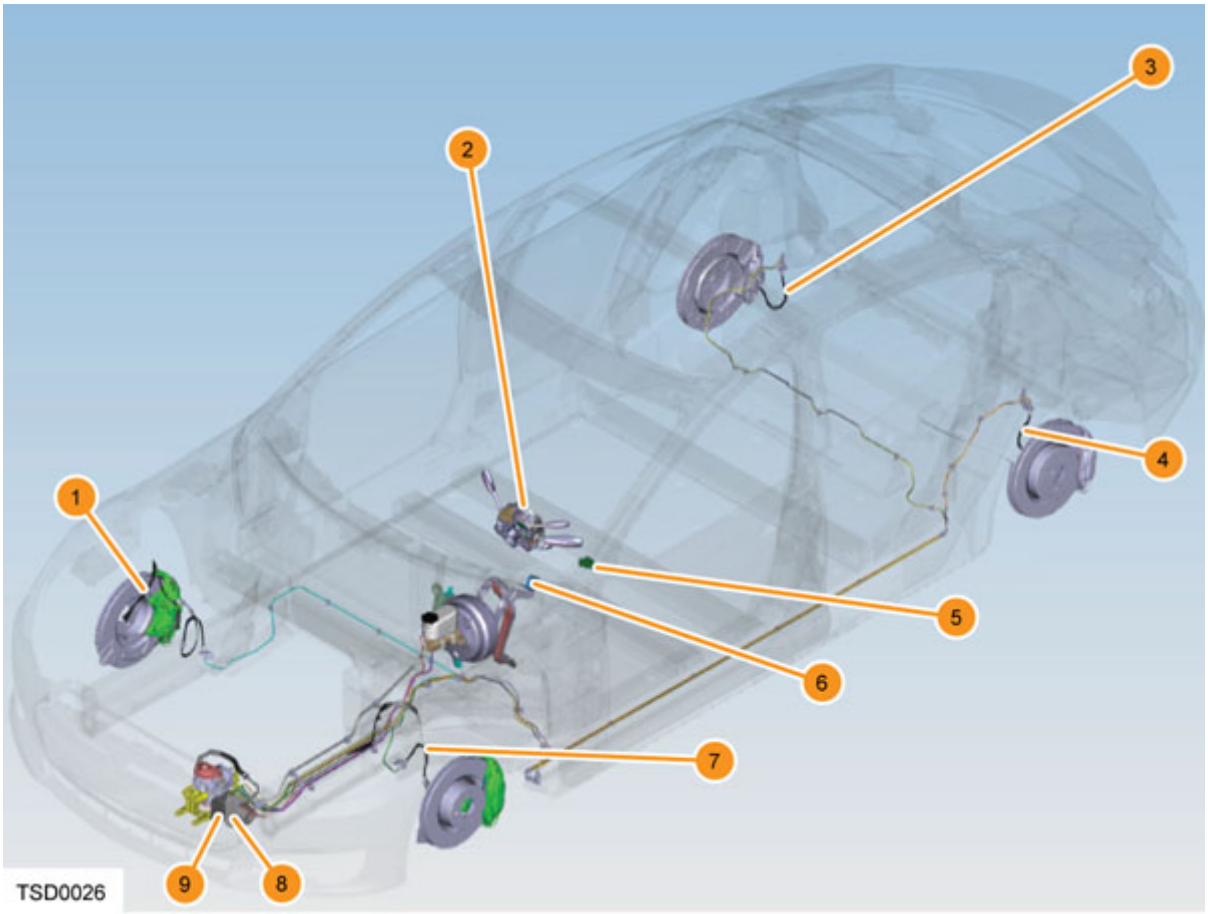
Stability Control and ABS

Overview

Component Location



1. RH front wheel speed sensor
2. Steering Angle Sensor (SAS)
3. RH rear wheel speed sensor
4. LH rear wheel speed sensor
5. Yaw rate sensor cluster
6. Brake pedal
7. LH front wheel speed sensor
8. Hydraulic control unit
9. Electronic Control Unit (ECU)

General

The Electronic Stability Control system (ESC) combines all active safety controls that assist with braking, acceleration, and cornering into one module. The following functions are present on the Model S ESC.

Anti-Lock Braking System (ABS)

The ABS controller constantly monitors and compares signals received from speed sensors located at each wheel. When the brake is applied and a wheel is about to lock, the ABS modulator reduces the brake pressure at the unstable wheel enough to prevent wheel locking. As soon as the wheel becomes stable, the ABS controller increases brake pressure, thereby maintaining optimal braking force at all times. The ABS control system performs these adjustments several hundred times per second on each wheel independently. This enables the driver to achieve the highest brake force physically possible, while maintaining vehicle stability and steering over any road surface.

Electronic Brake-Force Distribution (EBD)

EBD optimizes the distribution of braking force between front and rear wheels. EBD is superior to mechanical type proportioning or load compensation valves, as it can automatically compensate for changes in vehicle loading or road conditions.

EBD is only active during braking, and works to re-distribute brake force between front and rear axles before ABS takes effect.

Traction Control System (TCS)

TCS functions to prevent excessive motor torque from reaching the driven wheels. By monitoring wheel speeds, the TCS controller can modulate and reduce motor torque to prevent wheel spin. Tesla traction control has been developed especially to promote smooth wheel control during maximum acceleration. In cases where one side of the car is driving over a low traction surface (such as patchy ice), TCS can apply the brake at one wheel to stop it from spinning. This enables ascending gradients in conditions where one driven wheel has low grip.

Electronic Stability Control (ESC)

The ESC function assists the driver in maintaining control of the vehicle during cornering. ESC differs from TCS and ABS by using yaw rate and acceleration sensors in addition to wheel speed sensors. ESC calculates the intended path of the vehicle based on the driver’s inputs (from a steering angle sensor) and compares it to the measured rate of turn of the vehicle from the yaw rate sensor.

ESC monitors for under-steer or over-steer events during cornering. In the case of understeering, braking the rear inside wheel results in a positive yaw torque that helps the vehicle turn into the corner. During oversteering, braking the front outside wheel results in a negative yaw torque that steers the vehicle out of the corner and helps the rear axle regain traction. If the vehicle path deviates from the driver’s path, ESC briefly applies the brakes at individual wheels to help steer the vehicle back to the intended path. ESC also controls and limits engine power to the extent necessary to support lateral tire grip during cornering.

ESC works on all road surfaces and weather conditions to help utilize all available road force to keep the vehicle stable. However, ESC cannot evade the laws of physics, and does not prevent loss of control if a driver carries excessive speed into a corner. Furthermore, ESC only assists the vehicle to follow the path the driver is steering. ESC does not prevent the driver from steering a vehicle off the road.

Brake Assist System (BAS)

BAS helps the driver during panic or emergency braking events. In some emergency situations, the driver does not apply sufficient brake pedal force to achieve the maximum vehicle deceleration. If the conditions indicating an emergency brake event are satisfied, BAS uses the ESC pump to increase the brake pressure when the driver’s brake force is not sufficient.

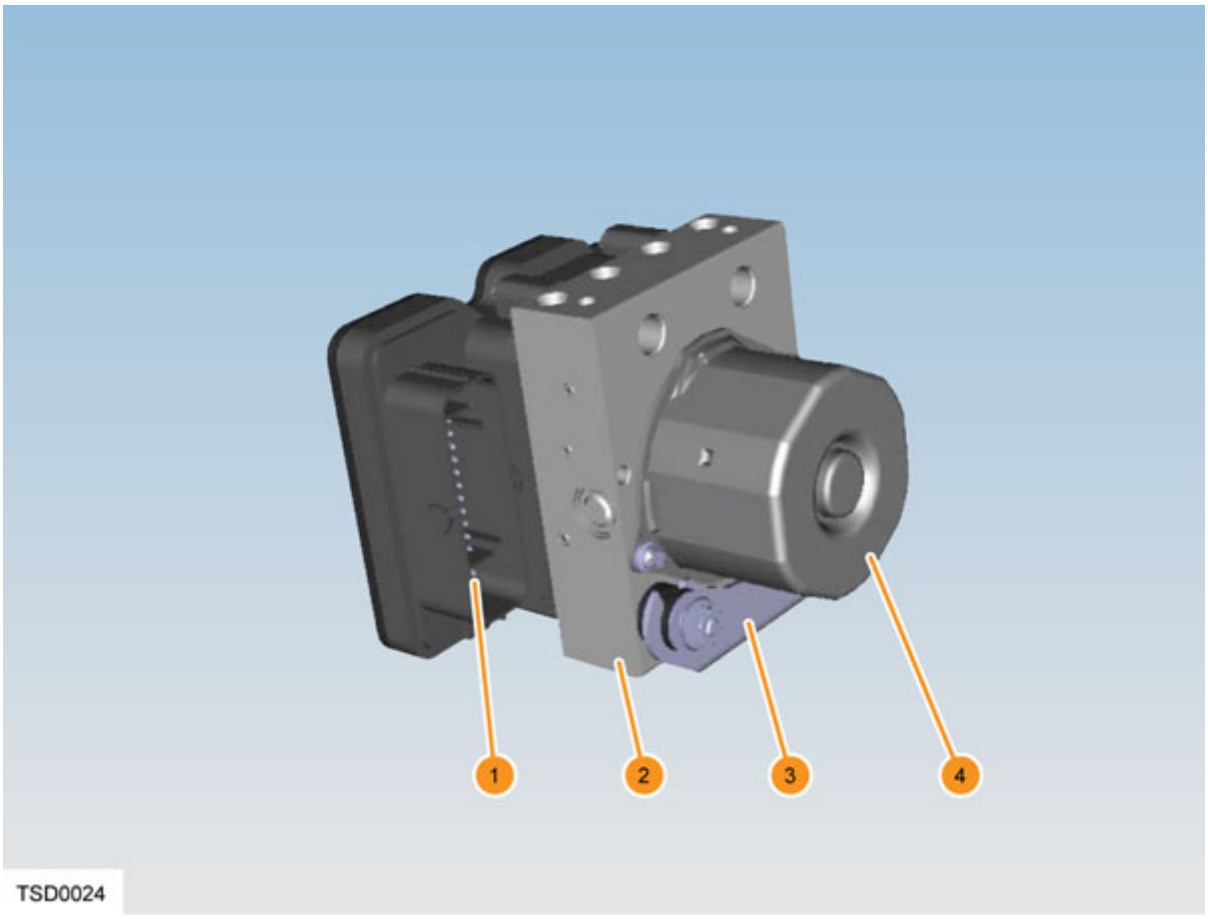
Hydraulic brake pressure is artificially increased much faster than pressure from the driver, and is maintained at the optimal ABS operating pressure. If the brake pedal force is further reduced by the driver, the BAS function is canceled.

WARNING: *ESC is an aid to retaining vehicle control and stability during braking, acceleration, and cornering:*

- ESC cannot defy the laws of physics acting on the vehicle.
- ESC does not prevent accidents resulting from excessive cornering speeds, following another vehicle too closely, hydroplaning, etc.
- The additional control provided by ESC must never be exploited in a dangerous or reckless manner that could jeopardize the safety of the driver or other road users.
- Having ABS fitted does not imply that the vehicle always stops in a shorter distance than an equivalent vehicle without ABS.

Component Descriptions

ESC Hydraulic Control Unit



1. ESC ECU attachment
2. Valve block
3. Mounting bracket
4. Pump motor

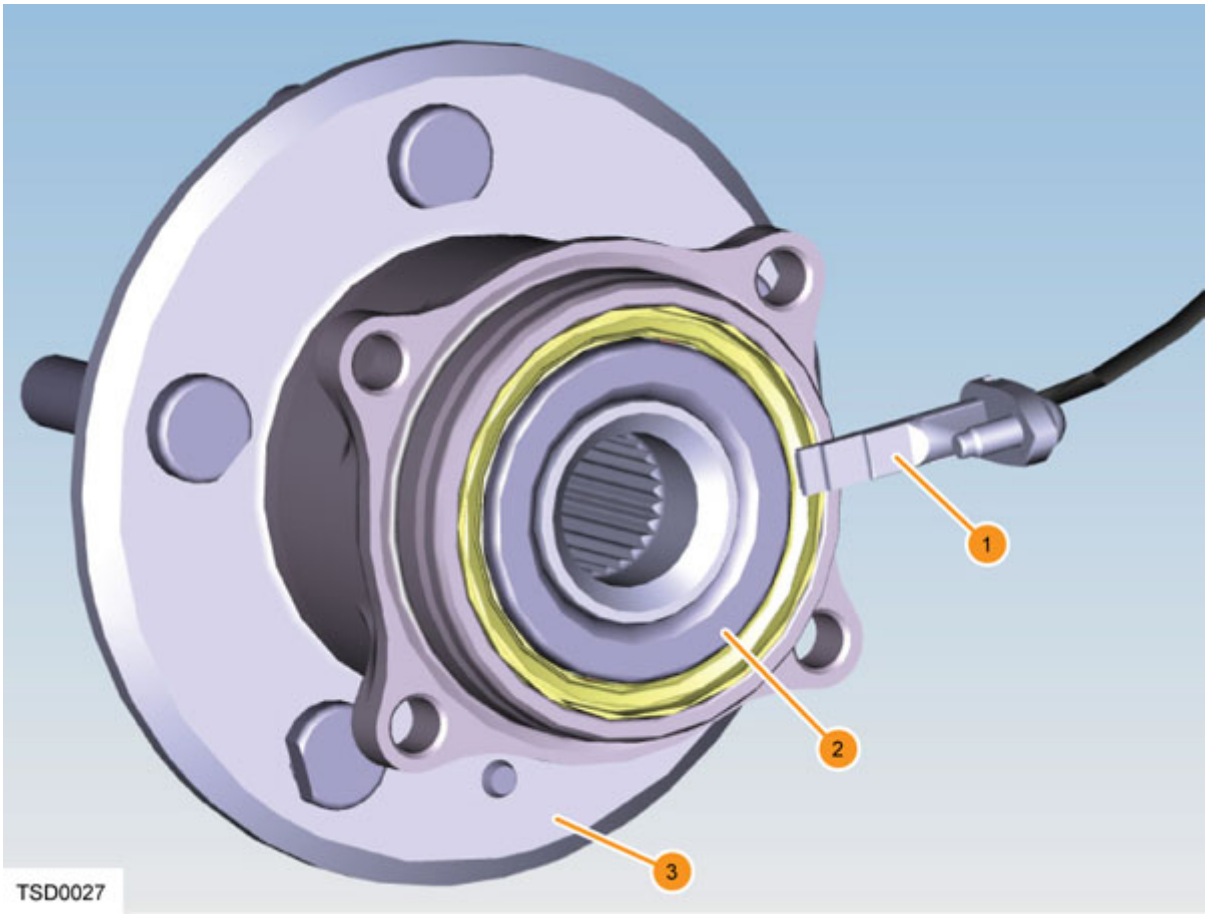
The central component of the ESC system is the hydraulic control unit. It consists of three main components:

- The ECU attachment, housing the processor and valve driver electronics
- The valve block, containing the hydraulic valves and accumulators
- The pump motor

The ESC hydraulic control unit is fitted on the left-hand side of the front sub-frame cross-member. It is supplied by two brake lines from each circuit of the tandem master cylinder. Four brake lines exit the valve block and connect to each brake caliper. All six brake line locations are marked on the valve block, indicating the correct hydraulic configuration.

The ESC hydraulic modulator is not serviceable. The modulator is designed to operate for the life of the vehicle. In the event of a fault, the entire unit must be changed. The ESC unit has a UDS interface accessible through the OBD-II port. It features an advanced troubleshooting system that can monitor and diagnose all related sensor components and the hydraulic control unit itself. Faults are best diagnosed by reading the diagnostic messages.

Wheel Speed Sensors



1. Wheel speed sensor
2. Sensor tone ring, integrated into wheel bearing
3. Hub

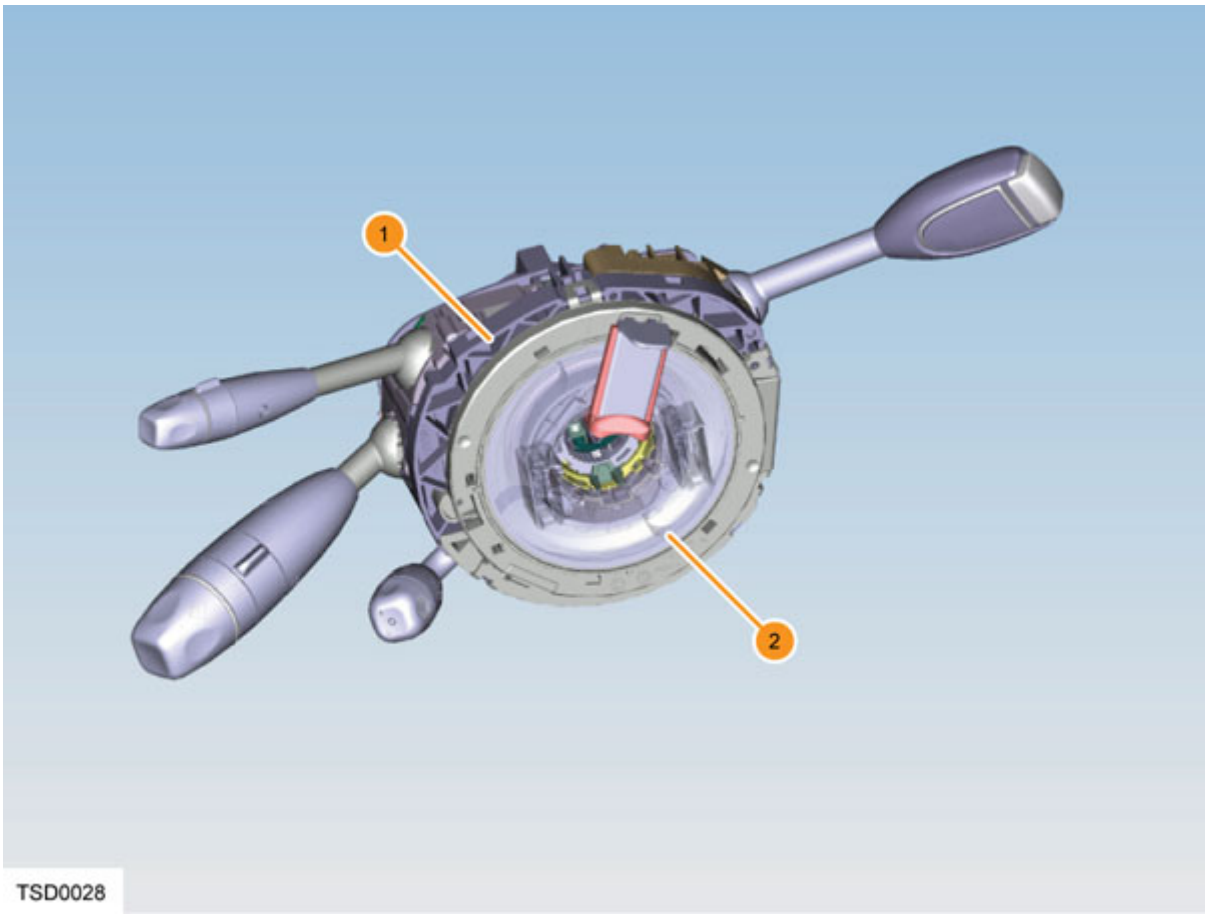
The wheel speed sensors provide the digital wheel speed signals to the ABS modulator. A wheel speed sensor is installed in each wheel bearing unit. The sensing element is situated to align with the magnetic sensor tone ring, integrated with the inboard bearing seal. Each seal contains magnetic elements arranged in pole-pairs that make up the tone ring. Only one side of the bearing contains the integrated tone ring.

As the wheels rotate, the pole-pairs in the seals induce sinusoidal voltage fluctuations in the wheel sensors (the Hall effect) that are converted into square wave signals. The signal frequency is proportional to the speed of each wheel.

The wheel speed sensors are active sensors. They output a current-based digital signal that has been converted from analogue form, and processed in the sensor unit before being sent to the ESC control unit. This ensures that disturbances and errors in the raw Hall effect signals are not passed to the ESC processor. The pulse width carries further direction and diagnostic information and is not proportional to vehicle speed.

The sensor element is non-serviceable. Most common faults occur because of broken or damaged wiring or connectors, with failed sensors being less common. Diagnostic troubleshooting indicates the type of fault.

Steering Angle Sensor

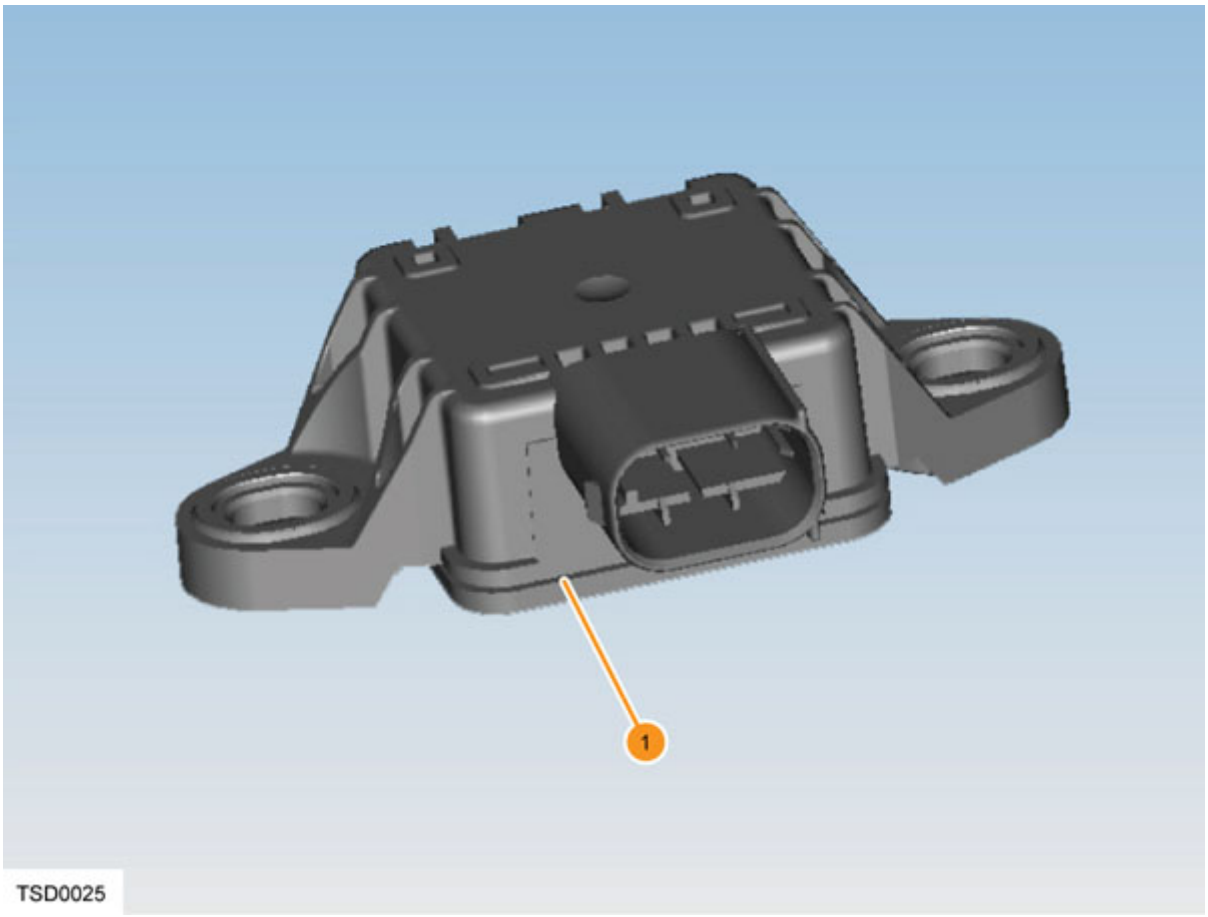


1. Steering column control module
2. Clockspring

The steering angle sensor is part of the Steering Column Control Module (SCCM). The sensor engages the steering column through a pair of detents that locate in slots in the steering column's outer sleeve when the stalk module is installed, thus centering the module on the column. The steering angle sensor communicates the steering angle to other vehicle systems via the high-speed chassis CAN network.

NOTE: *The sensor is position-sensitive, and must be assembled with the steering system in the straight-ahead position. The steering system (column, rack, and tie rods) must be correctly aligned. It is possible to assemble the steering angle sensor incorrectly. No setting procedure is required, provided the sensor is assembled conforming to the assembly procedure.*

Yaw Rate Sensor Cluster



1. Lateral acceleration and yaw rate sensor

The combined lateral acceleration/yaw rate sensor is located under the center console. The sensor is used for ESC operation and measures the vehicle's rotation around its vertical axis (yaw rate), while at the same time measuring the acceleration perpendicular to the driving direction. The ESC function uses the sensor inputs to detect the onset of side slip during cornering. The sensor communicates to the ESC control unit over the CAN network.

Indicator Lights

When the vehicle is turned on, the ABS ECU performs a check of the brake-related indicator lights on the instrument pack as part of the power-up procedure. The indicator lights are lit for approximately five seconds and then turned off. If a fault indicator light remains displayed after the check, a fault has been detected and requires repair.

Brake Fluid

DOT 3 or DOT 4 brake fluid is specified for use in the hydraulic braking circuit. Brake fluid is used to transfer brake pressure from the master cylinder through the brake pipes to the brake calipers. Braking generates heat energy, which is transferred into the braking components; therefore, brake fluid must have a high boiling point to remain efficient.

Brake fluid absorbs moisture from the atmosphere. The dry boiling point of brake fluid, when new, is 401°F (205°C). The boiling point of brake fluid that has absorbed moisture from the atmosphere is 284°F (140°C). If the brake fluid boils, compressible gas bubbles form, resulting in a longer pedal travel and potentially reducing braking effect. This is one of the causes of brake pedal fade.

CAUTION: *Do not use fluid from unsealed containers, as it might have absorbed moisture from the atmosphere. The correct specification of brake fluid must be used. Incorrect brake fluid can damage the seals within the hydraulic system and lead to brake failure.*

CAUTION: *Do not use synthetic brake fluid.*

NOTE: *Brake fluid must be replaced every 24 months.*

Operation

Normal Braking

Pressing the brake pedal applies pressure to the brake fluid in the system. The fluid transmits the pressure unhindered through the normally open inlet valves to operate the caliper pistons. When the brake pedal is released, the springs in the master cylinder return the master cylinder pistons to the rest position. Brake system pressure is relieved, the caliper pistons retract, and the brake pads no longer apply a braking force to the rotors.

ABS Braking Hydraulic Operating Principle

The ABS system is on standby whenever the vehicle is switched on. Self-monitoring for faults is continuous. If the ABS ECU detects a fault, it displays the instrument cluster indicator light and stores a Diagnostic Trouble Code (DTC).

During an ABS braking event, the ECU operates the inlet and outlet valves of the related brake and runs the pump motor. The inlet valve (normally open) closes to prevent further pressure increase at a targeted caliper. The outlet valve (normally closed) opens to reduce pressure from the targeted brake and allow the wheel to recover traction. When opened, the outlet valve allows brake fluid to return toward the hydraulic pump via an accumulator (one per brake circuit), and finally back to the master cylinder. The pump motor is operated to draw brake fluid from the accumulators and return it to the master cylinder. The pump motor must overpower the driver's foot and force fluid back up against the brake pedal during a pressure reduction. This causes the pedal pulsation felt during ABS activation. If the brake pedal is at rest, the system is open to atmospheric pressure. In this way, the wheel braking hydraulic pressure is modulated during an ABS event such that the wheel maintains the maximum braking effort for the traction available to that wheel, without locking the wheel.

NOTE: *During normal braking, the feel of the brake pedal on vehicles equipped with ABS is the same as that on non-ABS vehicles. During anti-lock braking operation, the driver experiences feedback in the form of a pulsating brake pedal and solenoid/pump motor noise from the ESP modulator. This is normal ABS operation, and the driver does not need to react any differently. It is not possible to damage the brake system or hinder stopping performance by pressing the brake pedal "too hard" during an ABS event.*

ESC Functional Principle

ESC operates similar to ABS with some additional features. For traction or stability control events, it must be possible to generate brake pressure without the driver depressing the brake pedal. To do this, the ESC pump motor is used both to draw fluid away from the brake caliper during ABS, and also to send fluid to a caliper to build brake pressure for traction and stability control events. An ESC hydraulic unit uses four extra valves and at least one pressure sensor, among other subtle hydraulic and electronic changes. A CAN interface to the drive inverter manages drive torque for both traction and stability control functions, and also for integration with other advanced driver assistance systems, such as cruise control.

System Failure

If the ABS system fails, normal braking is maintained. However, braking distances may increase and wheels may lock under heavy braking. The red brake and/or yellow ABS failure indicator lights display in the instrument cluster.