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Active safety

IN THIS ISSUE

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INTRODUCTION

The main cause of traffic accidents at global level derives from the loss of control of the vehicle, normally caused by reacting incorrectly to an emergency situation or exceeding the limit of grip of the tyre. The decisive factors on the frequency and magnitude of such risk situations is the unpredictable environment and road variability, which imply risks for the driver, passengers but also other road users.

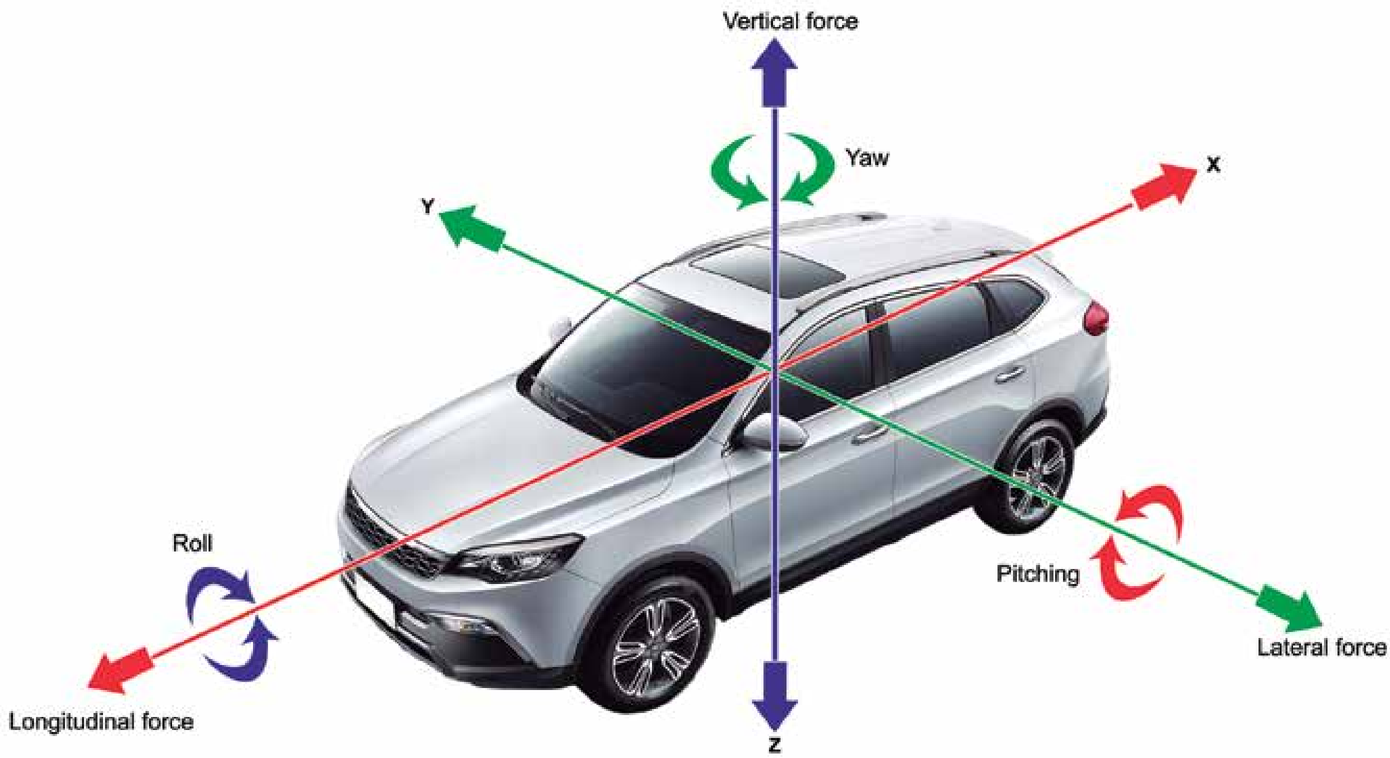
In order to reduce the number of critical situations, vehicle manufacturers have developed various technologies of active driving assistance, the so-called active safety systems whose function is to keep the vehicle steering capacity and correct or minimise the consequences of reaction errors. These technologies are based on the electronic control of traditionally mechanical systems in order to avoid the loss of adhesion and path of the vehicle. They rely on the analysis of the physical variables related to the vehicle dynamics and its management by the driver. The electronic systems are provided with logical response and high reaction speed, which in most cases are faster than the capacity of the driver and, therefore, increase the vehicle safety in loss-of-control situations.

The main and most significant active safety systems are related to the brake circuit and allow to maintain the stability and steerabiliity of the vehicle in critical situations and low grip. These are the **anti-lock braking systems** (ABS) and **stability control** (ESP). These systems are formed by a high number of components that allow to carry out their functions with total safety, but like any element, they are susceptible to breakdowns and can compromise the safety of the driver.

VEHICLE DYNAMICS

A large number of forces are produced during the car movement, and they influence the behaviour and dynamics of the vehicle. The stability of the assembly is conditioned by the inertial movements of the body, as it must control the running gear in order to maintain the trajectory imposed by the driver. According to the direction of said movements with respect to the centre axle of the vehicle, forces are divided into three groups:

- **Longitudinal dynamics:** It comprises the movements that occur in the longitudinal direction of the body (“X” coordinate) and which are caused mainly by the driving and braking forces. The variation between both causes the pitching of the body, which is described as the pivot of the body on the transverse axle (“Y” coordinate) caused by the inertia and the suspension travel.
- **Lateral dynamics:** It includes movements in the lateral direction of the body, included in the “Y” coordinate and which are mainly caused by the lateral forces and their inertias. The imbalance of the lateral forces that act on the axles can cause the vehicle to rotate about the vertical axis “Z”, a phenomenon known as yaw.
- **Vertical dynamics:** It includes the movements developed on the vertical axis, that refer to the “Z” coordinate and that are produced by the gravity force applied to the mass of the vehicle, that is to say, the weight and the force that the suspension exerts in the opposite direction. The imbalance of the forces causes the body to roll on its “X” longitudinal axis.



Inertia

In order to modify the movement of the vehicle, the sum of the forces that act on it must overcome the resistance that opposes all changes in speed or direction, a phenomenon known as inertia. **Inertia is the property that all bodies have to maintain the state they are in**, so it can be defined as the work done by a force. The magnitude of this force is proportional to the kinetic energy of the object and its orientation depends on the direction of the movement.

The kinetic energy and, therefore, the inertia force depend on the mass of the object and its speed. The higher these values are, the greater the resistance to overcome and the greater the strength necessary to modify the state of this object, meaning the speed and direction of its movement. For example, when a vehicle performs a hard braking, the driver perceives a force that pushes him against the steering wheel. Said force is the inertia and acts in the same way on the body of the vehicle, trying to keep the speed of circulation. Another example of inertial work is the centrifugal force that works in opposition to the changes in vehicle direction, always seeking the straight-line movement.

TYRE GRIP

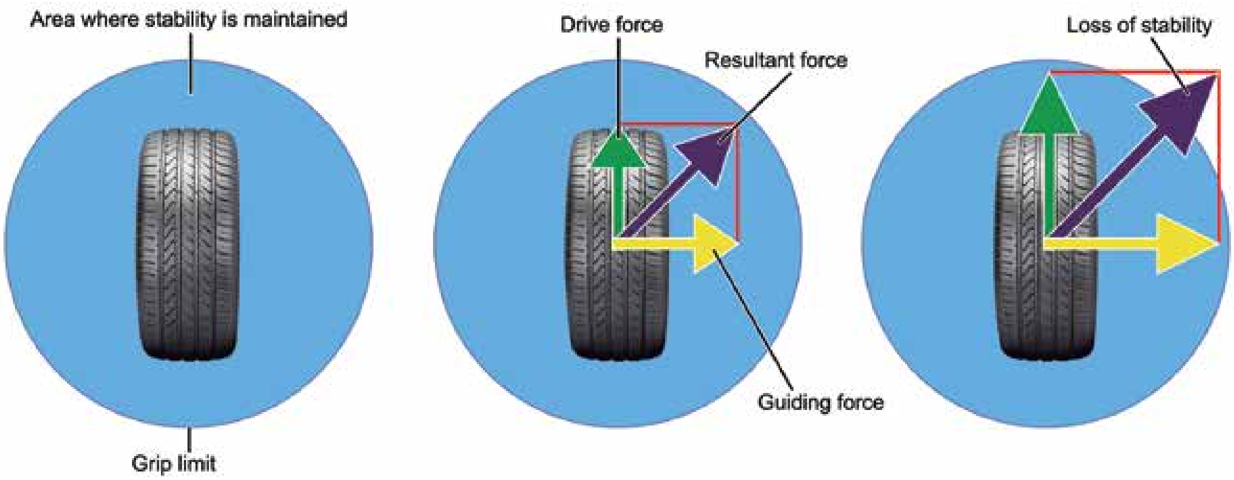
The forces related to the vehicle dynamics intervene in the longitudinal, lateral and vertical axles of the wheels. The longitudinal forces (driving and braking) are the ones that make possible or limit the vehicle to move forward and the lateral forces define its trajectory. The gravity force acts on the vertical axle. This force is variable depending on the weight bearing the wheel, a determining factor for the grip between tyre and road.

The grip between tyre and road determines the limit of force transmission between the vehicle and the surface on which it moves. The tyre grip depends on the following magnitudes:

- The contact surface of the tyre with the road
- The weight supported by the wheel
- The friction coefficient between the tyre and the road

Kamm’s Circle

Due to the constant variation of the 3 above-mentioned parameters, the tyre grip to the road is not a fixed value, nor is the maximum value of the forces that can be transmitted. This can be represented graphically by Kamm’s circle whose purpose is to show the limit of tyre grip in all directions at a specific moment. In order to keep the vehicle trajectory stable while driving, the tyres must transmit to the road the resultant force of the received forces. By applying Kamm’s circle you can see the interaction between the forces to which the tyre and its grip are subjected.



Systems of Longitudinal Dynamics

The systems of longitudinal dynamics are those whose function is to keep the vehicle running, especially in critical situations. They generally act on the braking system to reduce the effects of the driving and braking forces, which cause the pitching of the vehicle (by mass transfer) and the possible loss of control of the forward direction of the vehicle. The most relevant systems are: anti-lock braking systems, electronic differentials and traction control systems.

Systems of Lateral Dynamics

The loss of grip of one or several tyres together with the centrifugal force can cause lateral movements and yaw rates on the vehicle, which modify the trajectory requested by the driver, and cause the loss of stability and the understeer or oversteer of the vehicle. The systems of lateral dynamics act by modifying the orientation of the wheels or generating inertia moments in order to counteract the existing ones and, in this way, maintain the trajectory marked by the driver. Some of these systems are the stability control or the electric power steering.

Systems of Vertical Dynamics

These systems modify the suspension parameters while the vehicle is running. The aim is to perform a more progressive weight transfer during changes in vehicle direction or in accelerations, providing a high level of safety without compromising comfort. This is not possible in conventional suspensions, as it is necessary to achieve a balance between the absorption of irregularities (soft suspension) and the reduction of body oscillations (hard suspension). The systems that act on the vertical dynamics of the vehicle are the electronic control of the suspension and the active roll stabilisation.

ABS SYSTEM

Description

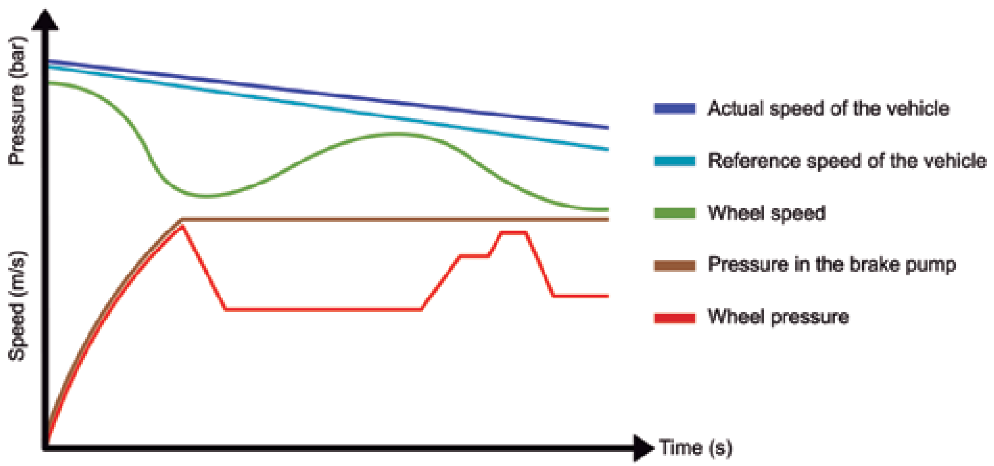
The first active safety system for automobiles of mass production is the anti-lock braking, commonly known as ABS. It is an electronically-managed system of the brake pressure whose main function is to prevent the wheels from locking up during braking in order to maintain the steering control and shorten the vehicle braking distance. The control system is inserted in the conventional brake circuit and works actively on it, so that to achieve the unlocking of the wheels during braking, in case that it takes place.

All current ABS systems, regardless of their manufacturer or variant, use the same operating strategy, as well as, similar detection and actuation methods. The regulation consists in maintaining or reducing the braking pressure on the wheel that shows a locking tendency and recover it, if necessary.

The locking tendency is detected when comparing the speed of each wheel with the reference speed of the vehicle, in other words, the average speed of the four wheels. If during braking, a wheel reduces its rotation speed to a greater extent than the reference value (by exceeding a preset percentage), it will be interpreted that said wheel has a locking tendency.

After it, the system will start the action procedure, which consists in interrupting the passage of brake fluid to the receiving piston of the wheel with locking tendency in order to avoid the pressure increase and the brake force, and with it, the possibility of greater tyre slipping. If the locking tendency is maintained in spite of this initial regulation, part of the fluid existing in the hydraulic circuit of this wheel will be released and the pressure in the channel will be reduced until recovering the adherence.

Once the intervened wheel equals its rotation speed with the reference speed of the vehicle, the braking pressure on that circuit is restored again.



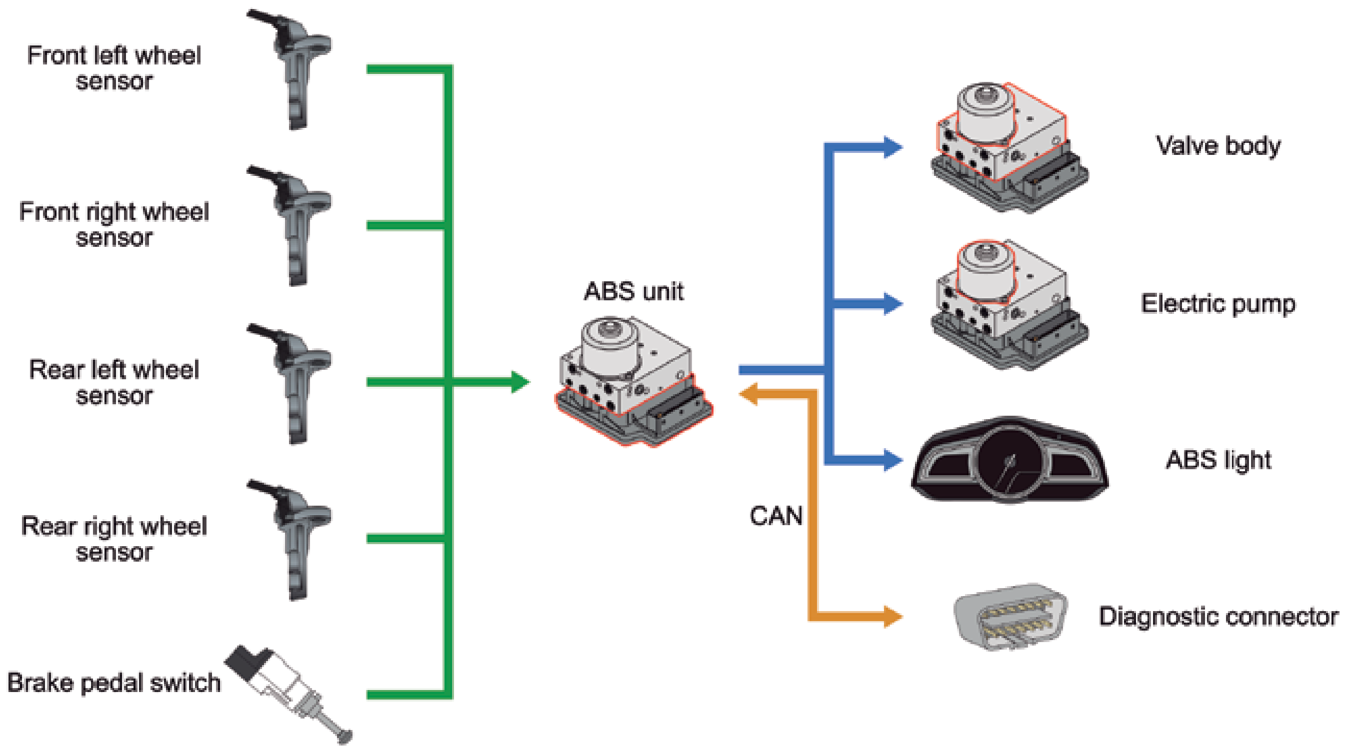
Components

The logical operating principle of the ABS systems implies the use of some specific components, which are similar in type and number for the different manufacturers. According to their purpose, they can be divided into:

Sensors: They transform physical magnitudes into electrical signals, which can be processed by an electronic unit or a computer. Two essential values are required for the operation of the anti-lock braking system: the speed of wheel rotation and the actuation state of the brake pedal.

Control unit: It transforms the electrical signals emitted by the sensors into mathematical or logical values by means of which an action can be generated.

Actuators: They transform the electrical signals emitted by the control unit into physical work in order to achieve the regulation of the brake pressure on the brake devices of the different wheels. On modern ABS systems, most actuators are integrated into an assembly called hydraulic modulator, formed by the valve body and the electric hydraulic pump. The also integrated arrangement of the control unit reduces to a minimum the electrical installation needed for greater system safety.



Sensors

Wheel Speed Sensors

Generally, wheel speed sensors are located in the axle carrier or, if not, in the axle. Their function is to measure the rotation speed of the wheel and transmit this magnitude to the control unit as an electrical signal. The frequency signals proportional to the speed of each of the wheels are used to calculate the reference speed and detect the locking tendency of the wheels. In case of a missing signal from some wheels, the system remains deactivated and records the failure for the self-diagnosis.

During the evolution of the ABS systems, different type of sensors have been used, and therefore inductive, Hall and magneto-resistive sensors can be found.

Brake Pedal Sensor

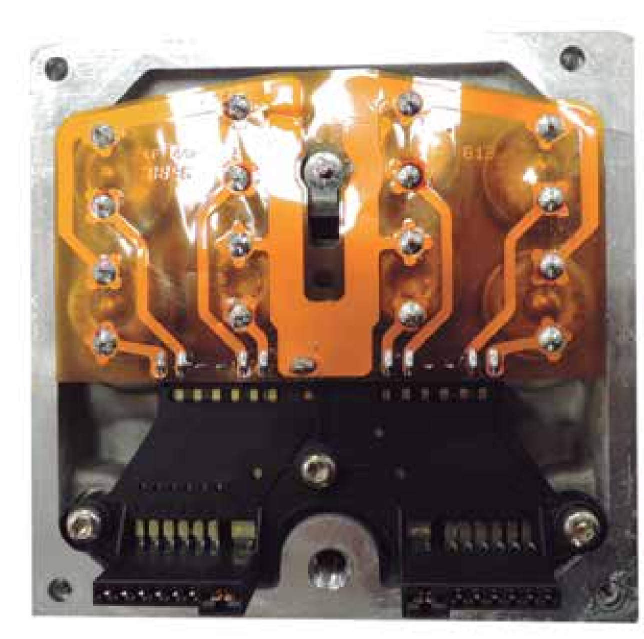
This sensor is usually located on the brake pedal support, although it can be also placed in the master cylinder. Its function is to inform the ABS unit when the brake pedal is applied by the driver, an essential factor for the logical detection of the locking of the wheels because of insufficient adherence/ excessive brake pressure. The information provided by the sensor ensures the sufficient advance of the pistons of the brake pump in order to establish a closed hydraulic circuit, so an adjustable pressure circuit, and allow the unit to discriminate between situations of loss of adherence due to excessive traction torque or due to excessive braking force.

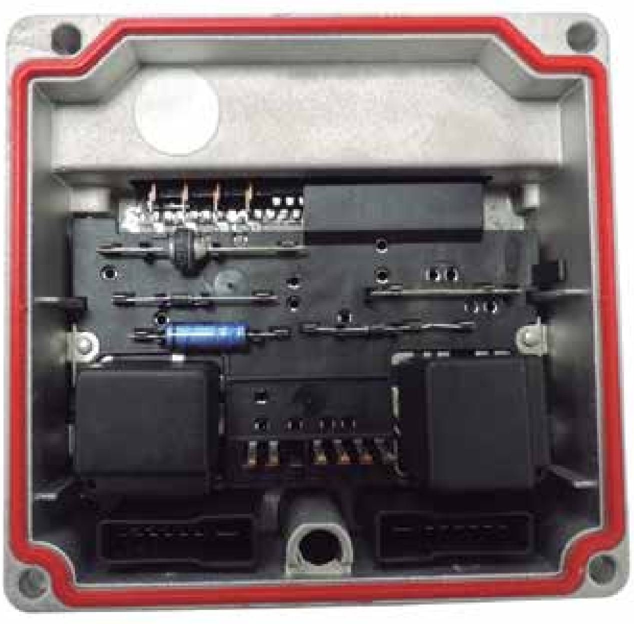
When the sensor is located on the brake pedal support, it can be a simple mechanical switch (old systems) or a dual switch of redundant signals, although Hall-type sensors are also used. In case that it is located in the brake pump, it can be a pressure mechanical switch (pressure switch), a piezoresistive pressure sensor or a Hall sensor, which reacts to the advance of the pistons of the brake pump.

Control Unit

It is the key element of the ABS system for a logical response, aimed at correcting driver's reaction errors and unforeseen factors that reduce the adherence. To do this, it constantly calculates the slipping degree of the wheels (by means of the continuous evaluation of sensor signals) and the braking modulation needed to recover the adherence. If needed and only when braking, the control unit generates the control signals necessary to carry out this regulation. It also has the function of continuously diagnosing the condition of the electrical and electronic components of the system, including the unit itself, in order to disconnect the system in case of detecting an anomaly and inform of the recorded faults.

Nowadays, the control unit and the hydraulic modulator form a single unit and integrate great part of the electrical equipment of the ABS system. The electronic control circuit, the solenoid valve coils and the relays necessary for the supply and activation of certain components are unified. This compact manufacturing technique eliminates intermediate electrical connections and reduces the electrical installation to the minimum, which removes the possibility of electrical failures, miscontacts, derivations or parasites, which could cause the incorrect regulation and intervention on the brake system.





The tasks performed by the ABS control unit can be classified into assumed or additional functions. The assumed functions are the minimum processes required for the proper system operation, which comprise the brake regulation and the self-diagnostic function. The additional functions are those performed for the support of other systems, as for example, the data entry in the CAN line of the vehicle and maximum torque calculation.

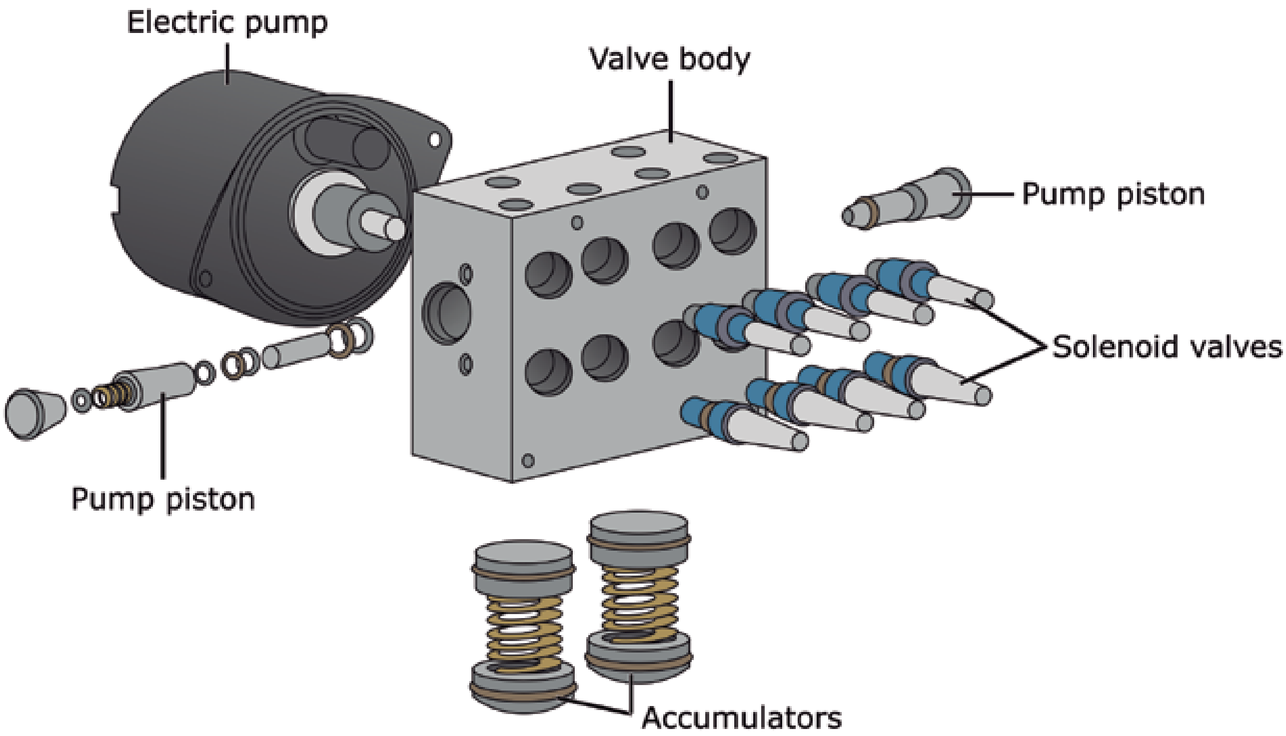
Hydraulic Modulator

The actuators, integrated into the electro-hydraulic modulator, modulate the brake pressure according to the control signals emitted by the ABS unit. They are alternated in the hydraulic circuit between the brake pump and the receiving pistons of the brake callipers, in an assembly with two inlets and four outlets that at rest keep the classic X-circuit configuration on most vehicles.

As a security measure, most manufacturers do not authorise the separation of the electrical and hydraulic parts of the ABS module, and their internal handling is completely forbidden. The separation of two functional halves can compromise the sealing of the assembly due to the high working pressure (up to 350 bar).

As with the sensors and detection strategies, the regulation processes are very similar for the different manufacturers, which entails a similar number and function of the actuators in all ABS systems. Constructively, they are distributed in the following way:

- **Valve body:** Valves, pressure accumulators, damping chambers and pistons of the electric pump are placed on a machined metallic block. The drills performed during the machining for the communication of the components clog in many cases with conical seat threaded plugs or pressed steel balls.
- **Electro-hydraulic pump:** It is a low-inertia electric motor with a drive shaft with off-centre cam, which actuates two pistons working against each spring in order to achieve an alternating movement. According to the manufacturer and ABS type, its power supply is performed by means of a relay or directly through the power circuit of the control unit, which can be modulated in this case.



Additional Functions

The evolution of the electronics and the logic processes has provided the ABS with additional functions, which allow to increase the number of situations in which it can operate so that to improve the active safety of the vehicle. In most cases, these functions are achieved by extending the software of the unit and small modifications on the hydraulic modulator, which do not imply an excessive production cost, but which are really useful for the final user, especially in adverse weather conditions and situations of unequal adherence.

Among the additional functions implemented are found:

- **Differential electronic lock:** It is known as EDS and performs the function of a self-locking differential on vehicles not fitted with it.
- **Traction control:** marketed under the name ASR (Anti-Slip Regulation) or TCS (Traction Control System), it improves the adherence of the drive wheels in acceleration from standstill.
- **Engine drag torque control:** It prevents the drive wheels from locking up during engine braking phases.
- **Brake force distribution**: It performs the function of the brake regulators of the rear axle.

As with the braking performance, the maximum traction capacity during accelerations depends on the tyre adherence and the sum of forces applied on it, by replacing in this case the brake force with the pulse torque. Therefore, if the driving force exceeds the tyre adherence capacity, the tyre will slip and this will cancel the transmission of the lateral forces. This fact allows to use a detection and control principle, which is very similar to the one used in the ABS function to keep the adherence and steering capacity.

The components used to perform these functions are basically the same as in the ABS system, but with slight modifications. It is only necessary to add the components aimed at allowing the increase of the brake pressure without the driver's intervention on the pedal and improve the communication of the Control Unit la with other electronic units of the vehicle.

The detection and control logic used to perform some of these functions turns out to be inverse or contrary to the logic that has been seen so far.

ESP SYSTEM

Description

The evolution of the electronic and communication systems between units allowed in 1995 the introduction of a new functionality related to the brake system. The stability control, also known as ESP from its acronym in German Elektronische Stabilitäts-Programm is a function, which combines the operation of the engine control unit and ABS to correct the losses of vehicle trajectory caused by tyre slipping even when the speed difference between them is not considerable.

As it occurs with the ABS, the operating logic of the different ESP systems is very similar, regardless of the manufacturer or version. The detection logic is based on comparing the theoretical trajectory of the vehicle (guidance intention of the driver) with the trajectory that he actually follows to see if there is a significant deviation, since it indicates loss of stability.

The system calculates the parameters that correspond to the trajectory desired by the driver on the basis of vehicle's speed, position of the steering wheel and data recorded in the unit. The actual trajectory is evaluated in accordance with the difference in the speed of the wheels, which determines the radius of the curve. The control unit constantly monitors and compares these values. It starts the intervention cycle in case of significant deviation between both values or an abnormal acceleration of vehicle's body, which indicates the lateral movement of the vehicle or the displacement about its own axle.

The system calculates the guidance and magnitude of the reaction forces required for reducing the forces that cause the loss of vehicle's stability, by braking one or several wheels and reducing the engine torque if necessary. The braking on one of the drive wheels causes the increase of transmission torque on the opposite wheel, which generates a powerful yaw torque on the regulated axle. Cross braking obtains yaw forces on the body, which allow to counteract the forces generated by the loss of adhesion of one of the axles.

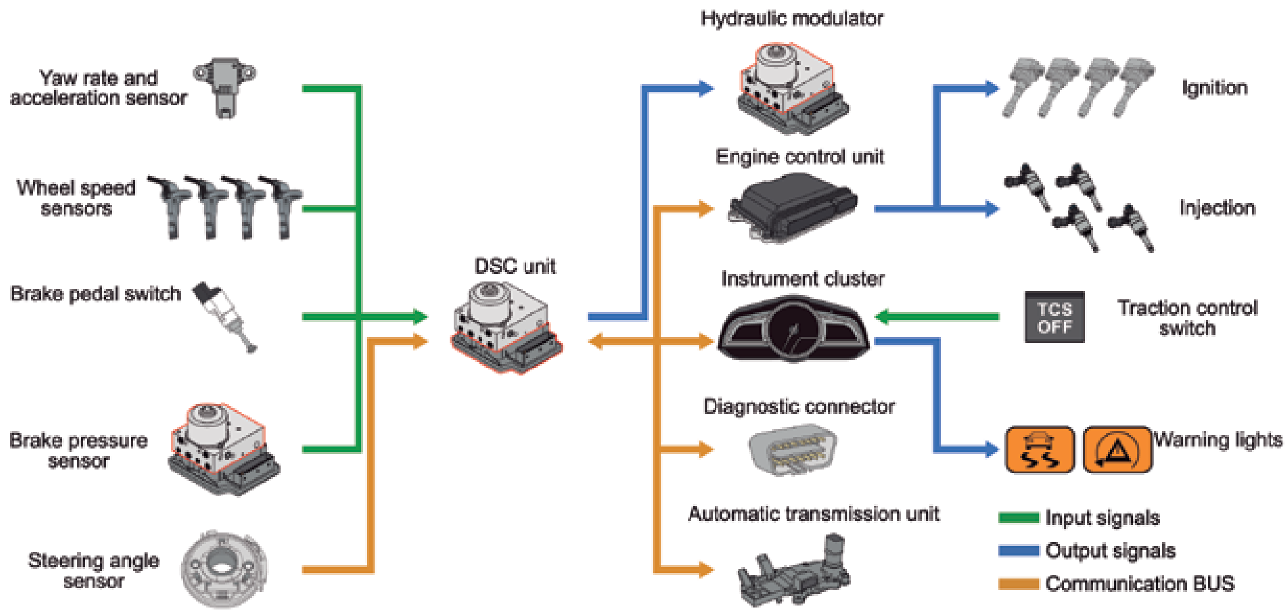
After the regulation, the condition of the vehicle is checked again to see if the intervention has been successful. If so, the intervention ends and passes to the condition of continuous supervision. If the intervention has not been successful, relevant interventions will be calculated and performed as if they were separate actions.

Components

In order to know the driver's intentions, the performance of the vehicle and carry out the necessary actions, the ESP system requires a higher number of components than the ABS system. Moreover, the communication between units and calculation speed is faster. Most of the new components are sensing elements.

Sensors

To detect the loss of stability even when there is no excessive slipping of the wheels in their turning direction, the unit requires new data related to the physical variables, which define the trajectory of the vehicle and the driver's reaction. These parameters, obtained by sensors or as data processed by third parties through communication protocols, can be classified into sensors aimed at informing of driver's intentions and sensors that determine the actual condition of the vehicle.



Control Unit

The stability control function requires a greater amount of data provided by other systems of the vehicle than the adhesion control functions, especially from the engine control unit, which keeps permanent communication through CAN-Bus.

The engine control unit must transmit the instantaneous engine torque at all times, as well as the information of the driver's intentions, as for example, the position of the accelerator pedal. At the request of the ESP unit, the engine control unit must modify the generated torque to adapt it to the stability control needs.

Other units that transmit relevant information for the ESP function are the automatic transmission unit (engaged gear), comfort unit or body unit (windscreen wiper actuation) and the towing unit, if fitted.

Hydraulic Modulator

The ESP systems increase the number of solenoid valves to four if compared with the ABS systems, two for each hydraulic circuit. The electric pump activates a larger number of plungers to achieve a greater flow of brake fluid and to increase the capacity of pressure regulation.

Sensors to Interpret the Driver's Intentions

Brake Pressure Sensor

The pressure that exists in the brake circuit is used to know the rest position of the brake pedal and calculate the braking forces that act on the wheels, regardless if the driver intervenes or not. The magnitude of the braking forces sets the limits of the lateral steering. It is an essential value for the stability, so in case that this signal is missing, it will not be possible to calculate the basic values for the regulation and the ESP system will remain disabled. The self-diagnostic function of the control unit analyses the consumption and the sensor signal, and records the relevant DTC code in case that a fault occurs.

The number, type and location of the pressure sensors differ depending on the manufacturer and management. The sensors used can be from a single sensor (to measure the pressure generated in the master cylinder) up to five sensors, which allows to know the individual pressure of each regulation channel. The sensors can be found in the body of the master cylinder, bolted to the hydraulic modulator or integrated in its interior. The sensors used are capacitive and piezoresistive pressure sensors.

Steering Angle Sensor

It is also called goniometric sensor and its function is to identify and transmit the position of the steering wheel in all its angular travel usually comprised between ±720º and ±900º and, in some cases, the rotation speed of the steering wheel. This sensor transmits to the ESP unit the signal created in specific digital format or by CAN-Bus protocol.

The position of the steering wheel is used to know the driver's intention to turn, calculate the theoretical travel that the wheels of the vehicle must perform and therefore the speed of each wheel. Moreover, the angular speed allows to calculate the variation of the centrifugal force of the vehicle. It is a basic signal for the detection of the ESP stability and regulation, so the system will remain disabled in case that this sensor fails.

The goniometric sensor has a control electronics with its own self-diagnostic function, which controls its proper operation and records the relevant DTC codes in case of a failure. As it occurs with the control units, it is possible to access the self-diagnostic system to display parameters, clear fault codes or perform the zero-point calibration of the sensor in accordance with the steering alignment of the vehicle.

The sensor is located in the steering column, either as an independent element or by forming an assembly with the tail lights and the airbag spiral spring. Two types of sensors have been used in the different ESP generations: magnetoresistive and optoelectronic sensors.

Button for Traction Control

This button is used to deactivate the functions of stability control and traction control. This option is useful and necessary in exceptional situations in which the slipping of the wheels must be allowed, regardless of whether they are drive or non-drive wheels, as for example:

- When driving on roads with deep snow or very loose surfaces.
- When fitting snow chains that provide irregular grip.
- To perform tests on a dyno or a brake tester.

A warning light on the dashboard shows that functions are deactivated until the driver activates them again by pressing the button or switching the ignition off. In case of a faulty button, the ESP and traction control functions cannot be deactivated and the warning light will not be displayed, since the self-diagnosis cannot detect faults related to this button. Nowadays, switches for turning traction control and ESP off are independent, as ESP cannot be completely deactivated by law, but it is possible to reduce its detection threshold and intrusion level.

Brake Pedal Switch

This switch is the same as the one used on ABS systems and for the engine management. It can be a dual and redundant mechanical switch or a Hall position sensor. Although the brake pedal switch is considered dispensable for the ESP function, its signal can be used to inform the control unit about the brake pedal actuation, so that this unit can modify action protocols of the functions, as for example to deactivate traction control.

Parking Brake Switch

It is a mechanical button located on the parking brake lever, which is only fitted in rear-wheel drive or all-wheel drive vehicles. Its function is to inform about the intentional actuation of the handbrake when driving, usually to slide the rear part of the vehicle and thus avoid the system intervention, which would cause an even more dangerous situation. At present, it is also used as a signal for additional functions as for example the start assist function, which prevents unintentional backward rolling of the vehicle on uphill slopes.

In case that this switch fails, there is no substitution function, so it will not be possible to change the ESP activation status while actuating the parking brake. The self-diagnostic system of the control unit also fails to recognise the fault of this element.

Sensors to Identify the Actual Situation of the Vehicle

Wheel Speed Sensors

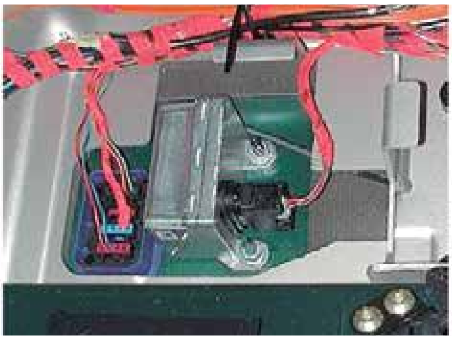
Their structure and operation are the same as in the ABS systems. In addition to calculating the longitudinal speed of the vehicle (reference speed) and the slipping degree of each wheel, it is an essential signal to know the trajectory of the vehicle in curve. Due to the wide speed range on which the ESP function actuates, the wheel speed sensors used are only magnetoresistive or Hall-type sensors, as they provide reliable interference-free signals at any speed.

Yaw Rate Sensor

It is also called angle speed sensor and its function is to measure the rotation speed of the vehicle about its vertical axis. This information is used to recognise skidding and calculate yaw torque, and it is essential for knowing the lateral slipping of the axles, without variation in the wheel speed.

Due to the function and working principle of this sensor, it needs to be located as closely as possible to the vehicle's centre of gravity, usually next to the parking brake lever, under the front seats or on the dashboard. However, it can be also fitted in the control unit itself. Its mounting position should not be modified under any circumstances, as this could lead to erroneous information and interventions that would cause even a more dangerous situation.

Different types of sensors have been used in the successive generations of stability control systems. According to their principle of operation they can be classified into: piezoelectric sensors and micromechanical sensors.



Lateral Acceleration Sensor

As the name suggests, it measures the lateral acceleration forces of the vehicle. It is usually located next to the yaw-rate sensor so that to achieve a neutral measurement without yaw interference. Its position should not be modified under any circumstances, as this would provide erroneous data and cause incorrect and dangerous intervention and regulation of the ESP. The mounting position and operation of the sensor is indicated on its housing by means of an arrow which should be always pointing the driving direction of the vehicle.

A missing signal or a signal which is out of range entails the deactivation of the ESP system with the subsequent warning light and DTC code stored in the unit.

As it has been already seen with other sensors, different strategies have been employed during the evolution of the ESP systems to measure the lateral acceleration. Hall sensors and micromechanical sensors have been mainly used for this purpose.

Longitudinal Acceleration Sensor

The longitudinal acceleration of the vehicle is a secondary parameter, which is usually obtained from the speed of the non-driving wheels. On all-wheel drive vehicles, the use of this sensor is necessary to calculate the inertia forces in situations of low grip. Its use is becoming increasingly common also on vehicles with two drive wheels.

The longitudinal acceleration allows to calculate the variation of adherence between both axles due to the mass movement, and it is also used as an additional signal and a check value of the brake pressure and slip signals of the drive wheels (transmitted torque).

It can be mounted on its own support under the dashboard, on the same support where the lateral acceleration sensor and yaw-rate sensor are housed or inside the control unit. The structure and operation of this type of sensors is identical to the ones of the lateral acceleration sensors, being the only difference its installation direction (longitudinal instead of lateral).

Combined Sensor

Yaw-rate, lateral acceleration and longitudinal acceleration sensors are combined in a single component (for greater safety). Manufactured by micromechanical technology on the same printed circuit board, they keep in all cases the relative position between them and deliver a more accurate measurement with a compact, robust and reliable structure.

Depending on the management used, the signals emitted by the sensor can be independent for each acceleration (one line for the lateral acceleration signal, another line for the yaw-rate signal, etc.) or by means of a single signal via CAN-Bus protocol. In the last case, the electronics is responsible for verifying at first the plausibility of all measured values in order to later handle the signal and transmit it through the multiplexed network. In any case, the lack of plausibility of one or several signals causes the stability control to switch off as well as to record the corresponding fault code.

Control Units

ESP Control Unit

This unit is the main stability control component and its operation consists in matching the dynamic response of the vehicle in critical situations to the driver's demands as quickly as possible. Based on the data provided by the sensors of the system and other electronic units of the vehicle, the unit analyses the objective dynamic condition (driver's demand) and calculates its actual dynamic situation. Once both positions have been calculated, the unit compares them and if the result is different, it determines the required intervention by means of a preset map and generates the required control signals to:

- Generate the sufficient hydraulic pressure to brake the wheels.
- Control selectively the brake force of the wheels.
- Reduce or increase the engine torque (by means of the engine control unit).
- Maintain or modify the engaged gear (by means of the automatic gearbox control unit, if exists).

After each correctional intervention, the unit compares again the actual state of the vehicle with the theoretical one to verify the result of the operation and repeats the working cycle if necessary.

Regarding the structure, the ESP control unit does not differ significantly from the ABS unit, as it also forms a single constructive element with the hydraulic unit. In its inside contains the relays and coils required to regulate the operation of the hydraulic actuators. It also has a fail-safe circuit with two high-performance processors whose results are continuously compared.

Functions

In addition to the main function of stability control, whose aim is to keep the desired driving trajectory of the vehicle, the control unit also performs the ABS and traction control functions, as well as other additional functions. To carry out these functions, the unit requires data and actuations from components that belong to other managements and which are transmitted through the CAN network. In this case, the CAN network capacity and transmission speed increase if compared with previous systems.

Apart from the active safety functions, other additional functions are added so that to improve the dynamic and driving comfort of the vehicle. In this way, the functions performed by the unit can be divided into classic functions and additional functions:

Classic Functions
- Stability control
- Anti-lock braking system
- Traction control
- Emergency brake assist
- Electronic differential lock
- Self-diagnosis

Additional Functions
- Start-up assist
- Downhill assist control
- Brake anticipation
- Brake disc wiper
- Fading Brake Support
- Trailer stabilisation

If due to a large number of interventions the processors experience overheating, all functions except ABS will be disabled until the unit returns to a safe working temperature.

Engine Control Unit

This unit is the key component for the proper operation of the stability control, as well as other functions, both assumed and additional. Its function is to inform the ESP unit of the driver's intentions (position of the accelerator pedal) and the instantaneous engine torque transmitted, as well as to act with respect to the requirements of this system (modify the position of the throttle valve, the injection time and ignition point). The required processes are transmitted through the multiplexed network.

In case that communication is interrupted or there is a failure in the engine management, which impedes the ESP unit to know the delivered engine torque or impedes its regulation, all stability control functions will be disconnected, except the ABS function. In this case, the error will be stored in the engine control unit.

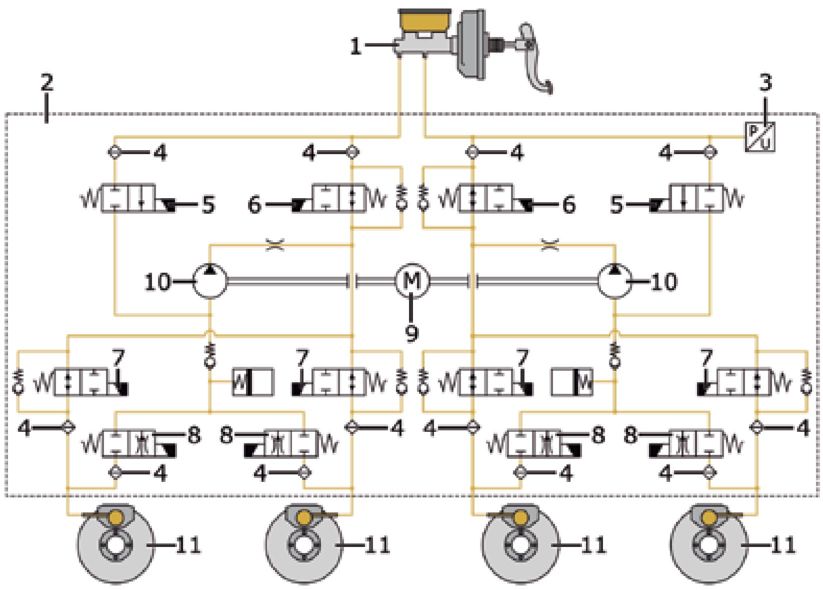
Other Control Units

They are also connected via CAN-Bus and provide additional information to carry out several additional functions. Among them we can find the automatic transmission control unit, whose objective is to inform about the engaged gear and prevent the gear shift on request of the ESP unit, or the on-board unit and body unit, which informs about the activation of the windscreen wiper.

The lack of communication between these units or the failure of the corresponding sensor to acquire the information required by the ESP unit will lead to the deactivation of the functions related to them, keeping enabled the remaining functions.

Hydraulic Modulator

If compared with the ABS systems, the ESP hydraulic modulator is fitted with four more solenoid valves (two for each circuit) and receives modifications in the electric hydraulic pump to achieve a faster response of pressure increase. The first ESP modulators were fitted with an additional priming pump, which is no longer used. The other hydraulic components remain without any significant variation and the configuration of two independent hydraulic control circuits for four regulation channels is maintained.



1- Brake pump
2- Hydraulic modulator
3- Pressure sensor
4- Filter
5- High-pressure solenoid valve
6- Inversion solenoid valve
7- Inlet solenoid valve
8- Exhaust solenoid valve
9- Electric pump motor
10- Electric pump piston
11- Brake device

Solenoid Valves

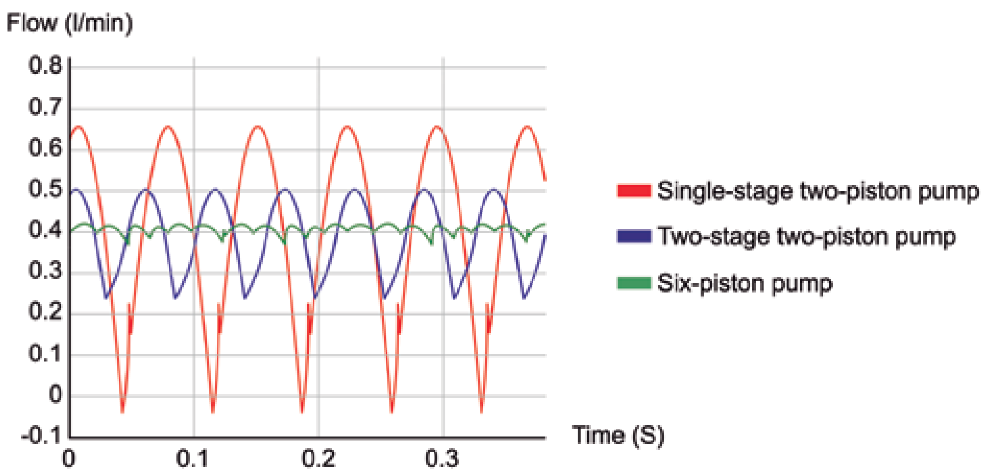
In the ESP systems only two-way and two-position (2/2) solenoid valves are used, which are controlled by means of a variable pulse-width modulation signal (PWM). There are four different types of solenoid valves depending on the purpose:

- **Inversion solenoid valves:** One of these valves is used for each hydraulic circuit (two in total) and its function is to control the fluid passage from the master cylinder to the intake solenoid valve (rest) or from the electric pump to the brake fluid tank during the pressure reduction phases (operation). Its position at rest is “usually open”.
- **Intake solenoid valves:** One intake valve for each regulation channel (four in total). Its function is to allow or limit the brake fluid passage towards the receiving piston of the corresponding channel. Its position is “usually open”, so at rest it allows the communication between the master cylinder and the receiving piston by keeping the configuration of the conventional brake circuit.
- **Exhaust solenoid valves:** There is one exhaust valve in each regulation channel so that to reduce the pressure existing in the receiving piston by the expansion of the fluid in the pressure accumulator. This valve has a throttle in the orifice that is connected with the accumulator to limit the discharge flow and reduce the pressure in a more “progressive” manner. Its position is “usually closed”.
- **High-pressure solenoid valves:** One of these valves is used for each hydraulic circuit (two in total) to allow or not the fluid passage from the master cylinder to the intake side of the pump and vice versa. Its position is “usually closed”.

Electric Hydraulic Pump

This pump draws in and compresses the fluid required to achieve the necessary pressures for the wheel braking without the driver’s intervention and to recover the fluid released from the cylinder receivers during the pressure reduction phases. It generally conserves the structure and operation of the twin-stage pumps used in the ABS systems, but with the difference that higher diameter pistons are used.

In the latest ESP systems, pumps with more pumping elements, usually six, are used. Their suction capacity is higher, which allows greater regulation capacity and quality. These pumps allow a wider pressure regulation range and a more linear fluid control so that to reduce pulses in the brake pedal.



TECHNICAL NOTES

This section covers the most common malfunctions related to the active safety system. Depending on the manufacturer and the different models, the number of faults occurring over the years may vary.

These faults are selected from the online platform: www.einavts.com. This platform has a series of sections that specify: make, model, line, system affected, and subsystem, which can be selected independently depending on the desired search.

MERCEDES-BENZ

MERCEDES-BENZ E CLASS (W211)	
Symptom	Fault codes recorded in the ABS control unit: C1540 - Road test not carried out. Not completed. C15DE - Drive test. Road test not performed. ABS warning light ON. Brake light ON. NOTE: This informative bulletin only affects those vehicles equipped with a SCB braking system (Sensotronic Brake Control).
Cause	• The SBC system has not been calibrated. After performing an operation on the ABS/SBC braking system, adaptations reset in the SBC system must be performed.
Solution	Repair procedure: • Read the fault codes in the ABS control unit using the diagnostic tool and confirm that ONE of the fault codes that appear in the field symptoms of this bulletin is displayed. • Reset adaptations using the diagnostic tool if the performed operations requiere it. • Reset adaptations manually by following the next steps: • Disconnect the diagnostic tool. • Start the engine. • Press the ‚ESP OFF' switch. • The indicator and signal lights will light up on the instrument cluster. • Drive the vehicle at 1st gear and in a straight line at a speed of 10 km/h approximately. • Drive about 30 metres and turn the steering wheel to the right with a rotation angle of less than 360º and turn the vehicle 180º (half turn). • Turn the steering wheel counterclockwise and repeat the manoeuvre performed in the previous step. • Keep driving by aligning the vehicle to the straight position. • The indicator and signal lights must go off. • Procedure carried out.

SEAT

ALTEA (5P1), ALTEA XL (5P5, 5P8), LEON (1P1), TOLEDO III (5P2)	
Symptom	Fault code recorded in the ABS/ESP hydraulic control unit (HCU). 01435 - Pressure sensor, Bank 1 (G201). Electrical fault. ESP system fault light on. Warning light for the ABS brake system is on.
Cause	Failure of the pressure sensor, G201. This sensor is located inside the ABS/ESP hydraulic control unit (HCU) block.
Solution	Repair procedure: • Read the fault codes recorded in the ABS/ESP hydraulic control unit (HCU), using the diagnostic tool. • Delete the fault codes recorded in the ABS/ESP hydraulic control unit (HCU), using the diagnostic tool. • Reprogramme the ABS/ESP hydraulic control unit (HCU) with updated software. • Carry out a second reading of the fault codes recorded in the ABS/ESP hydraulic control unit (HCU), using the diagnostic tool.

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NEXT

Multimeter Oscilloscope

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