Linear travel sensor.

The further the linear actuator travels into the pressure cylinder, the greater the value at the working circuit brake pressure sensor must be. If there is no pressure increase despite the movement of the linear actuator, there may be a leak in the brake system.



Deactivation of brake circuit 1 by channel deactivation, front, due to leakage detection

Index	Explanation
K1	Brake channel 1 with leakage (brake circuit 1)
K2	Brake channel 2 without leakage (brake circuit 1)
K3	Brake channel 3 without leakage (brake circuit 2)
K4	Brake channel 4 without leakage (brake circuit 2)

In the event of a deviation of the taught values of the linear travel and brake pressure sensors, the DSCi control unit assumes there is a leak. To identify the accordingly leaking brake circuit, the two pressure retaining valves of brake circuit 1 and the two pressure retaining valves of brake circuit 2 are closed in succession and opened again. If the brake pressure remains constant during the closing phase of the corresponding pressure retaining valves, the leaking brake circuit is identified and permanently closed via the two pressure retaining valves.

The vehicle is then slowed down via the brake circuit that is still intact along similar lines to a vehicle with a conventional brake.

2. Design and Description

The permanently closed brake circuit can only be restarted by eliminating the leakage and then deleting the fault memory.

⚠

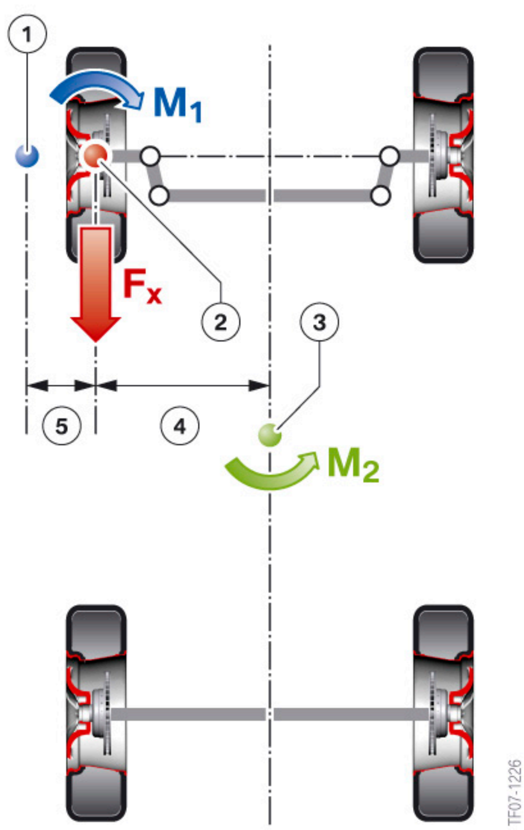
Deleting the fault memory to start a deactivated brake circuit is only useful after previously eliminating the leakage and checking for leaks. Failure to comply with this requirement may result in a renewed deactivation and consequently dangerous driving situations.

2.2.6. Braking with deactivated brake circuit

Current DSCi brake systems have a diagonal brake circuit split.

The two brake circuits are split as follows:

- Brake circuit 1 = front left wheel and rear right wheel
- Brake circuit 2 = front right wheel and rear left wheel.



Effect of kingpin offset with one-sided brake force

Index	Explanation
1	Intersection point of axis of movement with roadway (exaggerated)
2	Center of wheel contact face
3	Center of gravity of vehicle
4	Distance from center of wheel contact face to the vehicle longitudinal axis
5	Kingpin offset
F_x	One-sided application of brake force
M_1	Torque at the wheel
M_2	Yaw moment around the vertical vehicle axis

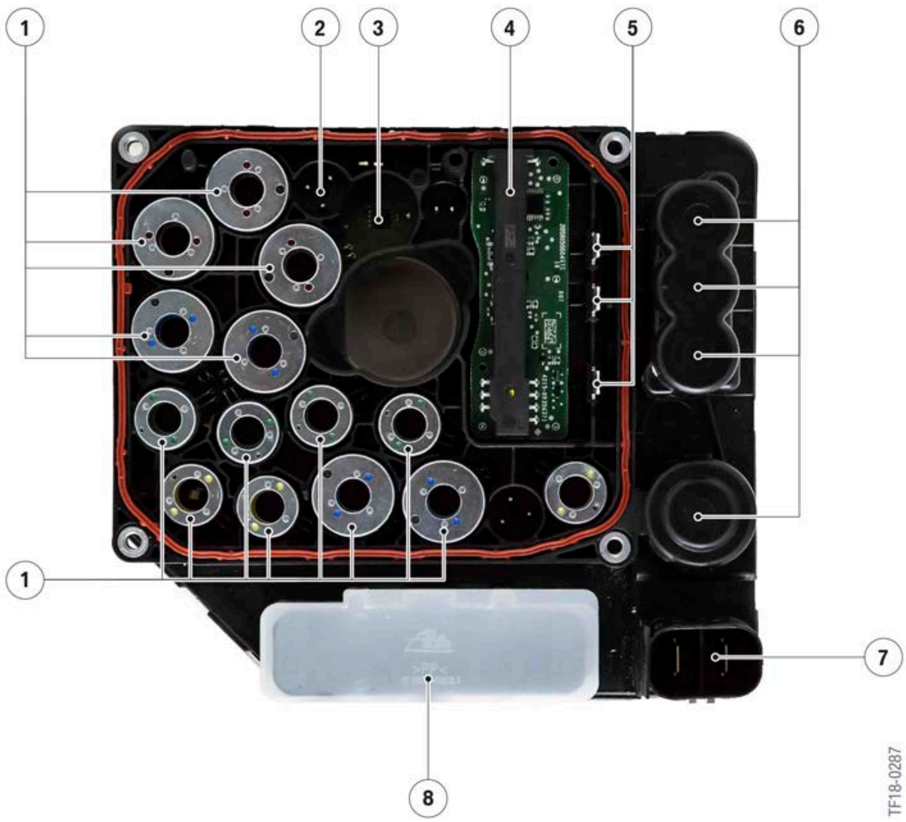
In the event of a failure of one of the two brake circuits, the vehicle is decelerated only via one while on the front axle. This one-sided deceleration of the wheels on the front axle generates a yaw moment around the vertical vehicle axis (M_2). To counteract this yaw moment, vehicles with diagonal brake force split have a negative kingpin offset. In the event of braking with only one intact brake circuit a torque is generated at the wheel (M_1) which counteracts the yaw moment around the vertical vehicle axis (M_2). A sudden, heavy pull on the vehicle during braking operations with a deactivated brake circuit is thus counteracted.

2.3. DSCi control unit

The DSCi control unit has 2 separate plug connections. One plug connection (8) supplies the DSCi control unit with the necessary working voltage and connects it to the vehicle electrical system. The other plug connection (7) supplies the linear actuator with voltage. Since the linear actuator has a very high power demand in electro-hydraulic brake-by-wire mode, it needs a working current of up to 80 A. For this reason, the second plug connection is as a rule connected to a loadable power source such as for example the jump start terminal point.

The DSCi unit is supplied via 1 ground connection (7) only. The control unit thus cannot be read out when plug (7) is pulled.

2. Design and Description



Interior view of DSCi control unit

Index	Explanation
1	Coils for solenoid valves
2	Connection, brake pressure sensor
3	Position sensor, electric motor
4	Linear travel sensor
5	Connections of electric motor (U, V, W)
6	Inverter (DC/AC) with capacitor box
7	Plug connection, DC voltage supply
8	Plug connection, vehicle electrical system

An inverter inside the DSCi control unit controls the linear actuator's electric motor.

⚠

The DSCi control unit cannot be replaced individually in the service workshop. In the event of a fault, the complete DSCi unit must be exchanged.

2.3.1. Virtual Integration Platform

Virtual Integration Platform in the DSCi control unit

Index	Explanation
DSC	Dynamic Stability Control
VIP	Virtual Integration Platform

2. Design and Description

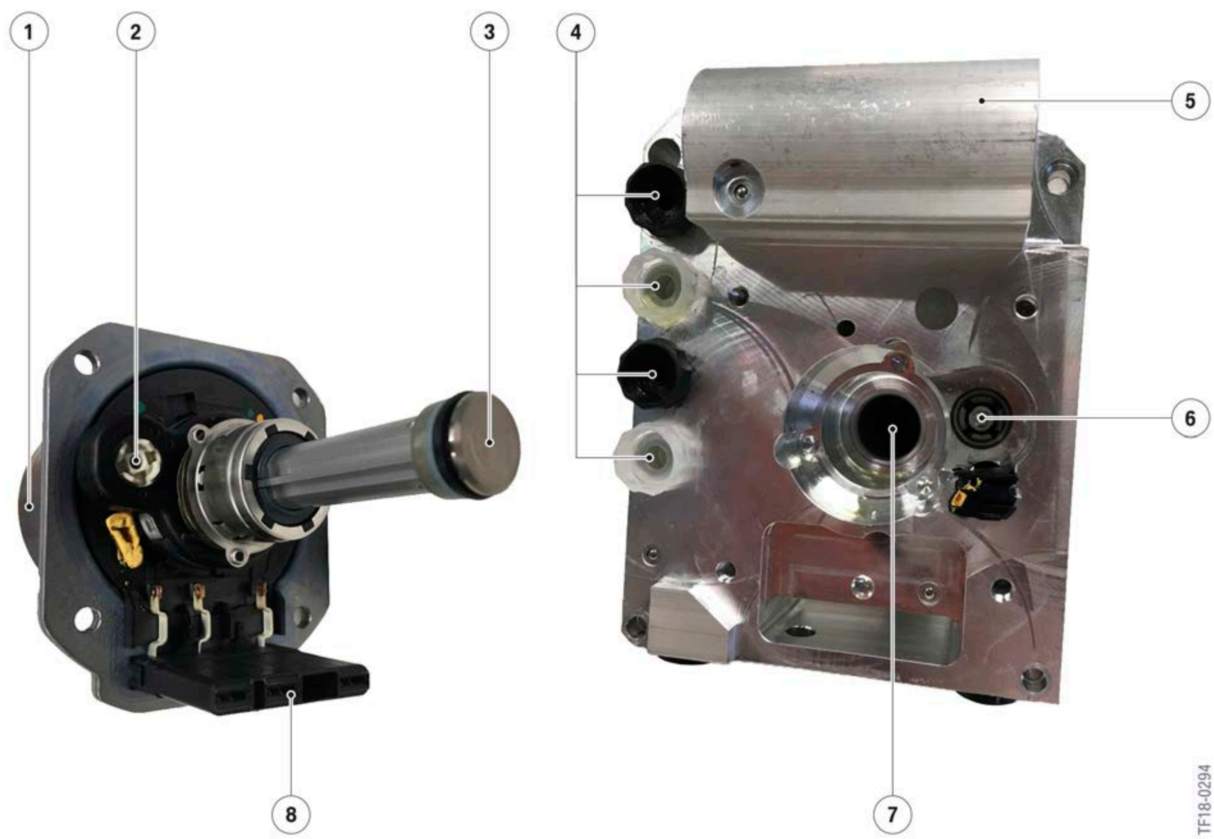
The DSCi unit consists of 2 control units which share a printed circuit board and a processor. Many computations of values from external sensors are performed in the Virtual Integration Platform (VIP). The computed sensor data are then made available via the bus to the other control units. In this way, for example, the signals from the yaw sensor and acceleration sensor are computed by the Virtual Integration Platform and made available to the DSCi control unit.

2.4. DSCi hydraulic control unit

The linear actuator is displaced in the hydraulic control unit pressure cylinder when the electric motor is actuated. This is done, in contrast to previous DSC return pumps, without pulsations. Damping elements to smooth the pressure peaks are therefore not required for the DSCi hydraulic unit.

Hydraulic brake pressure of up to around 200 bar can be achieved with the aid of a suitably high linear actuator transmission ratio.

To control the electric motor, the precise position of the rotor is communicated via a position sensor to the inverter.



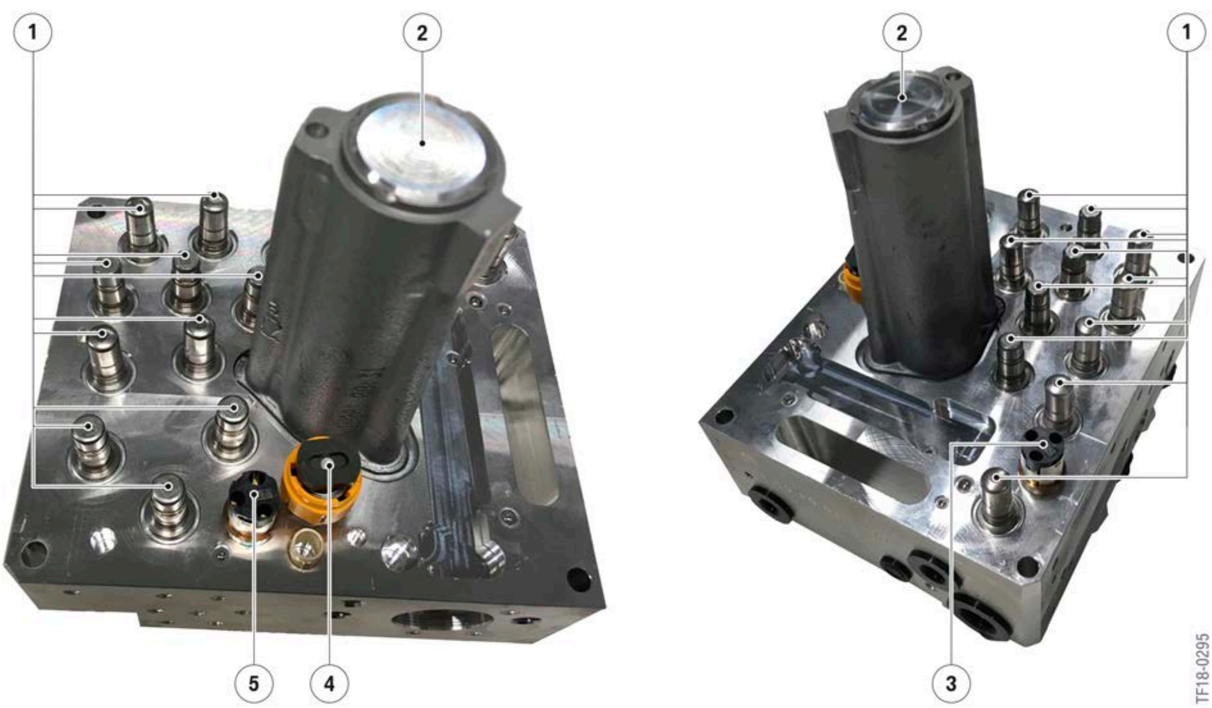
Interior view of DSCi hydraulic control unit with electric motor

Index	Explanation
1	Linear actuator electric motor (AC)
2	Shaft, position sensor, electric motor
3	Linear actuator
4	Connections of hydraulic lines
5	Brake pedal force simulator
6	Shaft, position sensor, electric motor
7	Pressure cylinder
8	Three-phase motor (U, V, W)

⚠

The DSCi hydraulic control unit cannot be individually replaced. In the event of a component fault, the complete DSCi unit must be exchanged.

As with previous DSC hydraulic control units, the different brake channels are switched via solenoid valves.

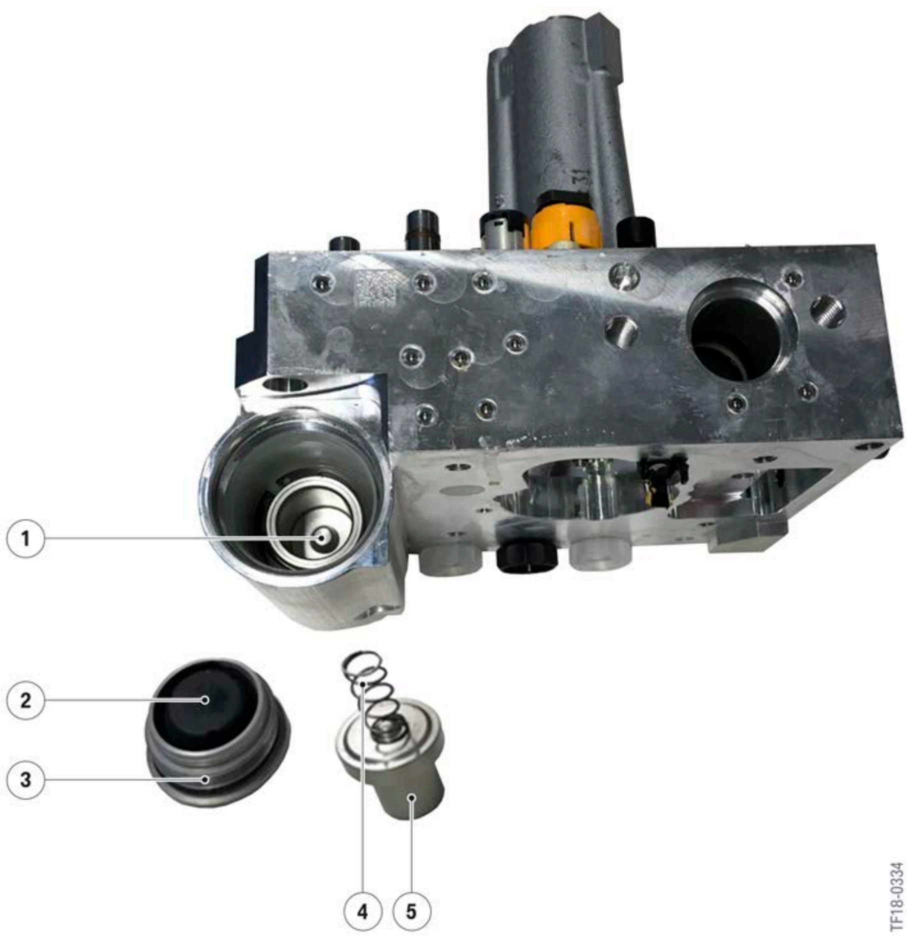


Interior view of DSCi hydraulic control unit

Index	Explanation
1	Solenoid valves
2	Linear actuator pressure cylinder
3	Brake pressure sensor simulator circuit
4	Position sensor, electric motor
5	Brake pressure sensor working circuit

2.4.1. Brake pedal force simulator

The brake pedal force simulator is equipped with a spring and an elastomer, which simulates the counterforce to the applied foot force. There is currently no provision for the possibility of adapting the spring rate in the service workshop by exchanging the spring.



Brake pedal force simulator of DSCi brake

Index	Explanation
1	Cylinder housing
2	Elastomer
3	Seal plug
4	Spring
5	Adapter

2.5. Control of electromechanical holding brake

As already familiar from the current DSC brake systems, the DSCi brake also assumes the function of controlling the electromechanical holding brake. The special features and differences from the DSC brake systems are set out in the following.

2.5.1. Dynamic emergency braking function

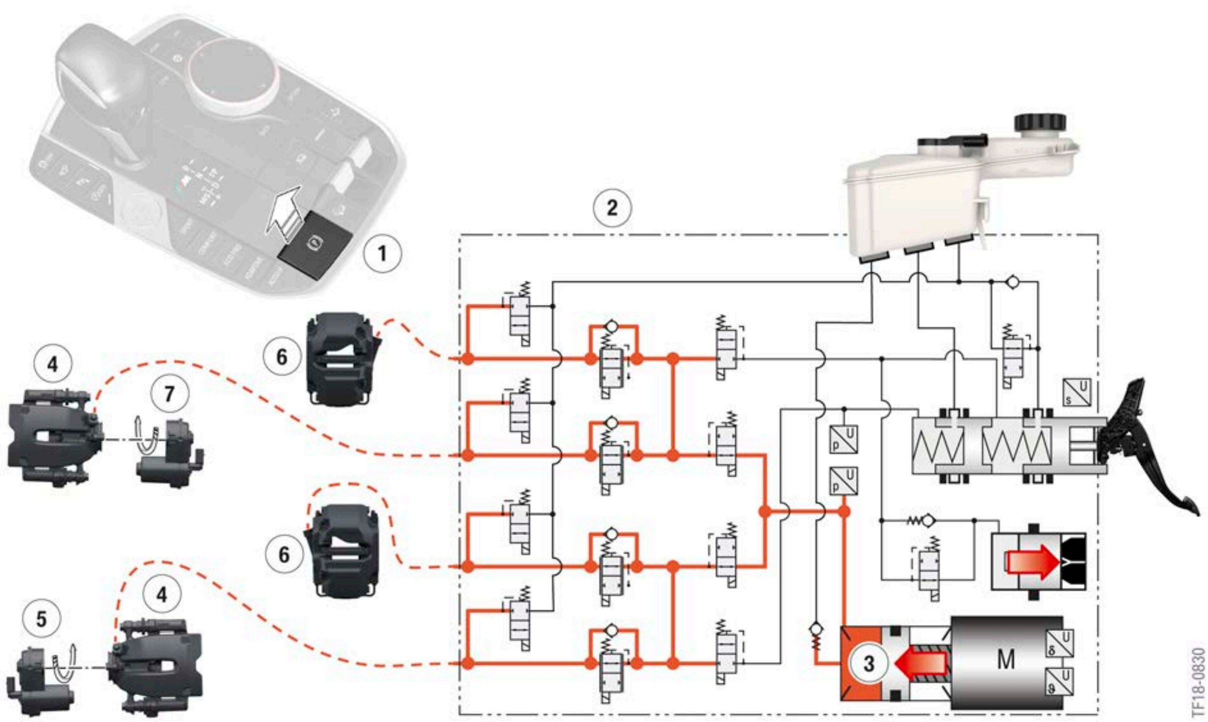
If the parking brake button is operated during the journey above a defined driving speed, the DSCi unit initiates a dynamic emergency braking operation. A pressure build-up occurs at all four wheel brakes as a result of the activation of the linear actuator and the different solenoid valves. The slip limits are monitored with the assistance of the four wheel speed sensors to ensure a stable braking operation until the vehicle comes to a standstill. The two actuators of the electromechanical holding brake are activated as soon as the vehicle comes to a standstill. The vehicle is then secured to prevent it from rolling away only by means of the parking brake.

Fallback level of dynamic emergency braking function

If the parking brake button is pressed while driving and the brake hydraulics fail, a controlled braking of the vehicle is performed via the actuators of the electromechanical holding brake. Controlled deceleration means that the slip limits of the rear axle are permanently monitored via the wheel speed sensors. If these are exceeded and an unstable driving situation occurs as a result, the actuators of the electromechanical hold brake are released until the performance values for slip at the rear wheels are once again stable.

2.5.2. Hydraulic power amplification

Pressing the parking brake button while the vehicle is stationary results in application of the brake pads. The vehicle is thereby secured against rolling away when it is stationary. In previous parking brake systems merely the two actuators of the electromechanical holding brake on the rear brake calipers were activated for this purpose.



Hydraulic power amplification of the electromechanical holding brake in the G05

Index	Explanation
1	Parking brake button
2	DSCi unit
3	Linear actuator
4	Brake caliper, rear
5	Actuator, electromechanical holding brake, rear left
6	Actuator, electromechanical holding brake, rear right

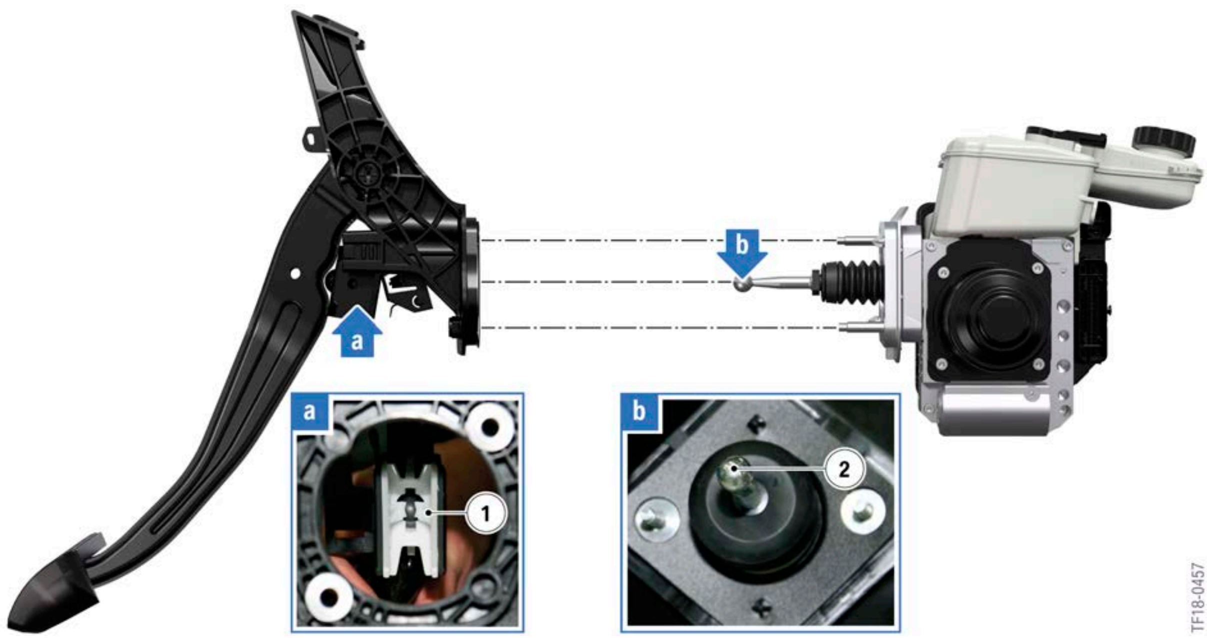
In some variants of the DSCi brake a hydraulic pressure build-up at all four wheel brakes occurs in parallel with activation of the electromechanical holding brake. This is effected by activation of the linear actuator and the various solenoid valves. This produces a higher preload force and reduced mechanical load on the components of the electromechanical holding brake.

The "hydraulic power amplification of the electromechanical holding brake" function is only briefly active while the brake pads are applied and does not serve to brake the vehicle continuously when stationary.

3. Service and Maintenance

3.1. Pedal mechanism mounting

The pedal mechanism is connected to the DSCi unit by means of a ball head and a plastic clamp.



DSCi brake pedal mechanism mounting

Index	Explanation
1	Plastic clamp
2	Ball head

The following special tool is needed to release the pedal mechanism.

Special tool for removing the pedal mechanism

3.2. Brake service

Brake servicing

Servicing of the wheel brake can be carried out in the customary manner. There is no risk of injury from an independent build-up of brake pressure. As with conventional (connected) brake systems, the brake pedal and the parking brake button must not be pressed in the course of various service tasks, such as for example when changing a brake pad.

Since the driver separator valves are in the rest position (de-energized) when the brake pedal is not pressed, the brake fluid volume may be displaced into the expansion tank when the brake piston is pressed back. As soon as the brake pedal is gently pressed, the driver separator valves are activated and closed the hydraulic line towards the expansion tank. The brake piston can no longer be pressed back.

If the ID transmitter has been removed from the vehicle and then brought back again, this can result in activation of the "pre-drive check". Because the pressure retaining valves in the DSCi hydraulic unit are closed during the entire test sequence, no brake pressure is directed into the wheel brakes.

⚠

Caution - Risk of injury when working on the wheel brake. Pressing the parking brake button may cause a hydraulic pressure build-up at all four wheel brakes.

3.2.1. Establishing the clearance

After being replaced, the brake pads must be applied to the brake disc. The small air gap thereby created must be big enough so that the brake pad is no longer applied to the brake disc, but at the same time, in the case of a braking operation, merely has to cover a very small distance. This ensures the fastest possible response by the wheel brake (approximately 0.1 to 0.2 s).

Since the brake pistons must be pressed back by hand in order to replace the brake pads, the distance (clearance) between brake disc and brake pad must be particularly large after each brake pad change. The following actions must be carried out in succession to establish the correct clearance after a brake pad change:

1 Renew the brake pads and if necessary the brake discs on one axle.
2 Pull the parking brake button without operating the footbrake.
3 Operate the footbrake after successfully activating the holding brake.
4 Release the holding brake again.
5 If required, renew the brake pads and if necessary the brake discs on the second axle.
6 Pull the parking brake button without operating the footbrake.
7 Operate the footbrake after successfully activating the holding brake.
8 Release the holding brake again.

Reducing the clearance as on DSC brake systems by pressing the footbrake could result in fault memory entries. It is important in particular to ensure that the process for establishing the clearance is completed for an individual axle. This means that after each change of the brake pads on one axle the correct clearance must be established before the brake pads on the second axle are renewed.

Because an increased brake fluid volume is needed to apply the brake pads, the linear actuator must cover a large distance. This is done however without a correspond pressure increase, which could activate leakage detection.

The following measures are used to avoid fault memory entries when changing brake pads caused by a slow pressure build-up when establishing the clearance:

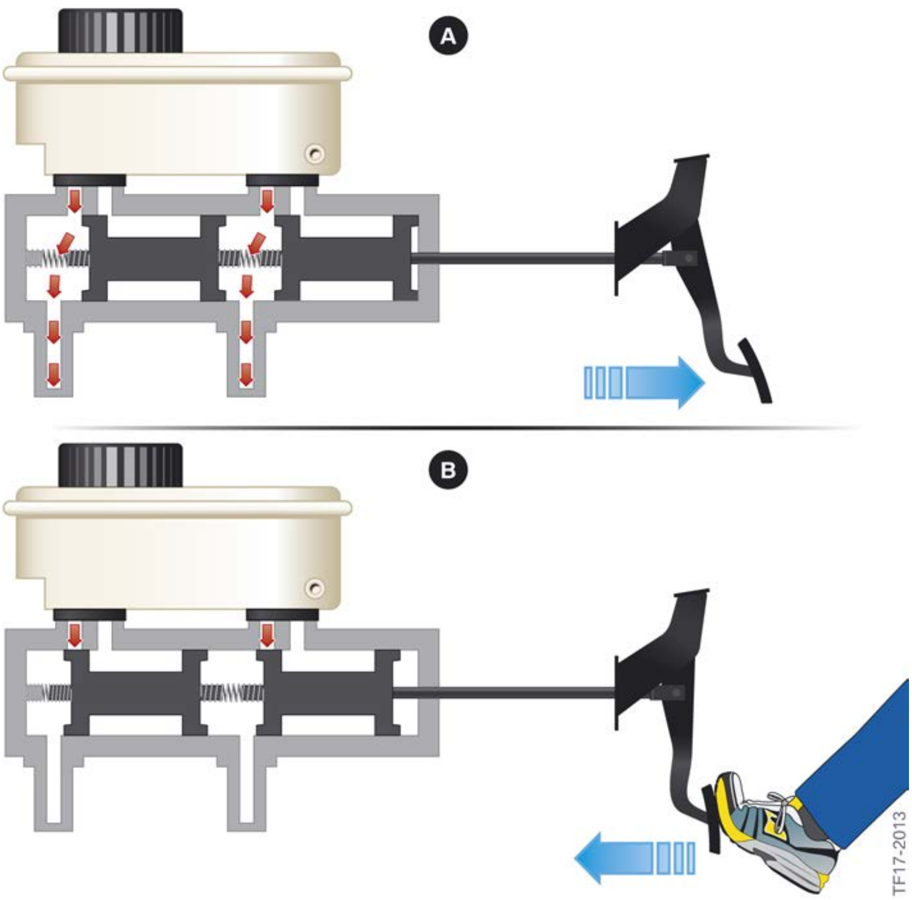
- Establishing of the clearance for an individual axle and thus a low brake fluid volume needed.
- Activation of the electromechanical holding brake and thus application of the brake pistons via actuators of the electromechanical holding brake.

⚠

An incorrect procedure in the course of brake servicing may result in an activation of leakage detection. Fault memory entries due to leakage detection may in turn result in activation of the fallback level. It is therefore absolutely essential to service the brake system in accordance with the currently applicable repair instructions!

3.3. Opening the brake line

3.3.1. DSC brake



Tandem brake master cylinder service position, DSC brake

Index	Explanation
A	Brake not activated
B	Brake operated

To minimize the dripping of opened brake lines as much as possible, a brake pedal tensioner was used in previous DSC brake systems before the brake hydraulics were opened.

3.3.2. DSCi brake

The DSCi brake system is subject to a permanent pressure build-up when the footbrake is pressed and the ignition is on. The linear actuator would thus displace the entire brake fluid volume of the expansion tank in the direction of the opened brake line.

⚠

The specifications in the current repair instructions must be followed!

3.4. Brake fluid

The BMW-prescribed DOT 4 low-viscosity brake fluid is required.

Trade name	BMW part number	Container
BMW brake fluid DOT 4 NV	83 13 0 443 023	0.25-liter container
BMW brake fluid DOT 4 NV	83 13 0 443 024	0.50-liter container
BMW brake fluid DOT 4 NV	83 13 0 443 026	1.0-liter container
BMW brake fluid DOT 4 NV	83 13 0 443 027	5.0-liter container
BMW brake fluid DOT 4 NV	83 13 0 443 028	30.0-liter container
BMW brake fluid DOT 4 NV	83 13 0 443 029	60.0-liter container

3.5. Brake bleeding

3.5.1. Note for Service

Particular importance is attached to bleeding the DSCi brake system. The background is the "Leakage detection" function. On vehicles subject to a maintenance backlog and with very old brake fluid and on vehicles for which the prescribed procedure for bleeding the DSCi brake was not followed, the fallback level may be activated in extreme cases.

Aggravating factors on top of the above-mentioned causes can be:

- Hot-climate country and very aggressive driving style
- Racetrack driving.

Because brake fluid permanently absorbs moisture from the environment, the proportion of water inside the brake hydraulics increases with increasing age. This can lead to vapor pockets forming in the brake hydraulics in situations where the wheel brake absorbs a great deal of heat. When vapor pockets are formed, the admitted brake pressure reduces since these gases are compressible and can thus be compressed. The signals of the brake pressure sensor in the working circuit and of the linear travel sensor are thus no longer plausible in relation to each other. If the stored threshold values are exceeded, this results in fault memory entries up to and including activation of the fallback level.

⚠

The brake fluid renewal must be performed with a bleeder unit.

3. Service and Maintenance

If the brake fluid is renewed by pressing the brake pedal and without using a bleeder unit, only a very small amount of the old brake fluid is removed from the brake system. Furthermore, instead of replacement, the brake fluids are subject to a high degree of mixing.

Top-up quantities for brake fluid renewal

The table below provides an overview of the top-up quantities required for changing the brake fluid in the different brake systems:

DSC brake	DSCi brake
Approx. 1 l	Approx. 2 l

The following work steps do not replace repair instructions. Merely the different states within the DSCi hydraulic control unit are shown.

⚠

To avoid malfunctions or impairments of the DSCi brake system, it is absolutely essential to follow the manufacturer's directions. Brake fluid renewal may only be carried out in accordance with the current repair instructions.

3.5.2. Brake fluid expansion tank

The filling volume of previous expansion tanks is approximately 0.2 l. The expansion tank of the DSCi brake system has a filling volume of approximately 0.6 l.

To minimize the mixing of old and new brake fluid as much as possible, it is essential to evacuate the old brake fluid before connecting the bleeder unit. Evacuation of the old brake fluid is performed by activating the brake fluid renewal routine.

3.5.3. Activating the routine for brake fluid renewal

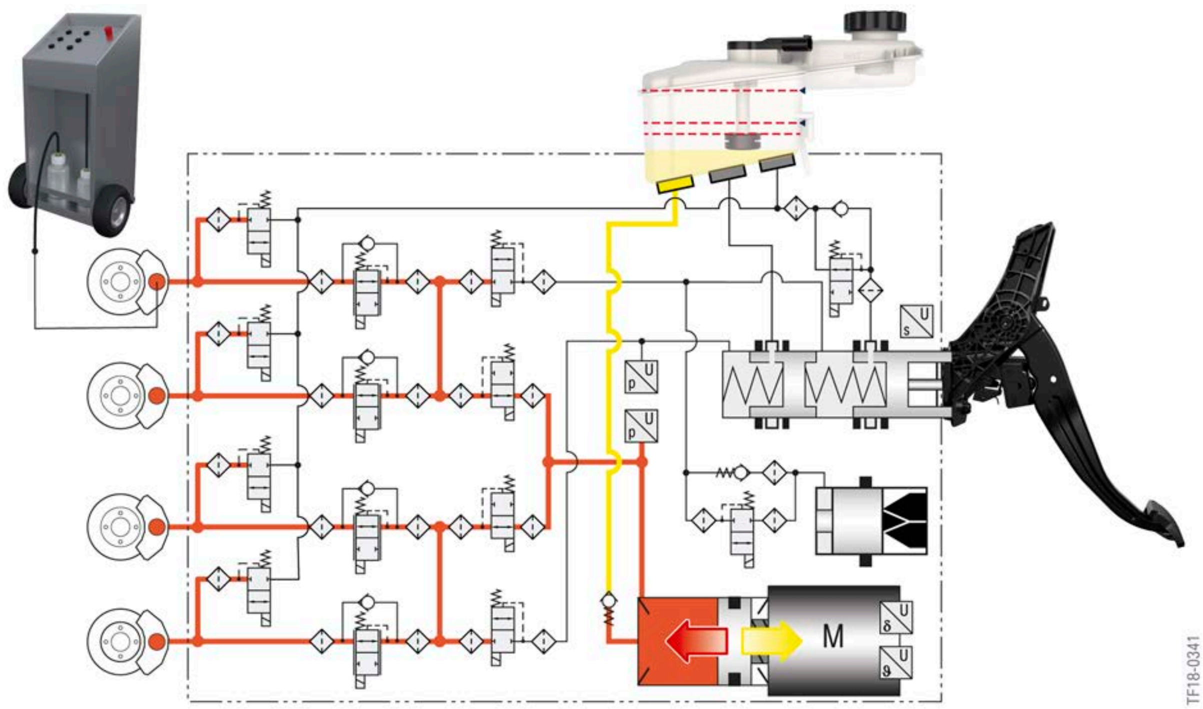
Renewing the brake fluid in the DSCi brake must always be performed with the aid of a routine. This can be carried out by the ISTA workshop information system or at a later time directly in the vehicle via a service menu.

The routine for brake fluid renewal serves to activate the linear actuator to evacuate the brake fluid volume of the expansion tank and to change the old brake fluid in the pressure chamber.

3.5.4. Evacuating the old brake fluid

The linear actuator is permanently activated when the routine for brake fluid renewal is activated. When the bleeder valve is opened, the old brake fluid flows off into the collecting container.

When the linear actuator is activated, old brake fluid is drawn from the expansion tank and then forced by compression into the collecting container.

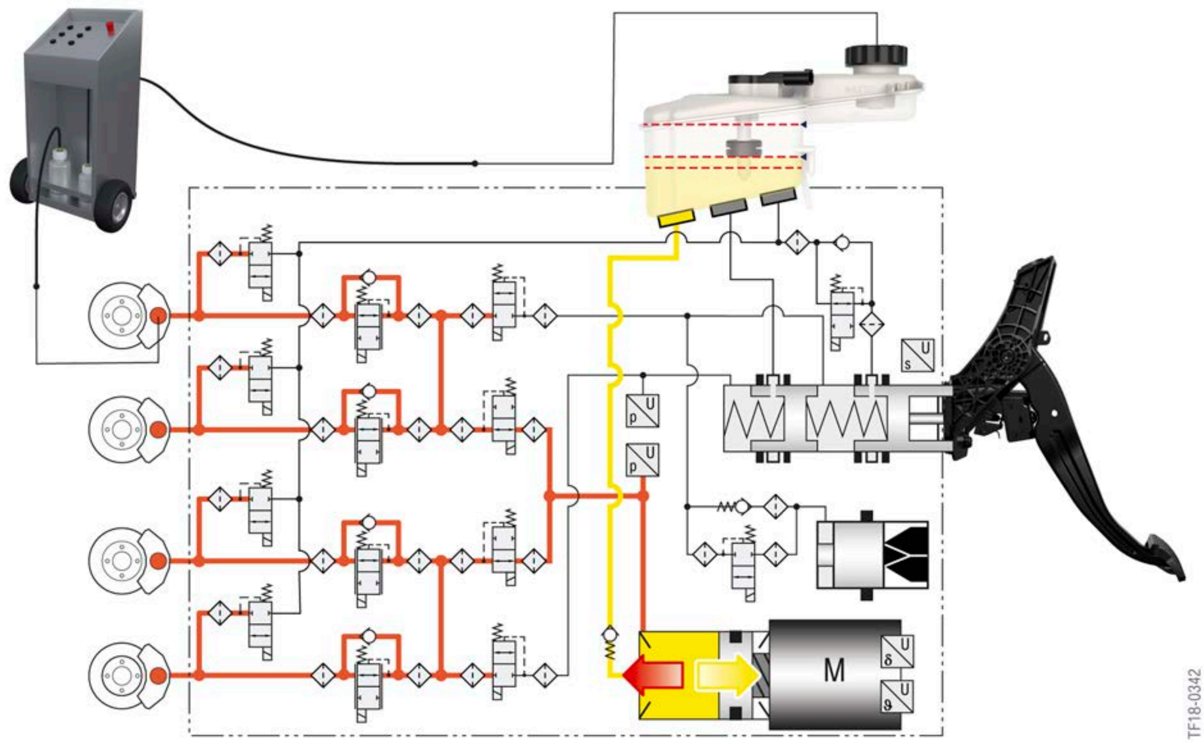


Evacuating the old brake fluid from the expansion tank as part of the routine for brake fluid renewal

Activation of the linear actuator is interrupted if the brake fluid level sensor detects a low fill level. This prevents the intake of air.

3.5.5. Flushing the pressure chamber

A flushing of the pressure chamber takes place in the following work step. The bleeder unit is connected to the expansion tank and turned on for this purpose. The brake fluid level sensor detects the changed expansion tank fill level. The linear actuator is activated again. A flushing of the pressure chamber takes place in response to intake and compression.



Flushing the pressure chamber with the aid of the linear actuator as part of the routine for brake fluid renewal

3.5.6. Sequence for brake bleeding

To supply the other brake channels with new brake fluid, the collecting container must be connected alternately to the remaining bleeder valves. The exact sequence specified in the repair instructions must be observed.

3.5.7. Final steps

To conclude, the fill level in the expansion tank must be checked and where necessary corrected. Furthermore, the leak-tightness of the brake hydraulics must be guaranteed after all servicing work has been completed.

⚠

Bleeding the DSCi brake without complying with the prescribed brake bleeding routine may result in activation of the fallback level in extreme cases. The background is the large brake fluid volume in the pressure chamber, which is flushed only as part of the routine for brake fluid renewal.

3.5.8. Brake bleeding routine for special cases

If air gets into the DSCi hydraulic control unit, a special brake bleeding routine must be initiated with the aid of the ISTA workshop information system. The air in the system is evacuated by a separate activation of the linear actuator and a more elaborate brake bleeding procedure.

3.6. Leak-testing the brake hydraulics

In the DSCi brake the maximum hydraulic brake pressure of approximately 200 bar is admitted exclusively while driving. When the brake pedal is pressed to maximum with the vehicle stationary, the DSCi control unit computes the brake pressure required for this driving condition.

The hydraulic brake pressure with the vehicle stationary and the brake pedal pressed to maximum is approximately:

- 160 bar in the simulator circuit
- 80 bar in the working circuit.

A leakage test with the vehicle stationary at maximum brake pressure as in conventional vehicles is therefore not possible with the DSCi brake.

3.7. DSC and DSCi unit

DSC and DSCi unit

Index	Explanation
A	DSC unit (separable)
B	DSCi unit (not separable)
1	DSC hydraulic control unit
2	DSC control unit
3	DSCi hydraulic control unit
4	DSCi control unit

3. Service and Maintenance

3.7.1. Notes for Service

In previously used DSC brake systems the DSC control unit could be replaced separately and re-taught with the existing DSC hydraulic control unit. A separate replacement of individual components, apart from the brake fluid expansion tank, is currently not possible on the DSCi unit.

Replacing the DSCi unit

The following measures must be carried out after the DSCi unit has been replaced:

- Programming and encoding
- Adjustment of DSCi control unit
- Adjustment of driving dynamics sensors.

During start-up the pressure sensors of the hydraulic unit are taught and the different values determined according to the position of the linear actuator.

⚠

The DSCi unit may not be opened. The DSCi control unit cannot be replaced separately.

3.8. Service functions in ISTA

The workshop employee has at his/her disposal the following service functions in the ISTA workshop information system:

- Brake bleeding routine for special cases
- Brake fluid renewal for maintenance work
- Adjustment of DSCi control unit for adjustment of pressure sensors
- Adjustment of driving dynamics sensors resets the acceleration sensors and yaw sensors.