

■ **Anti-Lock Braking System (ABS) and Anti-Slip Regulation (ASR)**

■ **2nd Edition**

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Anti-Lock Braking System (ABS)

Purpose

Anti-lock brake systems (ABS) - generally also referred to as anti-lock systems (ALS) - are designed to prevent the vehicle wheels from locking as a result of the service brake being applied with too much force, especially on slippery road surfaces.

The idea is to maintain cornering forces on braked wheels to ensure that the vehicle or vehicle combination retains its driving stability and manoeuvrability as far as physically possible. The available power transmission or grip between tyres and carriageway should also be utilised as far as possible to minimise the braking distance and maximise vehicle deceleration.

Why ABS?

Although today commercial vehicle brakes are designed to a very high technical standard, braking on slippery roads often results in potentially dangerous situations. During full or even partial braking on a slippery road it may no longer be possible to fully transfer the braking force onto the road due to the low coefficient of friction (friction coefficient (k)) between the tyres and the carriageway. The braking force is excessive and the wheels lock up. Locked wheels no longer provide any grip on the road and are almost incapable of transferring any cornering forces (steering and tracking forces). This often has dangerous consequences:

- The vehicle becomes unsteerable
- The vehicle breaks away in spite of countersteering, and starts to swerve.
- The braking distance is significantly increased
- Tractor-trailer combinations or semitrailer trains may break away or jackknife.

Load sensing valve influence

On dry roads today's load sensing valves (ALB) alone are often capable of preventing the wheels from locking if the vehicle is unladen; they also help the driver to effectively grade the braking process on wet road surfaces, but they are unable to prevent locking as such (no slip monitoring). In addition, they are unable to counteract any overreactions on the part of the driver, or any variances in frictional or adhesion coefficients which may apply to different sides of the vehicle, or indeed to its different axles (μ -split road surfaces).

Benefits of ABS:

Only the Anti-Lock Brake System (ABS)

- guarantees stable braking characteristics on all road surfaces.
- maintains steerability and generally reduces the braking distance
- prevents vehicle combinations from jackknifing
- reduces tyre wear.

Limits of ABS

Although ABS is an effective safety device, it can not suspend the limits defined by driving physics. Even a vehicle fitted with ABS will become uncontrollable if driven too fast around a corner.

So ABS is not a licence for a maladjusted style of driving or failure to observe the correct safety distance.

Anti-Slip Regulation (ASR)

Why ASR?

Increasing the engine output (accelerating) on a slippery road surface can easily lead to the maximum adhesion on one or all powered wheels being exceeded causing them to spin, especially if the vehicle is unladen or partially laden.

Spinning wheels when driving off or accelerating represent a safety risk just like locked wheel do when braking.

Reasons

- Wheels that spin transfer just as little cornering force as locked wheels.
- They also no longer transfer any tractive power onto the road.

Consequences

- Vehicles that do not move or get stuck.
- Vehicles that can no longer be steered, jackknife on uphill uphill gradients, or swerve in corners.

Benefits of ASR

ASR prevents the powered wheel from spinning and provides the following benefits:

- Tractive power and cornering forces are maintained.
- Stable driving behaviour is ensured when moving off, accelerating and negotiating corners on slippery roads.
- The indicator lamp (if installed) is used to warn the driver of slippery road conditions.
- Tyre wear is reduced to a minimum, and the motor vehicle's drive train protected
- The risk of accidents is further reduced.

ASR and ABS:

ASR represents a worthwhile addition to an ABS-controlled braking system. All that is required to turn ABS control into full ABS/ASR control is an ECU with the additional ASR function and a few additional components for controlling the differential brake and the engine. This why ASR is only available in combination with ABS.

Even a differential lock for off-road use and ASR do not exclude but complement each other.

Limits of ASR

The traction capacity of an all-wheel driven commercial vehicle can not be achieved by a motor vehicle with only one driving axle - not even with optimal ASR.

RSC and ESC

RSC (Roll Stability Control) From the ABS E version onwards, lorries, semitrailer tractors and buses can be equipped with Roll Stability Control (RSC) in addition to ASR. This function is integrated in the ABS control unit and can be activated by the vehicle manufacturer.

RSC controls the engine output and applies the service brake to reduce the risk of overturning in corners. RSC identifies the critical lateral acceleration for this purpose.

When the lateral acceleration exceeds a specific level, RSC reduces the engine torque, activates the engine brake and brakes, if required, the towing vehicle axles as well as the trailer, if applicable.

RSC also applies the brakes on the towing vehicle front axle by means of a 3/2 solenoid valve fitted there.

A lateral acceleration sensor and the software for signal processing, monitoring and driving dynamics control are integrated in the ABS control unit for RSC.

ESC (Electronic Stability Control)

Lorries, semitrailer tractors and buses can be equipped with Electronic Stability Control (ESC) in addition to ASR control. ESC is available from the ABS E version onwards and requires additional components.

Within physical limits, ESC operates automatically and takes corrective action in terms of engine output and brake to keep the vehicle on track during extreme driving situations.

It operates when driving as well as braking and comprises two independent functions:

Control of tracking stability (yaw Control)

This function is activated when the vehicle loses stability in critical situations (e.g. during a sudden change of track). In such situations ESC uses ABS or EBS to regulate the braking forces on each wheel, throttles the engine output, thereby reducing the risk of swerving when cornering and during avoidance manoeuvres.

ESC prevents potential "jackknifing" of a semitrailer train by simultaneous, dosed braking of the semitrailer even if it is equipped with a conventional braking system.

Driving stability control (ROP – Roll Over Protection)

This function is activated when there is a risk of overturning, e.g. when cornering too fast. The function is similar to RSC (Roll Stability Control).

The ESC control unit processes the data from the yaw rate, lateral acceleration and steering angle sensors and communicates with the ABS or EBS control unit via the braking system data bus.

The ESC function requires the following additional components:

- ABS control unit with ESC functionality
- ESC module
- Valves in accordance with the respective vehicle. The 3/2 solenoid valve on the front axle is needed to brake the front axle wheels separately. The 3/2 solenoid valve upstream of the trailer control valve is needed to brake the trailer at the same time.
- Brake pressure sensor
- Steering angle sensor

Development

1969	After extensive studies, the first prototype is presented to the public at the IAA Motor Show in 1969.
1974	WABCO and Mercedes-Benz enter into a co-operation agreement. Collaborative teamwork push both system development and vehicle testing ahead.
1975	WABCO begins to develop its own electronic systems based on analogue and integrated signal processing. Co-operation is extended to other manufacturers.
1980	Introduction of fully digitised electronics. Microcomputers are the core element and are used in commercial vehicles for the first time. Final winter testing in Lapland near the polar circle in the presence of experts from many different countries.
1981	Mercedes-Benz and, all little later, other vehicle manufacturers as well approve the WABCO ABS system. Series production of the A version (2 and 4 channel systems).
1986	Introduction of WABCO ASR (traction control system) with the B generation electronic control units. Introduction of 6-channel ABS.
1989	Introduction of modular VARIO-C ABS for trailers (with fault memory and ISO diagnostics).
1990	Introduction of the ABS/ASR C generation in the towing vehicle (with fault memory, ISO diagnosis and additional optional features).
From October 1991	EC Directive makes ABS compulsory for heavy-duty commercial vehicles.
1994	Introduction of the VARIO COMPACT SYSTEM (VCS) for trailers and integration of the now legally required speed limiter in towing vehicles of the C generation.
1996	Introduction of the ABS-D generation in towing vehicles and introduction of the electronically controlled braking system EBS for motor vehicles.
1998	Introduction of the EBS for trailers and phased statutory requirement for ABS also in lighter motor vehicles.
2000	Presentation of the ABS-E generation in the towing vehicle, partly with EBL (Electronic Brake Force Limitation) as a replacement for LSV.
2003	Enhancement of ABS through the RSC function (Roll Stability Control).
2004	Introduction of the 2nd generation Vario Compact ABS (VCS II) for trailers.
2008	Development of the ABS E4 version. This version provides further functions in addition to ABS: ESC (Electronic Stability Control), RSC (Roll Stability Control), ATC (Automatic Traction Control, with engine control), PLC (Power Line Carrier), XBR (external Brake Request, e.g. for WABCO OnGuard).

Theoretical ABS basics

The brake force coefficient (μ_B):

The brake force coefficient (adhesion) between the wheel and the carriageway determines the braking forces that can be transferred. It depends on the brake slip between the tyre and the road, and among the factors affecting it are:

- the condition of the road and the tyres
- the wheel or axle load
- the speed of the vehicle
- the temperature
- the tyre slip angle and/or the cornering force used.

The cornering force coefficient (μ_S):

Maintaining cornering stability is an essential requirement for the steerability of a vehicle. The cornering force coefficient decreases much more rapidly than the brake force coefficient in combination with the same brake slip.

The brake slip (λ):

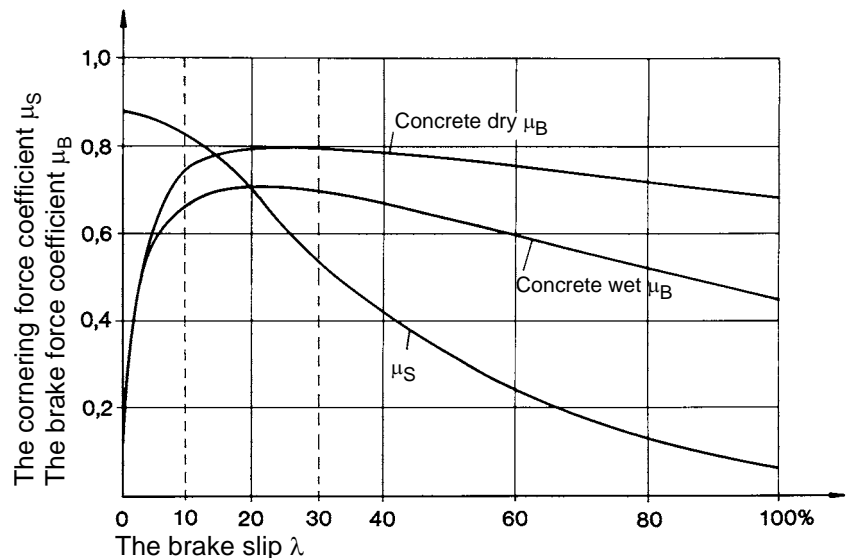
The brake slip is the percentage ratio of vehicle speed to wheel speed. The slip is defined by the following equation:

$$\text{brake slip } \lambda = \frac{V_F - V_R}{V_F} \times 100 \%$$

V_F = Vehicle speed

V_W = Wheel circumference speed

Explanation of the slip curves (μ_B and μ_S)



This illustration shows the relationship between the brake force coefficient μ_B , the cornering force coefficient μ_S and the brake slip λ for different road conditions.

While maximum adhesion is not achieved, it is possible to increase the braking force within the "stable" range by increasing the slip. In this case, there are also sufficiently large cornering forces available to keep the vehicle steerable and therefore stable.

If the unstable range of the μ - λ curve (between approx. 30 and 100%) is reached due excessive braking forces, the wheel is overbraked and will lock (100% slip). The vehicle is then almost completely unsteerable.

To prevent this from happening, the ABS system regulates adhesion between 10 % and 30 % slip.

Theoretical ASR basics

The traction slip (λ_{an}):

As with braking, the propulsion force that can be transferred from the tyre onto the road surface depends on the slip between the tyre and the road.

Traction slip is the percentage ratio of wheel speed to vehicle speed and is defined by the equation:

$$\lambda_{an} = \frac{V_R - V_F}{V_R} \times 100 (\%)$$

V_W = Wheel circumference speed

V_F = Vehicle speed

The traction-adhesion coefficient (μ_{an})

The traction-adhesion coefficient and thus the propulsion power depends on the same factors as the braking force coefficient described above.

When the wheels spin heavily ($\lambda_{on} = 100\%$), the adhesion will be reduced significantly below the maximum value. The cornering force coefficient also falls as drive slip increases, and by the time the wheels spin it is negligible.

ASR control

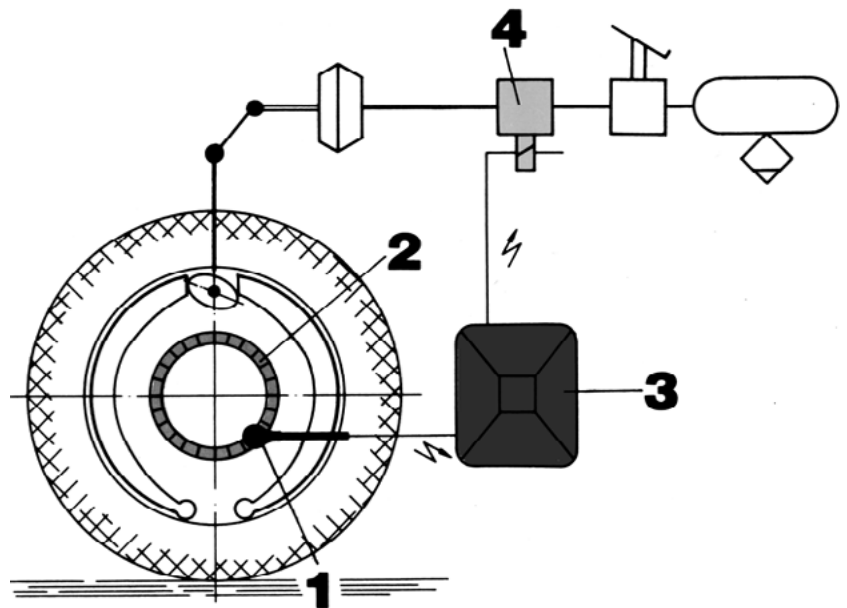
Drive slip regulators influence the acceleration events only if certain threshold values of the wheel slip or the wheel acceleration are exceeded.

Electronically operated solenoid valves brake the respective wheel proportionately or reduce the engine performance until the stable adhesion range is reached again.

If the event of further regulating action, the wheel is held in the proximity of the maximum possible adhesion within a slip range that is as narrow as possible.

Operation of the ABS

Structure of the ABS control circuit



1 = sensor, 2 = pole wheel, 3 - electronic control unit, 4 = solenoid valve

Operation

The fixed sensor connected to the axle continuously picks up the rotary movement of the wheel by means of the pole wheel. The electrical pulses generated within the sensor are transmitted to the electronic control unit (ECU) which uses them to compute the wheel speed.

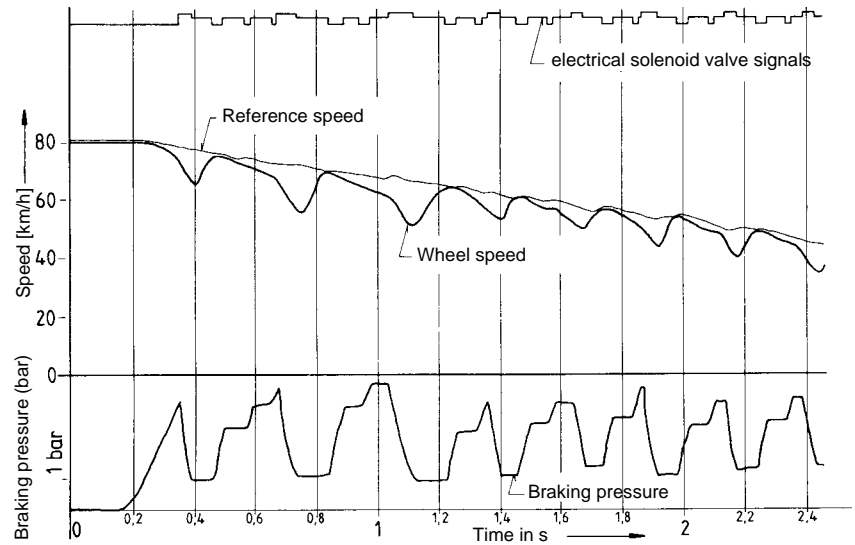
At the same time, the ECU uses a certain mode to determine a reference speed that is close to the vehicle speed, which is not actually measured.

From all of this information the ECU continuously computes the wheel acceleration (+b) or wheel deceleration (-b) and brake slip values.

When certain slip values are exceeded, the solenoid control valve is actuated. This causes the pressure in the brake cylinder to be limited or reduced, thereby keeping the wheel within its optimum slip range.

Example of an ABS control cycle:

The values recorded relate to the control cycle of one wheel. The initial vehicle speed is 80 km/h.



On the abscissa, the control cycles are recorded relative to time. In the area of the ordinate, the braking pressure is shown in the bottom section, and the middle section shows the reference and wheel speeds. The solenoid valve pulses appear in the top section.

The control procedure

The driver actuates the braking system. The brake pressure increases. The speed of the observed wheel suddenly drops much faster than the reference speed. Although the wheel is still within the stable braking range (i.e. between 10 % and 30 % slip), the electronic control unit already starts the control procedure.

The ABS solenoid valve is actuated and rapidly reduces the pressure in the brake cylinder of that wheel, and the wheel begins to accelerate again.

The electronics cause the solenoid control valve to reverse, keeping the braking pressure at a constant level until the wheel runs within the stable slip range again.

As soon as more braking force can be transferred, the braking pressure is increased by means of pulsing - i. e. alternately holding and increasing pressure. If the wheel speed drops significantly relative to the reference speed during this process, a new control cycle begins.

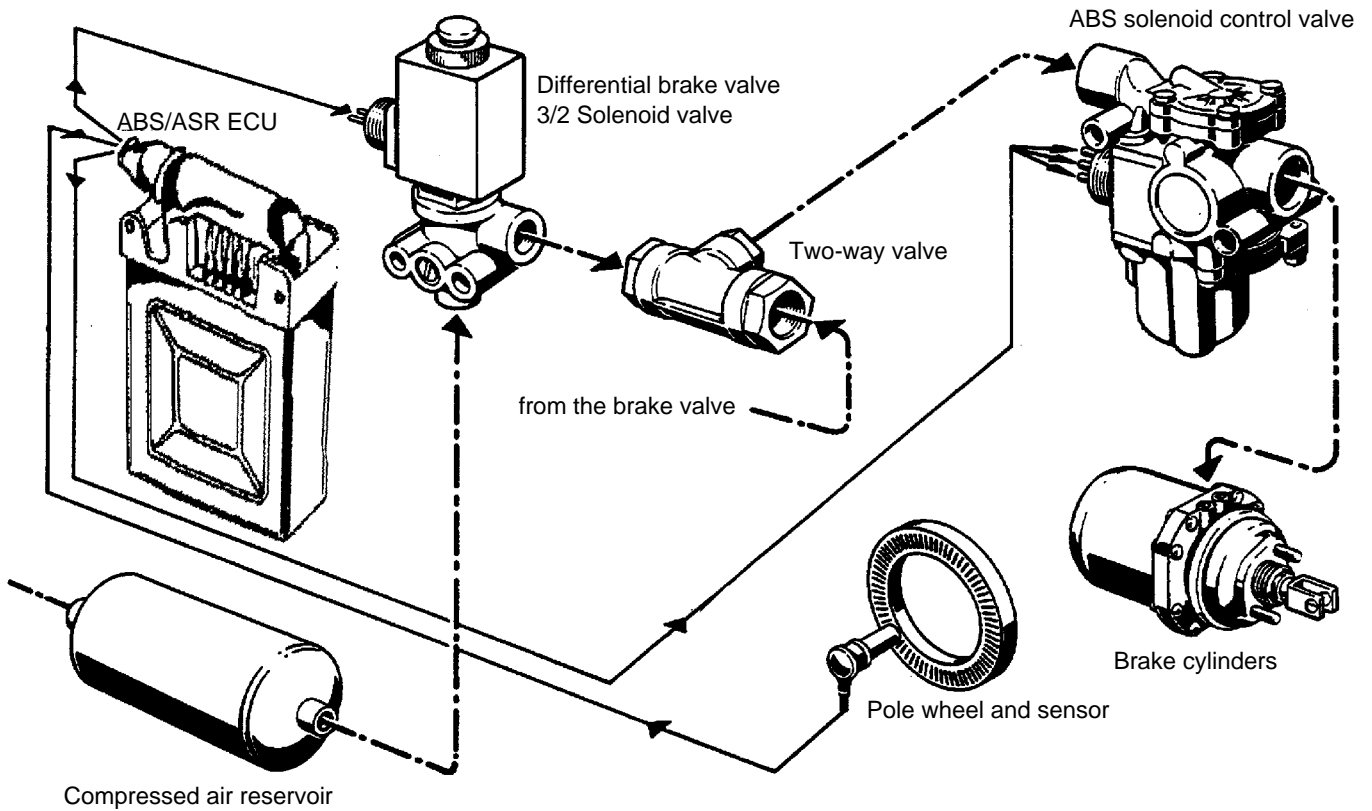
This procedure is repeated for as long as the brake pedal is pressed too hard for these road conditions or until the vehicle comes to a halt. The maximum control frequency which can be achieved here is 3 to 5 cycles per second.

Operation of ASR

Differential Brake Control:

Immediately after the ignition has been switched on and the vehicle moves off, the ECU monitors the rotational behaviour of all wheels above a wheel speed of approx. 2 km/h.

The speed and acceleration values of the powered wheels are compared to those of the non-powered wheels.



Function

When a certain difference in speed or slip threshold is exceeded, ASR control sets in.

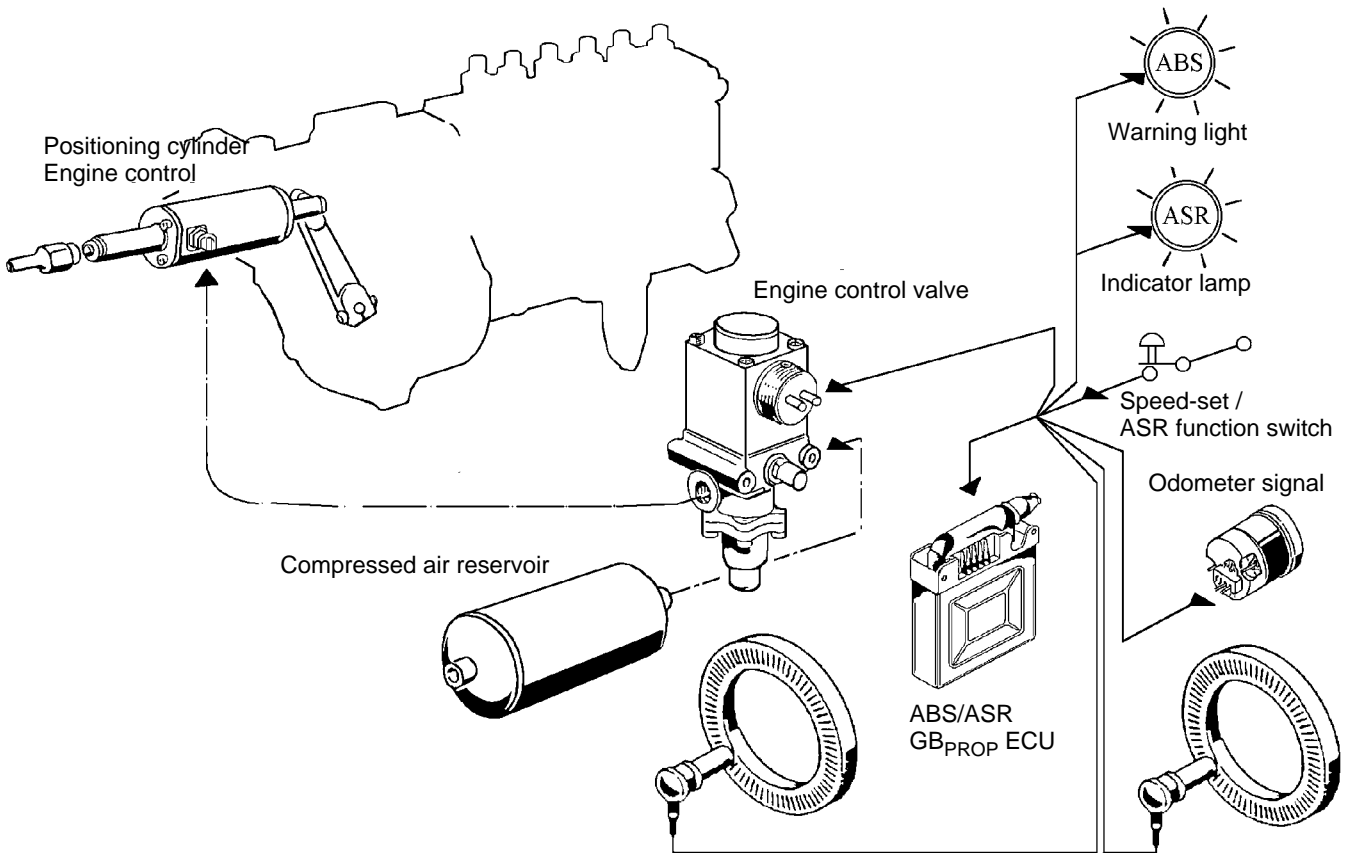
As soon as a driving wheel exceeds the slip threshold as it accelerates, the ECU will actuate the respective differential brake valve and thus control the braking pressure in the applicable brake cylinder of the service brake.

The engine's driving torque is now supported on this braked wheel, causing the propulsion power on the other wheel to increase - in much the same way as with engaged differential lock.

Engine control:

As soon as both powered wheels spins or the slip of one spinning wheel has exceeded a threshold value, the system switches from differential brake control engine control, reducing the engine output. Differential

brake control is now only used to synchronise the wheels. At a speed above 50 km/h only engine control is now used.



Function

Here the ECU controls the proportional valve which moves the the injection pump adjusting lever towards idle position via the ASR positioning cylinder, even if the driver continues to press the accelerator.

As soon values drop below the slip threshold due to the engine's braking effect, the proportional valve exhausts the positioning cylinder again. This causes the engine output to increase again up to the level selected by the driver via the accelerator pedal, or until another speed regulation cycle begins.

Note

This function can also be used as integrated speed limiting (GB_{PROP}) and complies with all legal requirements for speed limiting.

Use of differential braking and engine control

On wintery roads the coefficients of friction tend to vary. As a result, engine and differential brake control complement each other.

On an even road surface control is mainly implemented by a reduction of the engine speed, and differential brake control is restricted to synchronising the powered wheels.

If the friction coefficient differs on either side, differential brake control is prioritised and applies pressure only the brake cylinder of the spinning wheel. The driving torque is therefore transferred to the other wheel.

To avoid overheating the wheel brake, the differential brake threshold value is linearly increased above approx. 35 km/h so that the slip in-

creasingly regulated through engine speed control. Differential control is no longer initiated at speeds exceeding 50 km/h.

ASR engine control in vehicles with a drive-by-wire system

Electronic engine controls are often used in articulated buses but increasingly also for other motor vehicles. The mechanical linkage between the accelerator pedal and the fuel-injection pump is then dispensable apart from a short link between the electrical control motor and the pump adjusting lever.

The mechanical linkage is replaced by an electrical setpoint generator on the accelerator pedal (potentiometer) and a control motor fitted close to the fuel-injection pump.

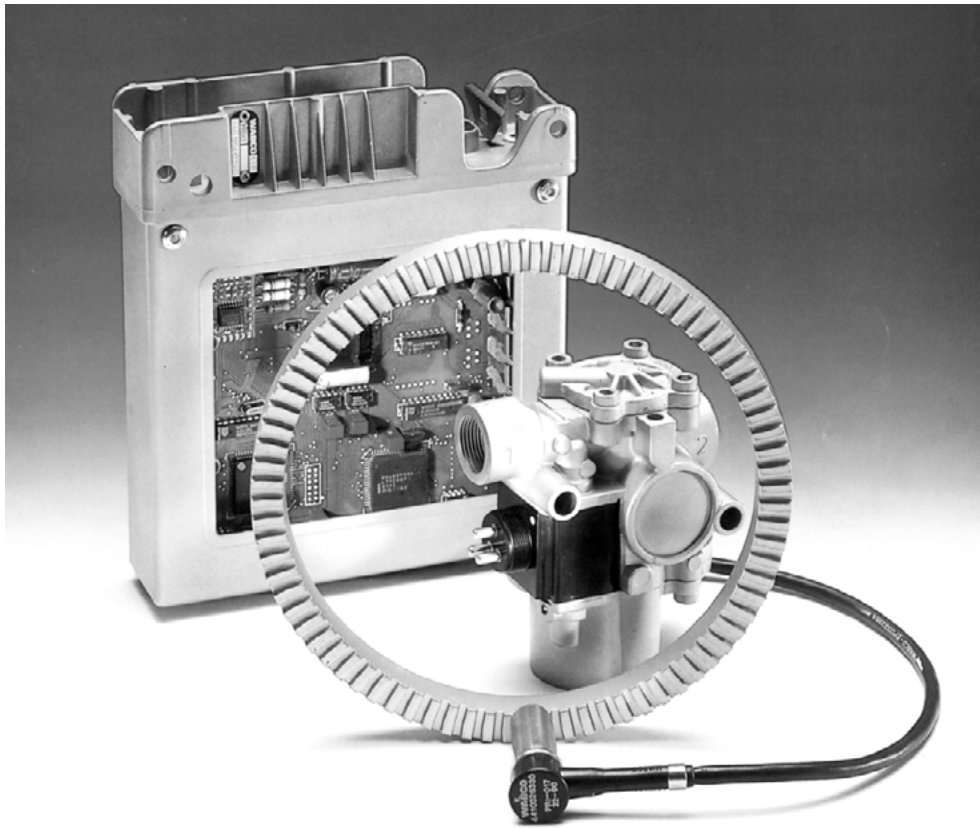
The control signal set by the ABS/ASR ECU is then relayed via digital interface to the ECU of the drive-by-wire system which in turn now transmits the corresponding control commands to the control motor.

Traction mode and ASR off-road switch

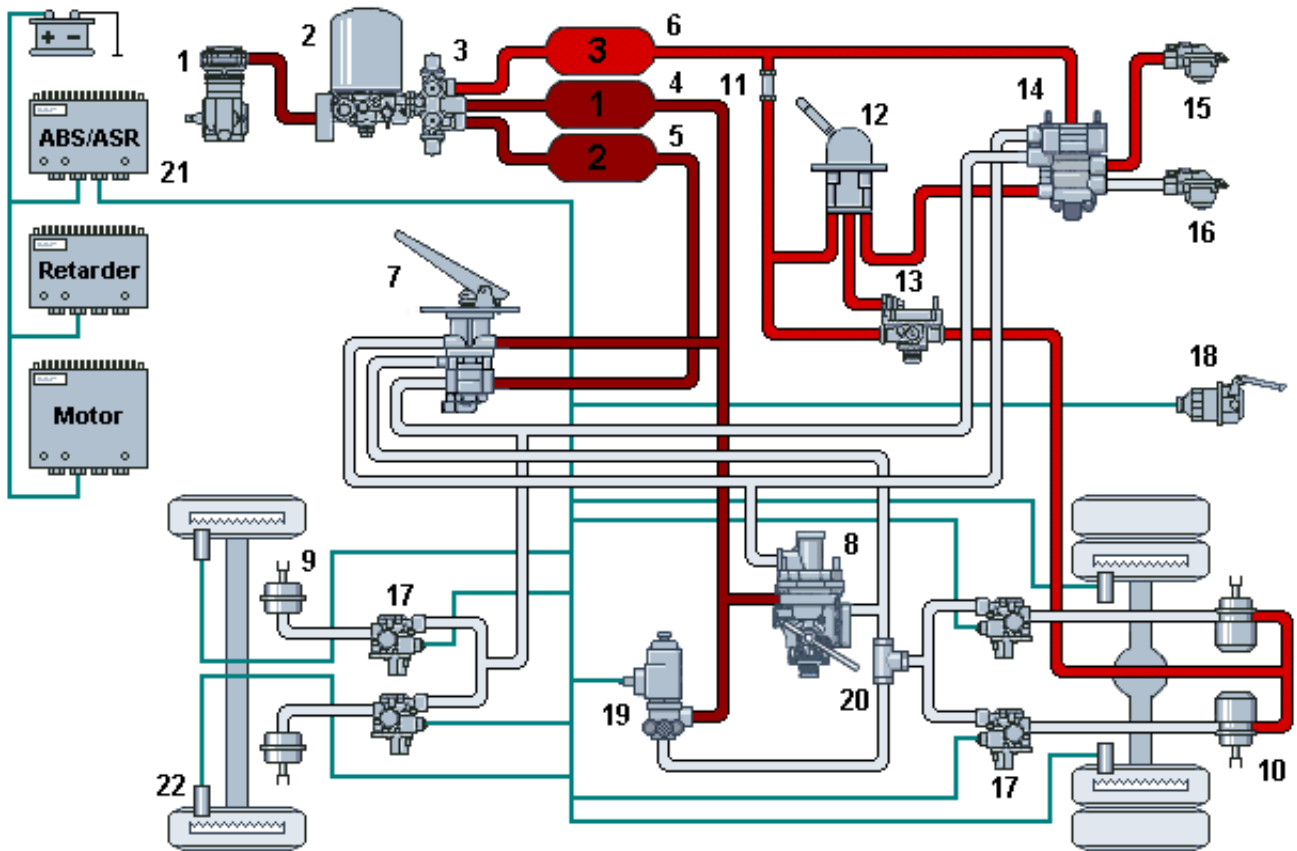
In deep snow or in similar conditions the traction force can be increased by actuating the "ASR off-road" button which is available as an option. If this button is activated, the ECU changes the conditions (slip thresholds) for ASR control to permit higher slip ratios.

The ASR lamp flashes in regular cycles while the button is actuated to indicate to the driver that stability may be reduced.

ABS and ASR components

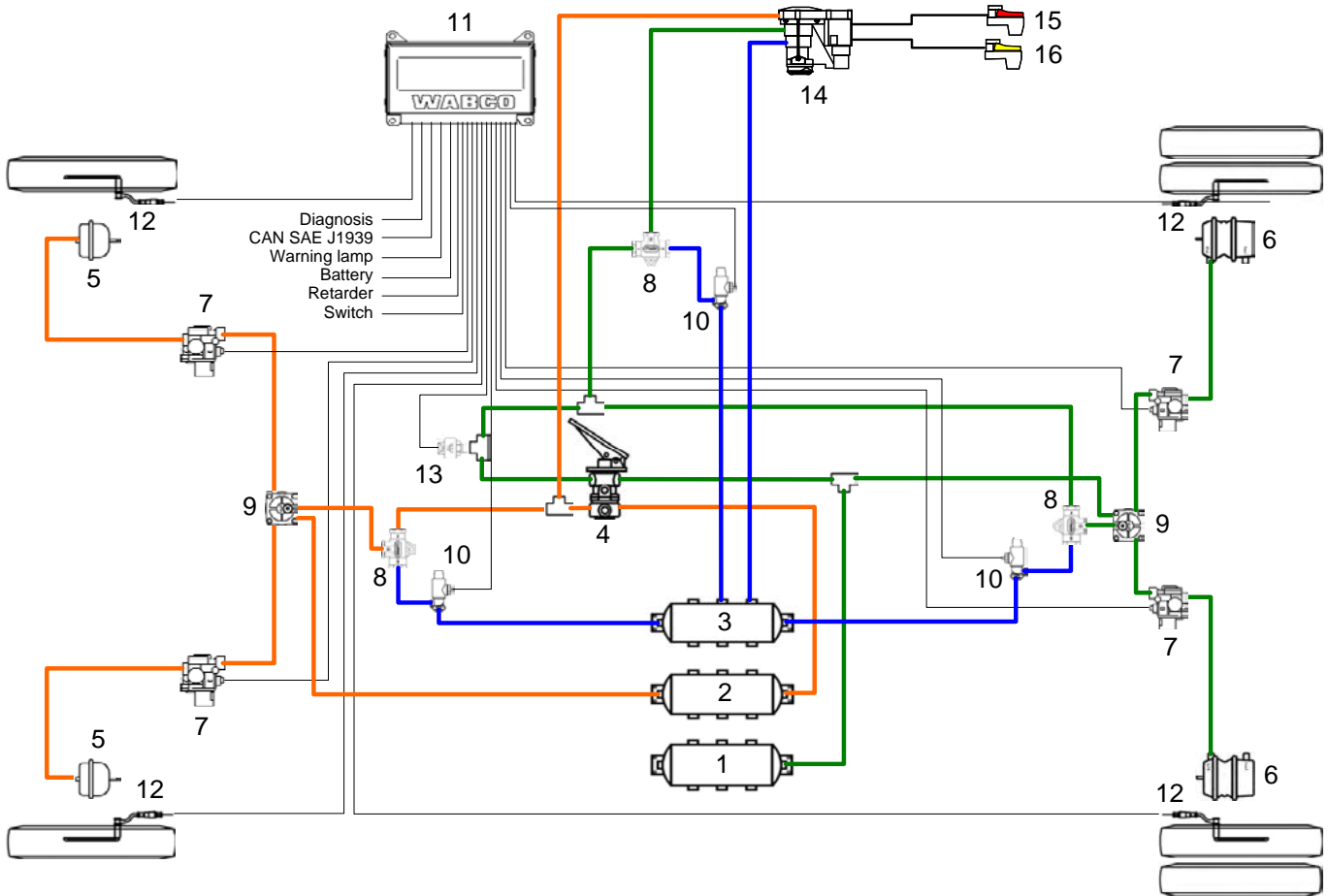


Structure of an EC Air Braking System with ABS / ASR fitted in the towing vehicle



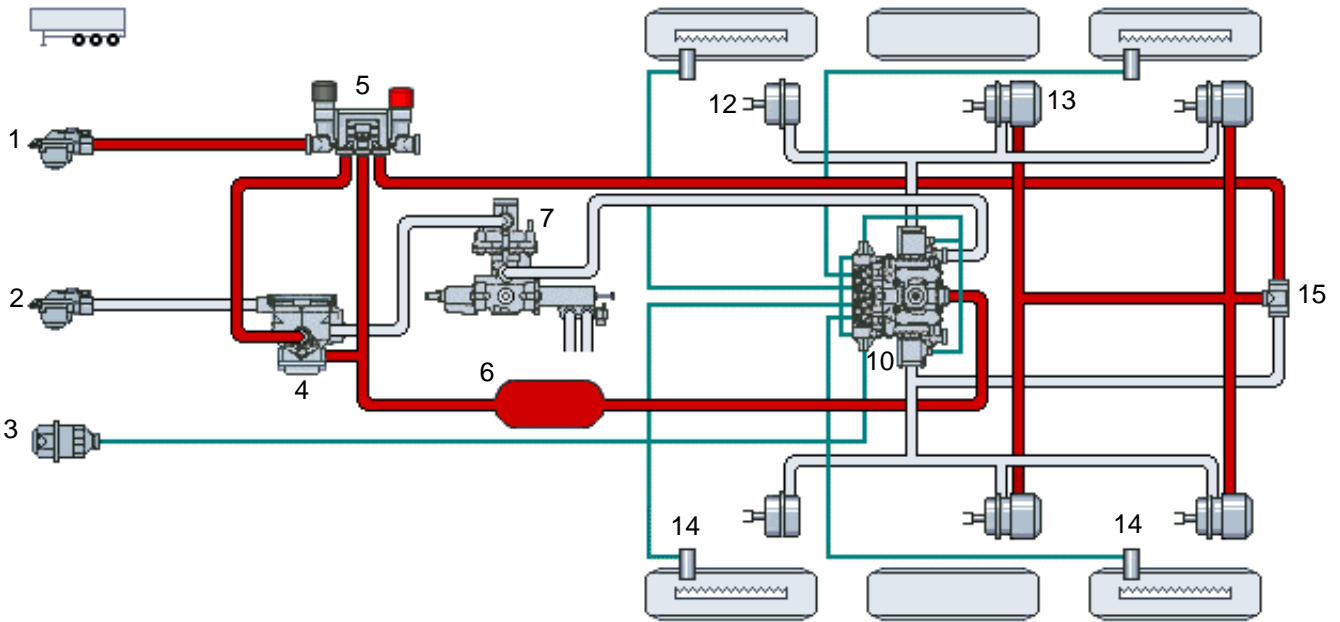
- | | | | |
|----|-----------------------------------|----|-------------------------|
| 1 | Compressor | 12 | Hand brake valve |
| 2 | Air dryer with pressure regulator | 13 | Relay valve |
| 3 | Four-circuit protection valve | 14 | Trailer control valve |
| 4 | Air reservoir circuit 1 | 15 | Coupling head "Supply" |
| 5 | Air reservoir circuit 2 | 16 | Coupling head "Brake" |
| 6 | Air reservoir circuit 3 | 17 | ABS solenoid valve |
| 7 | Towing vehicle brake valve | 18 | ABS plug connection |
| 8 | LSV controller | 19 | ASR solenoid valve |
| 9 | Brake chamber front axle | 20 | Two-way valve |
| 10 | Tristop cylinder rear axle | 21 | ABS/ASR ECU (D version) |
| 11 | Check valve | 22 | ABS sensors |

Structure of an air braking system with ABS E (with ESC/RSC) and ASR in the towing vehicle

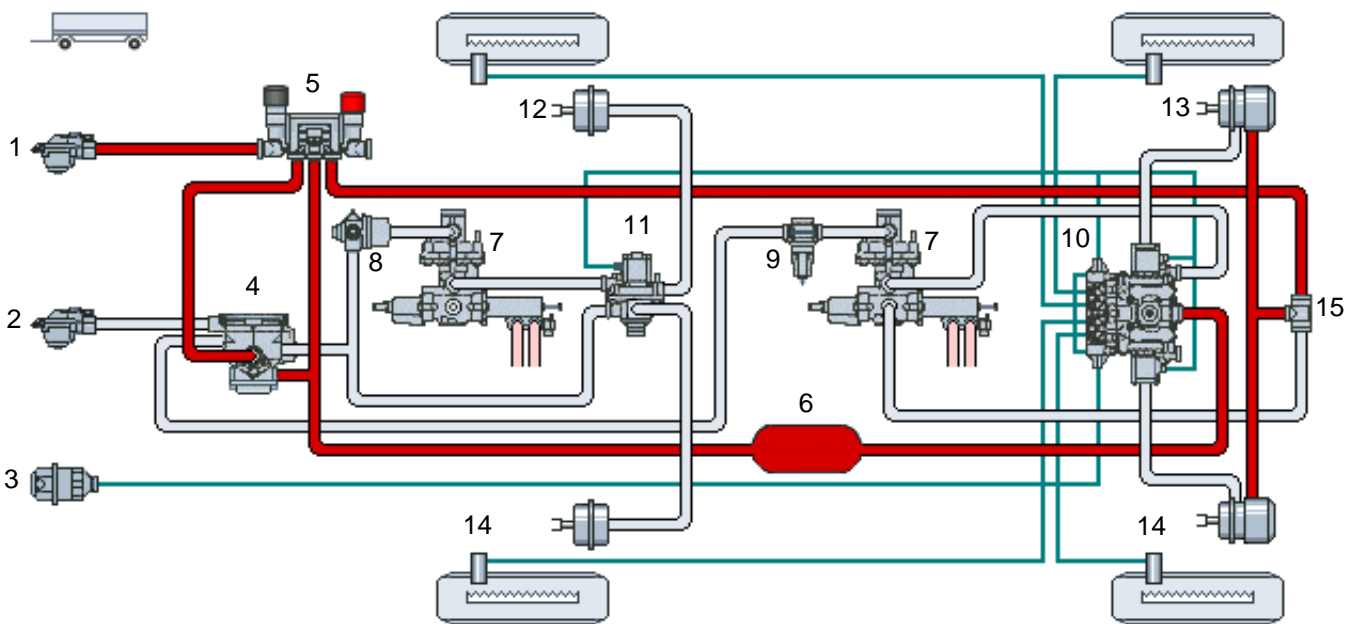


- | | | | |
|---|----------------------------|----|----------------------------------|
| 1 | Air reservoir circuit 1 | 9 | Pneumatic relay valve |
| 2 | Air reservoir circuit 2 | 10 | 3/2 directional control valve |
| 3 | Air reservoir circuit 3 | 11 | ECU ABS E Universal |
| 4 | Towing vehicle brake valve | 12 | ABS sensor |
| 5 | Brake chamber front axle | 13 | Pressure sensor for EBL function |
| 6 | Tristop cylinder rear axle | 14 | Trailer control valve |
| 7 | ABS solenoid control valve | 15 | Coupling head "Supply" |
| 8 | Two-way valve | 16 | Coupling head "Brake" |

Structure of an EC Air Braking System with ABS fitted in the trailer / semitrailer



- | | | | |
|---|------------------------------------|----|--|
| 1 | Coupling head "Supply" | 9 | Pressure limiting valve |
| 2 | Coupling Head "Brake" | 10 | VCS-ABS ECU with ABS Boxer relay valve |
| 3 | ABS plug connection | 11 | ABS relay valve steering axle |
| 4 | Trailer emergency valve | 12 | brake chamber |
| 5 | Dual release valve for BBA and FBA | 13 | Tristop cylinder |
| 6 | Air reservoir | 14 | ABS sensor |
| 7 | LSV controller | 15 | Two-way valve |
| 8 | Adapter valve | | |



Electronic Control Unit (ECU) 446 003/004 ... 0 on the towing vehicle

Purpose

The electronic control unit (ECU) uses the wheel sensor signals to calculate the road speed and the wheel speeds as well as the wheel deceleration and acceleration values. When required, it actuates the solenoid valves to prevent locking of the vehicle wheels.

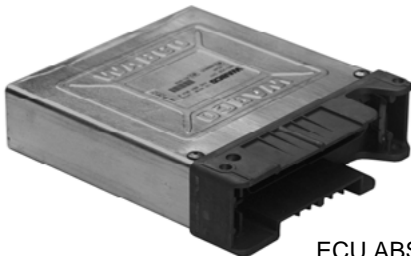
Operation

The 4- and 6-channel ECUs have two circuits, Each circuit monitors two (three in the case of a 6-channel ECU) diagonal vehicle wheels and can be divided into four functional groups:

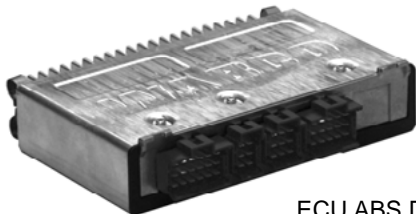
- Input circuit
- Master circuit
- Safety circuit
- Valve control



ECU ABS A / B



ECU ABS C



ECU ABS D



ECU ABS D-/E Basic



ECU ABS E Universal

In the **input circuit**, the signals generated by the speed sensors are filtered and converted into digital information.

The **master circuit** consists of a microcomputer. A complex program is used to compute and logically link the control signals and to transmit them to the valve control unit.

Each circuit has its own independent **safety circuit** which essentially consists of the safety computer and monitors the entire ABS system, i. e. the sensors, solenoid control valves, ECU and wiring, both before the vehicle moves off and while it is in motion.

It alerts the driver of any faults via a warning lamp and deactivates ABS control for one wheel or both diagonal wheels, or the entire ABS in certain cases. Here the braking system continues to be fully operational, only the ASR is partially or fully deactivated.

ECUs from the C generation onward permanently store any faults detected for diagnostics. The fault memory can be read out or deleted via the diagnostic connection (e.g. to ISO standard), or by exciting a flash-code.

The valve controllers contain power transistors (output stages) which are driven by the signals received from the master circuit, and which switch the current for actuating the control valves.

ECU ABS generation E

The RSC (Roll Stability Control) function has been integrated in the ECUs of the E generation. A lateral acceleration sensor and the software for signal processing, monitoring and driving dynamics control are integrated in the ABS control unit for this purpose.

It is possible to control the engine via CAN SAE J1939.

The new diagnostic function "Automatic clearing of the diagnostic memory" is used to automatically delete a diagnostic message or the associated address if the message does not recur within 250 hours.

The benefit of this procedure is that the diagnostic memory is cleared of diagnostic messages that were generated during production or commissioning of the vehicle but not deleted. The warranty for the ECU may be affected in this case.

Design types

The ECUs are supplied with 4 channels (446 004 ... 0) or 6 channels (446 003 0.. 0) for on-board voltages of 24 or 12 volts. For vehicles braked in combination (Air Over Hydraulic or AOH units) with only one pressurising cylinder on the steering axle, special 4S/3M ECUs are available, i.e. using only one solenoid valve to control the front axle.

The non-steered axle(s) is/are controlled individually (IC). Modified individual control (MIC) is used for the steered axle. For vehicles with 4S/3M ECUs on the other hand the modified axle control (MAR, see Trailer ABS) is used on the steering axle.

Two sensors and one modulator are fitted on the steering axle for MAR. Control occurs per axle because the braking pressure is equal on all wheels of this axle. With MAR, none of the wheels on the axle will lock.

In combination with Variable Axle Control there are also two sensors and one modulator fitted on the steering axle. With VAR, however, one wheel is permitted to lock in contrast to MAE. VAR can be adjusted by means of various parameters.

The previous A and B generations used the ECUs in both the motor vehicle and the trailer ABS. With the introduction of the ABS-C generation, there is a distinction between towing vehicle ECUs and trailer ECUs (VARIO-C or VCS I and VCS II systems) due to the implementation of special functions (e.g. ASR, GB_{Prop}),.

Compatibility

The ECUs of the B and 4-Channel-C-generation (35-pin plug) are backwards compatible.

A 54-pin electronic plug was required for the 6-channel C generation. 35 to 54 pin adapter plugs are available for diagnostics.

The ECUs from the D generation onward are not backwards compatible, because the cable harness and the plug concept (modular design) have changed.

Installation

The ECU is installed in the protected environment of the driver's cab. For trailers, the ECU is located in a special protective housing which is mounted on the vehicle frame.

Testing

The electronic control unit and the connected solenoid valves, sensors and the cabling are monitored by the integrated safety circuit and any faults are indicated.

Any additional inspection of the electronic control unit itself is only possible on a special test bench in the manufacturing plant.

Note

Always switch off the ignition before removing or installing the electronic control unit, i.e. always switch off the ignition when disconnecting or connecting the ECU plug!

VARIO-C Control Unit for Trailer ABS 446 105 ... 0

Configuration

The electronic control unit for VARIO-C ABS for trailers is based on the same electronics technology as the C-type ECU for towing vehicles although it has been designed specifically for the trailer environment.

This means that it can be mounted on the vehicle frame, that it is designed as a modular system with up to 6 sensors and 3 solenoid valves (6S/3M), and that it can detect up to two lifting axles.

Operation



The VARIO-C ECU is based on a single circuit, as the ECUs described above, and is subdivided into four circuits:

- Input circuit
- Master circuit
- Safety circuit
- Valve control

It processes the signals from three functional groups using two sensors respectively and one solenoid valve respectively whose presence is detected automatically. Any faults detected are stored permanently for the purpose of diagnosis. The fault memory can be read out and deleted by exciting a flash-code, or by using the ISO diagnostic connection.

Design types

The ECUs are available for on-board voltages of 24 or 12 volts.

In addition to a standard ECU for the respective voltage which can be used for implementing any system from 2S/1M to 6S/3M, there is one lean variant each specifically for semitrailers; these can, however, be used only to control 4S/2M or smaller systems.

A special ECU (VARIO-C plus) can be operated with ABS solenoid relay valves or the ABS solenoid control valves (mixed configuration per axle is also possible).

Testing

The same instructions apply as for towing vehicle ECUs.

VARIO Compact ABS (VCS) for trailers

Configuration

The ECU of the VARIO-COMPACT-ABS represents a further development of the tried and proven VARIO-C ABS.

VCS is ready-to-fit ABS system for trailers and meets all the statutory requirements defined for category A.

Design types

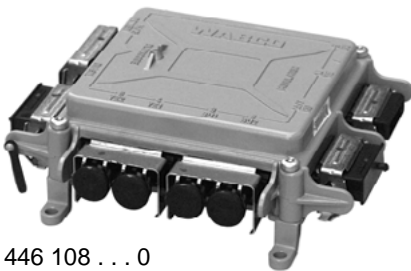


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According to the specific requirements defined by the vehicle manufacturers, VCS II is available as a compact unit or as separate modules (i.e., ECU and valves can be installed separately).

Plugs on the outside and new types of cable connections mean that it is no longer necessary to open the ECU for installation or diagnosis.

The systems range from the 2S/2M system for semitrailers to the 4S/3M system for drawbar trailers or for a semitrailers with steering axles.



446 108 . . . 0

Operation

The VCS ECU is based on a single circuit with one, two or three control channels and is subdivided into four circuits like the ECUs described above:

- Input circuit
- Master circuit
- Safety circuit
- Valve control

Any faults detected are stored permanently for the purpose of diagnosis. The fault memory can be read out and deleted by exciting a flash-code, or by using the ISO diagnostic connection.

Testing

The same instructions apply as for the ECUs described above.

VARIO Compact ABS 2. Generation (VCS II) for trailers

Development

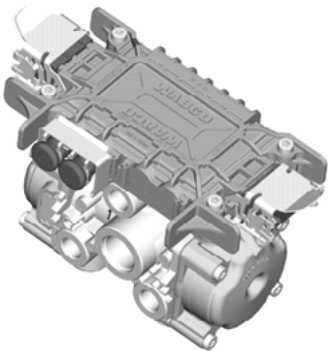
With VCS II WABCO has developed the 2nd generation VARIO Compact ABS. It represents another example to the modular design principle, since technically VCS II is based on the established ABS system for the NAFTA market, TCSII. An ISO 11992 interface and the 8-pin connector principle of the Trailer EBS was also integrated.

Variants

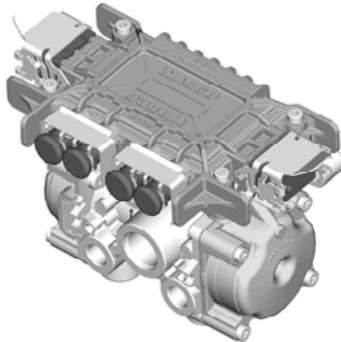
The VCS II systems range from the 2S/2M system designed for semi-trailers to the 4S/3M system for drawbar trailers or semitrailers with a steering axle for example.

VCS II is available as a compact unit or as separate modules (i.e., ECU and valves can be installed separately).

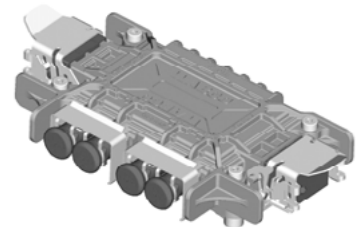
The Premium variant and the separate ECU are equipped with a towing vehicle - trailer interface according to ISO 11992. A 12V version of the Premium variant is available under the WABCO product number 400 500 083 0.



Standard variant 400 500 070. 0



Premium variant 400 500 081 0



Separate electronic control unit 446 108 085 0

GenericIO functionality

All variants of the VCS II are equipped with additional in- and outputs or an analogue input.

This permits the implementation of functions beyond ABS in the trailer. These inputs/outputs are called Generic Input/Output (GenericIO).

The following predefined GenericIO functions can be configured via the Diagnostic Software on the PC:

- Wear indication (BVA)
- Integrated speed-dependent switch (ISS)
- Power supply
- Speed signal
- ECAS interface
- ELM interface
- Lift axle control

Diagnostic port

The ECU has a diagnostic port in accordance with ISO standard 14230. The KWP2000 standard (ISO 14230-2) or JED 677 are used as the diagnostic protocol.

Diagnosis via CAN interface is supported with the Separate ECU and the Premium variant as of 2005.

Rod sensor 441 032 ... 0 and pole wheel:

Purpose

The rod sensor and the pole wheel pick up the rotary motion of the wheel. The pole wheels for medium-duty and heavy-duty commercial vehicles have 100 teeth; for wheels with a smaller rolling circumference, pole wheels with 80 teeth may also be used. Because of the diagonal reference speed generated in the ECU, the ratio of the number of teeth and the wheel circumference on the front and rear wheels must be identical to an accuracy of a few percent.

Operation

The bar sensor operates inductively and essentially consists of a permanent magnet with a round pole pin and a coil. The rotation of the pole wheel connected to the wheel hub produces a change in the magnetic flux picked up by the sensor coil, thereby generating an alternating voltage. The frequency of this voltage is proportional to the wheel speed.

Design types



The rod sensor has been developed specifically for use in commercial vehicles. High temperature stability and resistance to vibration ensure that it operates reliably even in extreme conditions.

The internal structure of recent WABCO sensors was modified to increase the output voltage at the identical wheel speed. This ensures ABS and ASR operation even at very low wheel speeds although the air gaps have widened. These sensors are identified by a "K", an "S" or "S+" on the sensor head. They are system-compatible and can be used in combination with previous sensors.

With the introduction of the VARIO-B wiring system, WABCO have included two sensor types with a moulded-on coupling socket which, in combination with special sensor extension cables of various lengths, facilitate the installation, particularly in trailers.

Sensor installation



The speed sensor is clamped adjustable into a hole in the steering-axle stub or a special sensor bracket via clamp bushing 899 760 510 4 (CuBe) or 899 759 815 4 (CrNi).

At the front axle, the sensor is manually pushed into the clamp bushing all the way to the stop position while the wheel is mounted. At the rear axle or at the trailer axles, the sensor has to be pushed into the clamp bush up to the stop position with the wheel hub removed. Putting on the wheel hub, it is then pressed out again until the sensor bears against the pole wheel.

Note

There is no need to set a minimum air gap for the sensor because due to the wheel bearing play the gap is adjusted automatically during the first few wheel rotations.

Examples of sensor installation on a trailer axle.

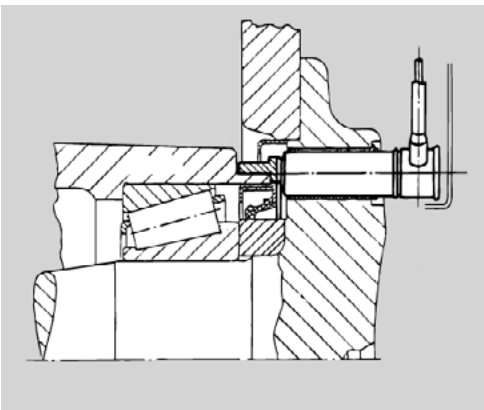


Lubricant

With installations that are exposed to heavier contamination we recommend using a clamp bushing and sensor with a thermally stable and splashproof grease to guard against corrosion of the hole in the axle stub and the penetration of dirt.

We recommend: "Klueber Staburags NBU 30 PTM"
 1 kg can WABCO no. 830 502 063 4
 5 g pad WABCO no. 830 502 068 4

Maintenance



Apart from regular checks of the wheel bearing clearance, the sensor should be pushed all the way to the stop position again by hand when carrying out any work on the wheel brake.

Never use force or unsuitable tools such as pointed or sharp objects to adjust the speed sensor (if the air gap is too large). Doing so may damage the sensor cap!

When replacing a sensor, it is advisable to replace the clamp bushing as well.

Testing

Resistance of the sensor coil, proper setting for the air gap and the sensor/wheel allocation can be tested using the ABS Tester or the Diagnostic Controller.

ABS Solenoid Valves 472 195 ... 0

Purpose



During a braking process, the solenoid control valves are used to adjust the brake cylinder pressure in relation to the control signals received from the ECU. On the powered axle they are also used for ASR differential brake control.

They permit the following ABS functions:

- Pressure build-up
- Pressure hold
- Pressure reduction

Design types

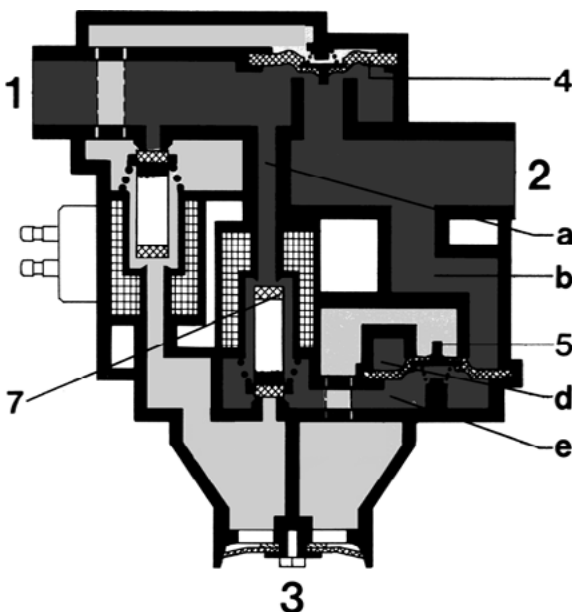
Solenoid control valves are available for on-board voltages of 24 and 12 volts.

The different types vary in terms of different connecting threads (metric screw-threads, inch-based threads, stepped hole for Voss connectors) and in the way the connecting plug is fastened (Kostal screw-in plug, bayonet locking or snap fastener). A variant with fording ability is also available for special-purpose vehicles.

Operation

The valve consists of a double solenoid and two diaphragm sections. The extremely fast-acting solenoid valves only control the pressure from the pilot control chambers of the diaphragms. These then control the brake cylinder pressures via corresponding cross-sections.

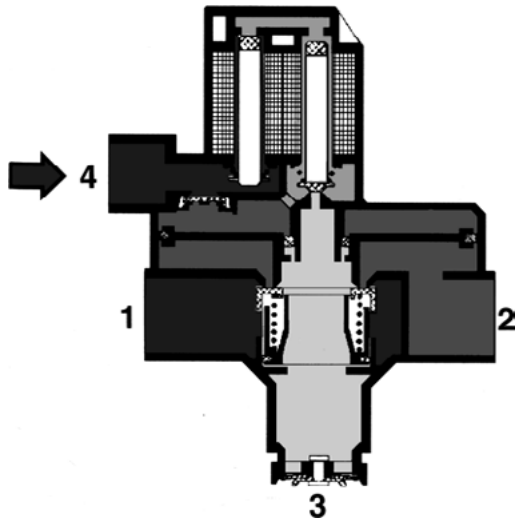
a. Pressure build-up



Neither of the solenoids (I and II) are actuated (free position).

The input pressure from port (1) immediately opens the inlet diaphragm (4). This causes chamber (b) to be pressurised, and the compressed air flows via port (2) to the brake cylinder and into annular duct (d) above the outlet diaphragm (5). At the same time, compressed air flows through the open valve and duct (a) into chamber (e) beneath the outlet diaphragm (5). Unless actuated, the solenoid will not reverse. Any increase in pressure in port (1) is passed on through port (2). The same applies vice-versa whenever the pressure is reduced.

b. Pressure reduction

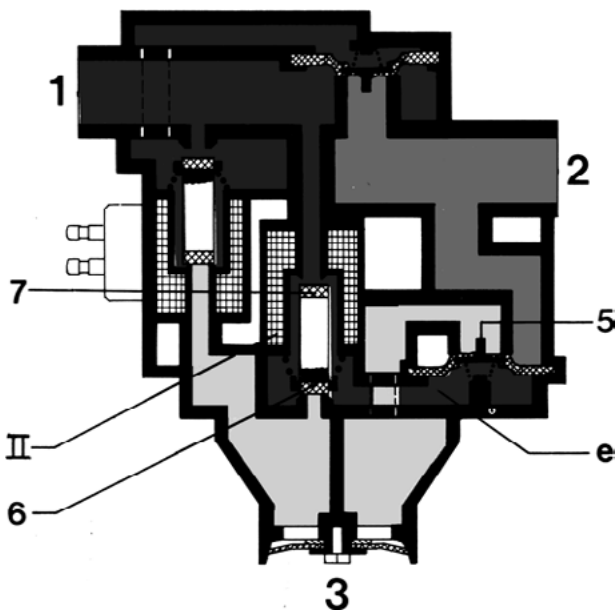


Both solenoids (I and II) are actuated. Solenoid I (inlet valve) closes valve (8) and opens valve (9). The compressed air from port (1) thus flows through chamber (g), duct (h) and into chamber (k) where it closes the inlet diaphragm (4).

Solenoid II (outlet valve) closes valve (7) and opens valve (6). This causes the pressure in chamber (e) to be reduced via exhaust (3). The outlet diaphragm (5) opens.

The braking pressure at port (2) escapes to atmosphere through chamber (c), duct (f) and exhaust (3) until the solenoid valve reverses.

c. Pressure hold



Only solenoid I (inlet valve) is actuated. Since solenoid II (outlet valve) is switched off, valve (6) is closed and valve (7) opened. This allows the pressure from port (1) to flow into chamber (e), closing the outlet diaphragm (5). The solenoid control valve is thus in the "pressure hold" position.

Maintenance

Special maintenance that extends beyond the legally specified inspections is not required.

Testing

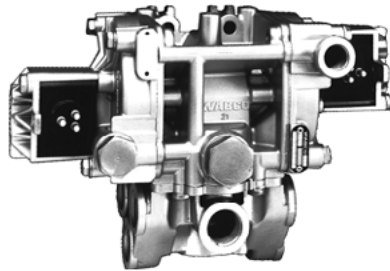
Resistance of the solenoid coils, proper functioning of inlet and outlet solenoids and proper wheel allocation can be tested using the ABS Tester or the Diagnostic Controller.

ABS solenoid relay valve 472 195 02 . 0 or 472 195 04 . 0

Purpose



472 195 02 . 0



472 195 04 . 0

472 195 02. 0 472 195 04. 0

The ABS relay valve is used in trailer ABS VARIO-C. Its purpose is to control the brake cylinder pressure for ABS control.

It enables the following three ABS functions:

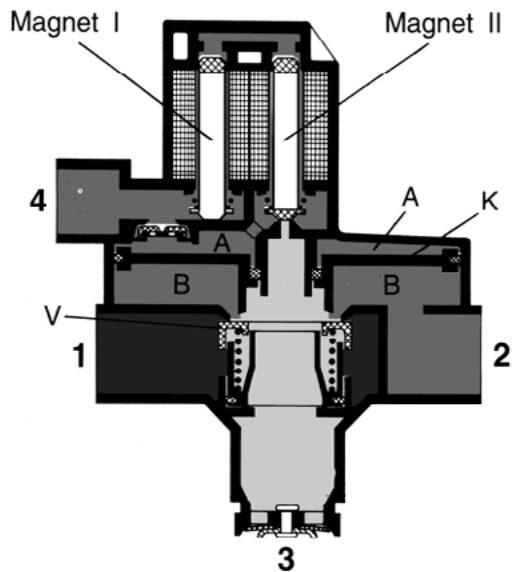
- Pressure build-up
- Pressure hold
- Pressure reduction

When not actuated (solenoids currentless), the valve operates like a relay valve and rapidly increases or decreases the pressure in the brake cylinders.

Design types

The ABS solenoid relay valve is available for on-board voltages of 24 volts (472 195 020 0) or 12 volts (472 195 021 0). A **twin valve** is also available. (472 195 04. 0). Two ABS relay valves with shared connections for control and supply pressure are here combined in one compact valve.

Operation



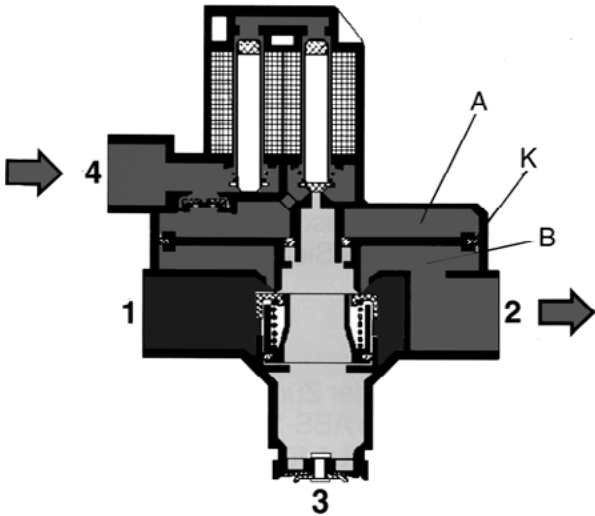
The input pressure from port (4) (e. g. 1 bar) passes solenoids I and II (in free position) and flows into the upper piston chamber A, pushing piston K downwards. The piston makes contact with valve V during this process and closes the outlet and opens the inlet. The air supply at port (1) flows via chamber B and port (2) to the brake cylinders downstream.

At the same time, pressure builds up in chamber B, acting on the underside of piston K. Since the piston's upper and under sides have similar surfaces, the inlet is closed by valve V as soon as the pressure in chamber B is identical to the input pressure in chamber A. The end position has now been reached.

If the pilot pressure at port (4) drops, piston K is pushed upwards by the pressure in chamber B. The outlet is opened and the pressure on the port (2) is reduced to the same value via the exhaust (3).

ABS functions

Pressure build-up



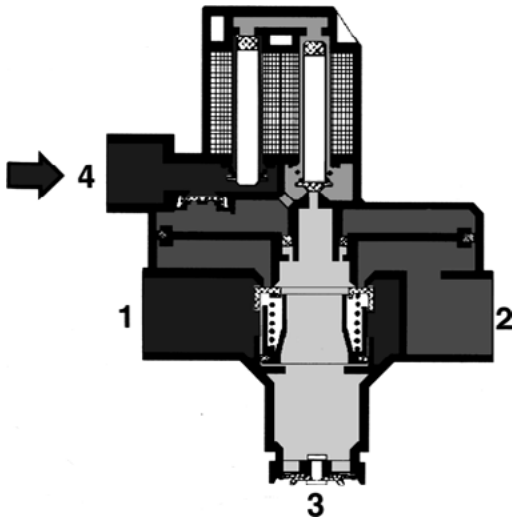
Both solenoids are currentless.

Pilot pressure is applied on port (4)

There is a visible gap between the annular piston and the seat.

Air flows from port (1) to (2).

b. Pressure hold



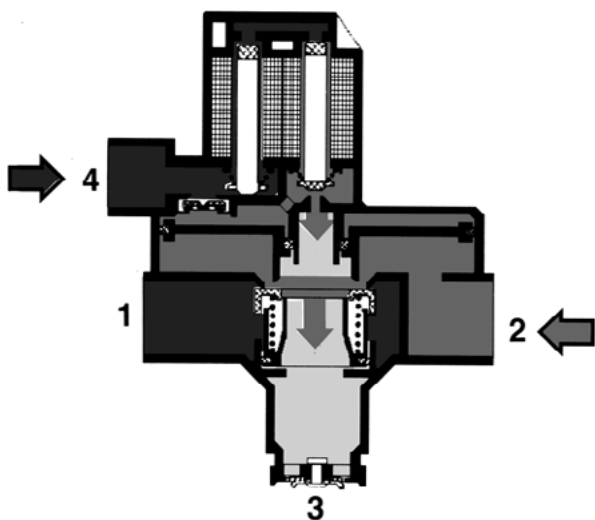
Solenoid I is excited. The armature has retracted. The air passage from (4) to chamber A is thus interrupted (in spite of the increasing pilot pressure).

The pressures adjust itself to equal levels in chambers A and B.

The annular piston rests on the seats.

Air can neither flow from (1) to (2) nor from (2) to the outside.

c. Pressure reduction



The solenoid has been excited, the anchor has attracted. The solenoid is in free position again.

1. Pilot pressure locked against chamber A.
2. The raised seal at the foot of solenoid II allows the air from chamber A to escape to atmosphere through the inner opening of the annular piston.

This causes piston K to be raised, and the gap which is now visible at the annular piston allows the air to escape from B, port (2) and the connected brake cylinder.

Maintenance and testing

As described above for the ABS solenoid valve.

Additional components for ASR

Differential brake valve 472 1.. ... 0



These are fitted upstream of the solenoid control valves. When actuated by the ECU, it regulates the reservoir pressure for the ABS solenoid control valves via a two-way valve independently of the brake valve.

While in the ASR B and C generation required a separate differential brake valve for each powered wheel, only one valve is installed with the D generation. If a differential brake control is necessary, it controls the supply pressure to the ABS solenoid valves of both powered wheels. The ABS valve of the wheel that is not to be braked is then switched to the blocking position (Hold pressure).

Proportional valve 472 250 . 0



The proportional valve is fitted upstream of the positioning cylinder and controls the position of the governor lever on the injection pump using the pressure that is regulated through to the cylinder.

The regulated output pressure level is in direct proportion to the regulated solenoid current for the proportional valve coming from the ABS/ASR ECU (regulated by pulse width modulation (PWM)).

The low hysteresis allows a wide range of positioning cylinder pressures, which permit very fast as well as virtually stationary adjusting movements of the governor lever. Apart from the ASR engine control, this device can therefore also be used for speed limiting (SLprop).

Two-way valve 434 208 0



The two-way valve is fitted between the differential brake valves and the ABS solenoid control valves. The two-way valves allow alternate actuation of the solenoid control valve respectively fitted downstream of the service brake and ASR control.

In the event of an ABS or ASR control process, the subsequent sensitive air inlet and outlet air to and from the brake cylinders connected downstream is controlled by the respective ABS solenoid valve.

In contrast to the ASR B and C generation, which required a dedicated two-way valve for each powered wheel, only one valve is installed for the D generation. If differential brake control is necessary, it controls the supply pressure to the ABS solenoid valves of both powered wheels. The ABS valve of the wheel that is not to be braked is then switched to the blocking position (Hold pressure) by the ECU.

Two-way valve 534 017... 0



In order to permit the two-way alternate air intake of the positioning cylinder on the governor lever of the engine cut-off and proportional valve, another two-way valve with smaller flow cross-sections must be fitted between the engine cut-off valve and the engine control valve.

Here the variant 534 017 ... 0 is often used.

3/2 way solenoid valve 472 170 ... 0



The 3/2 way solenoid valve is located between the air reservoir and the ABS solenoid valve on the towing vehicle front axle.

It is used to allow the RSC or ESC functions of the ABS ECU to brake the towing vehicle's front wheels independently of the driver's desire to brake in critical driving situations.

Positioning cylinder for mechanical engine control 421 44. ... 0



The positioning cylinder is located within the control linkage between the accelerator pedal and the fuel-injection pump. Type and dimensions depend on the kind of engine and fuel-injection pump used.

When actuated by the proportional valve, the operating cylinder moves the fuel-injection pump towards its idle position.

Idle stop cylinder 421 444 . 0



On single-lever fuel-injection pumps, an additional idle stop cylinder prevents the engine from being switched off during an ASR control process or a speed limiting process.

In this case the positioning cylinders and the idle stop cylinder need to be actuated at the same time to switch off the engine.

An idle stop cylinder is dispensable with twin-lever pumps, since switching off is achieved by a second lever not affected by ASR.

ABS / EBS trailer helix cable 446 008 243 / 244 / 700 0



Major progress in terms of trailer brake control has been achieved through the electronic transmission of the driver braking request. Because this request is put to immediate effect in the Trailer EBS, valuable split seconds are saved in the event of an emergency, reducing the braking distance.

This means that the old ABS coil is no longer just a power supply but also the only transmitter of the important CAN bus braking information.

Special functions of the ABS

ABS control of the engine brake or a retarder:

ABS for motor vehicles has also been designed for controlling the engine brake or a retarder. This is achieved by means of two-position control. Through a signal from the ECU, a relay actuates a solenoid valve which blocks the air supply for the engine brake cylinder and exhausts the cylinder.

With retarders, the control process implemented accordingly by the two-position signal deactivating the electrical retarder control via a relay.

If the engine brake or the retarder are operated on their own, and if one rear wheel or both rear wheels on the axle with sensors show excessive slip, the engine brake or retarder is switched off until the tendency to lock no longer applies. It is then automatically switched on again until a tendency to lock is perceived once more, or until the driver switches it off.

If the engine brake and the service brake are applied simultaneously, the pressures of the service brake and the engine brake are regulated whenever a tendency to lock is perceived.

Differential lock circuit in lorries with all-wheel drive and ABS

If the driver actuates the ("longitudinal") differential lock for the transfer gear between front and rear axle(s), the longitudinal lock is usually opened automatically when ABS control commences, and kept open until the end of the braking process.

ABS reversal for off-road use (A and B version):

The standard ABS function has been optimised for normal road conditions. In order to achieve the shortest possible braking distance even for heavy-duty off-road applications in the construction and military sectors, vehicles for such applications today often permit deactivation of ABS at speeds below 15 km/h.

For deactivation, the driver needs to actuate an "off-road ABS" switch. In this case the ABS warning lamp comes on as soon as deactivation comes into effect at speeds below 15 km/h and the wheels could lock up.

Off-road ABS C version

Optionally the C version offers a special "off-road ABS logic" which provides the normal ABS function within the upper speed range, but allows greater wheel slip at speeds below 40 km/h; it also allows the wheels to lock at speeds below 15 km/h.

This permits higher deceleration values to be achieved during off-road operation by allowing the wheels to "dig in" temporarily whilst maintaining a certain degree of stability and steerability.

The ABS warning lamp will flash to let the driver know that "off-road ABS" is active. For newer vehicles the legislator requires the system to revert to the "road logic" automatically after the ignition is switched off and on again.

Testing the Anti-Lock Braking System (ABS)

Safety circuit, component fault detection and measures to be taken

The safety circuit:

When the ignition is switched on or the engine is started, the safety circuit briefly energises the solenoid valves and also checks the other essential ABS and electronic components.

If all ABS components operate fault-free and sufficiently high alternating voltages are then generated with activation of all the sensors, the warning lamp - which was switched on with the ignition - goes out at a speed of **approx. 7 km/h**. In newer vehicles it already goes out after **approx. 2 seconds** after the ignition is switched on, provided the system is detected as fault-free and no fault was present during the last trip.

Monitoring process when driving

In addition to permanent passive monitoring of the control signals and the solenoid actuations in terms of plausibility, essential components such as solenoids, sensors and wiring are subject to cyclical monitoring processes while the vehicle is in motion (with or without application of the brakes).

The components within the ECU also constantly monitor each other.

System responses in the event of faults

If an electrical fault occurs within the ABS system, the driver is alerted by activation of the warning lamp.

The safety circuit will switch off or alter the control process in such a way that any undue impairment of braking safety is avoided and at least normal braking performance is maintained.

The dual-circuit 4- and 6-channel systems and the single-circuit VARIO-C or VCS trailer systems may respond differently to certain component defects in terms of the ABS function that can still be provided due to the different system designs.

All detected faults will cause the warning lamp to light up, at least for as long as the fault is present. Intermittent contact will cause the warning lamp to stay on until the end of operation and it will not light up again with return to operation unless the fault recurs.

C and D generation ECUs also store the fault in the non-volatile memory of the unit.

Mechanical defects

Any mechanical defects on the control valves, especially those which can cause leakages and thus a loss in pressure, cannot be detected by the ABS safety circuit. They can only be detected - like similar defects in other components of the braking system - by the driver, or when the vehicle is being serviced (special brake test or intermediate inspection).

ABS/ASR control lamps



Example

The towing vehicle usually has three ABS control lamps to indicate functions and continuous monitoring of the ABS system.

- ABS warning lamp for motor vehicles
- ABS warning lamp for trailers
- ABS information lamp for indication to the driver (not mandatory)

If ASR is installed in the towing vehicle an additional ASR lamp is generally also installed.

Display on the instrument panel display



Example in the Mercedes Actros2

In newer vehicles, warning and fault signals are transmitted to the instrument panel display via the vehicle data bus and displayed there.

The warning lamps (previously also called safety lamps)

a. Warning lamp for motor vehicles

The lamp lights up when the ignition is switched on. It goes out after approx. 2 seconds if the ABS safety circuit has not detected any faults or the vehicle has exceeded a speed of approx. 7 km/h .

b. Warning lamp for trailers

This lamp lights up when the ignition is switched on, provided a trailer with ABS has been hitched and the ABS connector is plugged in. The lamp also goes out (as for warning lamps for towing vehicles) after around 2 seconds if the ABS safety circuit has not detected any faults or the vehicle has reached a speed of approx. 7 km/h.

Both warning lamps stay off even when the vehicle stops in traffic (e. g. at a red traffic light).

When the ABS warning lamps have gone out, the Anti-Lock Braking System is operational. However, ABS control will not commence until one or several wheels show a tendency to lock during braking action.

Important note

The driver must make sure that the warning lamp(s) has (have) gone out before starting to drive! If a warning lamp does not go out at speeds exceeding 7 km/h, or if it comes on while the vehicle is moving, there is a fault in the respective ABS system.

Important!

Drive carefully when the warning lamp is on The vehicle's braking behaviour may change.

To remedy this defect, the vehicle must be taken to an authorised workshop as soon as possible.

The Indicator lamp

The indicator lamp shows the driver whether a trailer with or without ABS has been hitched. After the ignition is switched on, It will stay on if a trailer without ABS has been hitched or the ABS connector for the trailer ABS is not plugged in. It will either stay on permanently or only when the brake is applied (depending on the configuration of the vehicle manufacturer).

The indicator lamp will not come on if the trailer has ABS or the motor vehicle is driven without a trailer.

The indicator lamp is not mandatory!

ASR lamp

Vehicles with ASR generally also have an additional ASR control lamp: This lamp indicates to the driver that ASR is in operation and is therefore also a warning indicating that road conditions are slippery.

To test proper function of the ASR lamp, it lights up for around 1 second after the ignition is switched on.

When driving, the ASR lamp lights up

- if ASR control is in operation (warning of slippery conditions for the driver)
- when the "2nd.limit speed" - activated by the driver via the ASR/Speed set switch - is reached, provided that the GB_{PROP} speed limiter is integrated.
- If the ECU has detected ASR/GBProp_{PROP} faults (e.g. electrical lines to the prop. valve open).

The ASR lamp flashes uniformly if the ASR switch or, in the case of integrated GB_{PROP}, the ASR/speed set switch is in "ASR off-road" position to increase the slip threshold.

In addition, the ASR lamp can be used to signal a flash code for diagnostic purposes in towing vehicles with a C or D version of the ABS control unit when a push-button installed for this purpose is pressed.

When is a more extensive check of the ABS system necessary?

The ABS must be checked whenever the fault lamp lights up while the vehicle is moving, or does not go out after the vehicle drives off.

Diagnosis

Diagnosis of the ABS ECU includes

- Fault analysis (fault readout and storage)
- Setting the system parameters
- Start-up

The ABS electronic control units from the C generation for towing vehicles and the VARIO-C generation for trailers onwards have an integrated fault memory and a diagnostic interface to ISO Standard 9141.

ISO diagnosis via PC and diagnostic interface



Laptop "Toughbook"

Diagnostic Interface Set

The corresponding Diagnostic Software is available for the ABS versions in towing vehicles and for VCS-ABS in trailers, as well as other electronic WABCO systems.

In connection with the Diagnostic Interface from WABCO the software provides extensive and convenient diagnosis.

For diagnosis you need

- a standard PC or laptop,
- the WABCO System Diagnostic Software,
- a Diagnostic Interface,
- and cables to match the vehicle type

ISO diagnosis with the Compact-Tester



The cost-effective Compact-Testers for ABS in towing vehicles (C and D generation) or trailer ABS (VARIO C and VCS) provide easy readout and clearing of the fault memory.

Depending on the system, special functions (e.g system commissioning, function test and reading out the odometer integrated in VCS) are also possible.

WABCO Flash-Code

A limited but still useful and low-cost diagnosis is provided by the flash-code implemented in ABS C type ECUs or higher.

A flash-code can be excited by connecting a special diagnostic line to earth. For towing vehicle ABS/ASR systems and trailer ABS, the warning lamp is used for indication.

The tester can interpret the pulse sequences using a flash-code list to determine whether the system is in order and which type of fault was detected. ABS can also be used to reset the system and to read out the flash codes of the installed system.

ISO diagnosis using the Diagnostic Controller



The Diagnostic Controller has now been superseded by PC Diagnosis. This diagnostic device can be used to read out (via the diagnostic interface according to ISO standard 9141) and display in plain text any stored faults and to delete them.

The Diagnostic Controller can also be used for other electronic WABCO devices in addition to WABCO ABS. The respective test program is supplied on different program cards. These guide the tester through the test procedure without the need for extra testing instructions.