Product Manual

ABS 6 Standard
Anti-lock Braking System

- Basic Principles of Operation of the System
- Component Descriptions
- Troubleshooting and Fault-Finding
- Service Guidance to ensure Safe and Efficient Operation

KNORR-BREMSE
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This disclaimer is an English translation of a German text, which should be referred to for all legal purposes.
Before working on or around air braking systems and devices, the following precautions should be observed:

- Stop the engine before working under a vehicle.

- Always chock the wheels because depleting vehicle air system pressure may cause the vehicle to roll. Keep hands away from actuator push rods and slack adjusters / brake levers; they may apply as system pressure drops.

- Examine all pipework for signs of kinks, dents, abrasion, drying out or overheating.

- Check the attachment of all pipework; it should be supported so that it cannot abrade or be subjected to excessive heat.

- Never connect or disconnect a hose or line containing air pressure, it may whip as air escapes. Never remove a device or pipe plug unless you are sure that all system pressure has been depleted.

- Never exceed recommended values of maximum air pressure and always wear safety glasses when working with air pressure systems. Never look into air jets or direct them at anyone.

- Never attempt to dismantle a device until you have read and understood recommended procedures. Some units contain powerful springs and injury can result if not properly dismantled. Use only correct tools and observe all precautions relative to the use of these tools.
1. General Information

1.1 Service Intervals

3 years or 300,000 km – check the functionality of the system using specialist Knorr-Bremse test equipment. In the case of failure, the defective part is to be replaced – the servicing of a defective part is not permitted. There are no serviceable ABS components in the system.

Note:
The electrical functionality of the ABS components – Electronic Control Unit, modulators, sensors and cabling – is checked automatically by in-built self diagnostic software and the driver is warned of any malfunction or failure.

Additional checks:

In addition to the above and legally required periodic vehicle inspection, it is recommended that simple routine inspections of a general nature be carried out to maintain the braking system at a high level of functionality.

These simple routine inspections should be:

1) On a monthly basis remove any moisture in the reservoirs, using the reservoir drain valves. If the amount of moisture is excessive check the operation of the air dryer or other moisture extraction devices

2) On a 6-monthly / 50,000 km basis check the complete braking system for excessive leakage during a maximum pressure foot brake application with the vehicle stationary and the parking brake released.
1. General Information

1.2 Principles of Anti-lock Braking System (ABS) Operation

1.2.1 Introduction

An Anti-lock Braking System (ABS) is used to prevent the wheels of a vehicle locking whilst braking.

It is well known that a wheel operating on wet ice has very little friction (adhesion) and hence can transmit little braking or traction effort to the ice. On dry asphalt there is much more friction (adhesion) available and optimum braking and traction can be achieved. The friction (μ) between the tyre and the road is created by relative movement between their two surfaces, i.e. difference in surface speeds, and this is called ‘slip’ (λ), which is normally expressed as a percentage:

- 0% slip means that the surface speed of the tyre and the road are equal.
- 100% slip when braking means that the wheel has stopped rotating, i.e. the surface speed of the tyre is zero, but the vehicle is still in motion (maximum difference in surface speeds – full lock).

Small percentages of slip are required to create the maximum available friction between the tyre and the road, but should the slip become excessive (generally >20%) the wheel is considered to be locked under braking (or spinning under acceleration). The level of friction present is dependent on many factors, the most significant of which are the condition of the tyre and the road surface and the percentage of ‘slip’ between the tyre and the road. Fig. 1 shows some typical curves for the level of friction present on different road surfaces with different levels of slip. Most of the curves show that the level of friction drops only slightly as the wheel starts to lock and in these cases, once the wheel has locked, it will continue to transmit a high percentage of the maximum braking effort available. However, in the case of wet asphalt, once the wheel starts to lock, the friction drops significantly and the wheel will rapidly move into a “full lock” situation. This is because the wheel is able to transmit less braking effort causing increased slip, which in turn reduces the level of friction and braking.

![Fig. 1](image-url)
1. General Information

Once a wheel has started to lock then it can no longer transmit the necessary torque for the desired braking and it is also unable to transmit effective lateral forces for steering or cornering, i.e. the wheel ‘slides’. Fig. 2 shows how the friction available for cornering falls dramatically when the wheel starts to lock due to braking. The inability of a wheel on a steering axle to transmit lateral (cornering) force means that the vehicle will no longer be under the full directional control of the driver.

It is therefore important that wheels are prevented, whenever possible, from locking under braking conditions so that the directional stability of the vehicle is maintained.

ABS will prevent locking of the wheels on all road surfaces and provide the driver with the directional control that he needs. In most cases, by preventing wheel lock, ABS also results in a reduced stopping distance for the vehicle.

ABS is an addition to a basic service braking system used on a commercial vehicle or bus and involves the installation of an Electronic Control Unit (ECU), pressure modulator valves, sensing rings, wheel speed sensors and associated electrical wiring (see Fig. 3).

![Fig. 2](image-url)
1.2.2 Operation

ABS constantly monitors the rotational speed of all wheels and compares the speed of each wheel to an average of all wheel speeds (Reference Speed) calculated by the Electronic Control Unit (ECU). By doing this the system can detect when one or more wheels slow down excessively. A sensing ring and wheel speed sensor are installed at each wheel and, when the wheel rotates, they react together to send a sinusoidal electrical signal to the ECU. By analysing the frequency of this signal the ECU can monitor the rotational speed of each wheel and calculate its acceleration or deceleration.

When braking takes place, at any moment in time the ECU can determine if the rotational speed of any wheel varies from the Reference Speed. If one wheel is on a slippery surface and is unable to support the level of braking that it is being asked to contribute then the wheel speed will drop in relation to the Reference Speed, i.e. the ‘slip’ and deceleration of that wheel will start to increase. The ECU will normally detect this during the application of the brake and before the wheel becomes locked. As soon as this deviation of wheel speed is detected the ECU will no longer include that wheel in its Reference Speed calculation.

Once the ECU detects excessive slip or a rapid change in deceleration on a wheel (see Fig. 4) it sends an electrical signal to the appropriate pressure modulator valve to release the pressure in the service brake actuator on that wheel (see also Section 2.6).
If an ABS equipped vehicle is fitted with an “Endurance Braking Device”, for example an Engine Exhaust Brake or Drive Line Retarder, when the ECU signals the pressure modulator valve to intervene in the control of the brake application it also sends a signal to switch off the endurance braking device until braking returns to normal. The signal to endurance braking device can be from a relay inside the ECU or via a CAN data link conforming to SAE J1939.
When the pressure modulator valve has exhausted sufficient air pressure from the service brake actuator, the adhesion between the tyre and the road will cause the rotational speed of the wheel to increase. The ECU detects this increase in wheel speed and sends an electrical signal to the pressure modulator valve to stop exhausting the air pressure (see Fig. 5).

As the rotational speed of this wheel continues to increase, the ECU will send an electrical signal to the appropriate pressure modulator valve to re-apply the service brake on that wheel. The pressure will be increased in the service brake actuator in steps by pulsing the pressure modulator valve solenoids. At the end of each stepped increase in pressure the ECU will check to ensure that the rotation speed of the wheel is increasing towards the speed of the other wheels and if it is the ECU will signal a further stepped increase in pressure (see Fig. 6). Once the speed of the wheel approaches that of the other wheels the ECU will again include its input into the Reference Speed calculation.
1. General Information

These stepped increases will continue until the pressure in the service brake actuator reaches the level set by the foot valve. If at any time the ECU detects that the slip of the wheel is increasing again and there is a rapid change in deceleration it will signal the pressure modulator valve to exhaust again the pressure in the service brake actuator. This cycle of exhausting the brake pressure and then re-applying it in small steps (see Fig. 7) will be repeated many times every second in order to obtain the maximum amount of braking available from the wheel and to maintain the directional stability of the vehicle.

After several exhaust and re-application cycles of the brake the ECU can predict the point at which the speed of the wheel will start to increase and so is able to lessen the degree of release of the brake. With this smaller release of pressure the re-application steps will be of smaller increments giving the ABS improved control over the braking of the wheel thereby contributing to a shorter stopping distance.

The control cycle described above relates to one wheel, but it is quite probable that more than one wheel on a vehicle may show a tendency to lock during a service brake application. If this is the case then the ECU will control all wheels showing a tendency to lock in a similar manner with some limitations.

When the vehicle is being driven on a road surface having different levels of adhesion between the left and right side then it is likely that the wheel on the surface with the lower level of adhesion will show a tendency to lock resulting in an ABS intervention on that wheel. If the wheel with no tendency to lock (on the surface with higher level of adhesion) is left to provide a normal service brake application on that wheel then a situation will exist across the axle with one wheel being fully braked and the other wheel having little or no braking, due to its tendency to lock. This difference in braking across the axle can induce a yaw or turning moment on the vehicle which, if on the steering axle of the vehicle, would make it difficult to control. For this reason the ‘Individual Regulation’ (IR) method of control in the ABS 6 system is applied only to the drive axle of the vehicle.

In order to minimise the above ‘yaw’ effect on the steering axle of the vehicle, the ABS 6 system uses ‘Modified Individual Regulation’ (MIR) on the steering axle. With MIR, when one wheel shows a tendency to lock and the ABS intervenes to restrict
or reduce the pressure in the brake actuator on that wheel, it also limits the pressure in the brake actuator on the other wheel. This limitation is managed by the ECU to ensure the imbalance in braking across the axle is within limits that allow the driver to retain “steerability” of the vehicle and he is not subjected to “snatching” of the steering wheel. Under these circumstances the theoretical maximum amount of braking that could be available is not achieved on that axle and the stopping distance will be marginally longer than if the axle were controlled using IR. However, the ability of the driver to retain directional control of the vehicle is preferable in most circumstances to a marginally shorter stopping distance.

The control processes described above are performed by the ABS so long as valid signals are being sent from the wheel speed sensors to the ECU. The ECU requires a minimum peak voltage before it recognises the signal from the wheel speed sensor as valid and thereafter it uses the frequency of the signal to monitor the rotational speed of the wheel. The speed at which the signals from the wheel speed sensors become valid is dependent on the gap between the wheel speed sensor and the sensing ring, but is normally in the range of 5 to 8 km/h. This is known as the ‘lock out speed’ and below this speed the ECU becomes inactive and there is no ABS function.

The system described above relates to a 2-axle, towing or non-towing, vehicle with a 4 x 2 configuration (i.e. 2 driven wheels) equipped with a wheel speed sensor on each of the 4 wheels and a pressure modulator valve controlling the service brake actuator on each of the 4 wheels. Such a system is designated 4S/4M, i.e. 4 sensors/4 modulators. A 4S/4M system can be used to provide the ABS function on a 3 axle, towing or non-towing, vehicle by combining the control of the actuators on the left and right side of the rear bogie (see Fig. 8).
1.3 General Advice when working with ABS

In order for ABS to work effectively the system must be maintained in such a condition that the electrical cabling has minimal electrical resistance and the pneumatic piping presents minimal restriction to the flow of air in the service brake system. If these two criteria are met then the ECU will receive and send clean, accurate electrical signals and the pressure modulator valves will be able to control the pressure in the service brake actuators rapidly and accurately.

1.3.1 Dos and Don’ts for Drivers / Operators:

- Never switch off the ignition while driving as this will also switch off the ABS.
- Do not assume that with ABS fitted to a vehicle it is safe to drive faster or more aggressively. ABS may not shorten stopping distances in all situations.
- If the ABS warning lamp comes on and stays on, the system must be checked as soon as possible (normal braking will still be available but without the ABS function).
- Do not attempt to “pump” the brakes during a wheel lock situation. The ABS can apply and release the required brakes much quicker than a driver. In addition, any “pumping” could upset the operation of the ABS.
- The efficient operation of the ABS relies upon the tyres obtaining the maximum adhesion possible with the road surface and so their condition is important. Replace any worn or damaged tyres at the earliest opportunity.
- Fit the same diameter tyres to all wheels, conforming to the vehicle manufacturer’s recommendations.
- Ensure that the tyres are correctly inflated at all times. A tyre running with low pressure will have a reduced rolling radius and conversely a tyre with high pressure will have an increased rolling radius. If one tyre has a rolling radius different to the other tyres then its rotational speed will differ and, if this difference is outside predetermined limits, the ECU will indicate a fault and turn off the ABS function.
- The efficient operation of the ABS relies upon the efficient operation of the braking system. Ensure that clearance adjustment is made for any worn brake linings so that the stroke of the service brake actuators is at the optimum level. Ensure that the brakes are maintained to eliminate “brake squeal” as its presence can distort the electrical signals from the wheel speed sensor and prevent operation of the ABS.
- The efficient operation of the ABS relies on reliable wheel speed information being supplied by the wheel speed sensors in conjunction with the sensing rings. These rely on correct maintenance of the wheel bearings to ensure that the run-out of the sensing ring is within acceptable limits. Always ensure that the wheel run-out is within the manufacturer’s specification.
- When installing ancillary electrical equipment on the vehicle do not use the electrical supply to the ABS as a power source for the equipment.
1.3.2 Dos and Don’ts for ABS electrical components and cabling

- Before commencing work on a vehicle, always chock the wheels to prevent the vehicle rolling when the brakes are released.

- Do not connect or disconnect any ABS component with the ignition switched on.

- When carrying out any welding on the vehicle always ensure that all electrical connections to the ECU are removed temporarily (see Fig. 9). Voltage spikes caused by the welding equipment could otherwise possibly damage the ECU. Never use any electrical equipment as the earth for the welding equipment.

- If the ECU is connected, never run the engine and alternator without a well-connected battery in the circuit. Voltage spikes caused by the alternator could possibly damage the ECU if they were not absorbed by the battery.

- If a vehicle fitted with ABS has a flat battery, it can be recharged with an external charger or battery at the same rated voltage. Do not attempt to start a vehicle using a “booster start” device since this could supply excessive voltage.

- When installing ancillary electrical equipment on the vehicle do not use the electrical supply to the ABS as a power source for the equipment.

- If any ancillary equipment is installed on the vehicle ensure that any wiring and antennae are not routed near to the ABS ECU or ABS cabling.

- If any modifications are made to the vehicle that require an increase in the length of the cables between the ECU and the wheel speed sensors then new purpose-made extension cables from the system manufacturer must be used, either in addition to or in place of those already fitted. These must be the correct length to suit the installation since looping of excess cable may induce radio frequency interference and ABS malfunction.
Any new ABS cables must be routed so that:

- They are protected from damage due to stones thrown up from the road.
- They are not prone to being snagged and ripped off.
- They are not subject to any mechanical strain or tension under any condition of suspension travel or steering movement.

If the insulation of any cable becomes damaged then the cable must be replaced. Under no circumstances must any cable be cut and rejoined (see Fig. 10).

When removing and refitting electrical connectors take great care to ensure the correct alignment of the plug and socket. There are normally location spigots and grooves in the mating parts to ensure correct alignment and therefore correct electrical connections. Do not attempt to force any plug into a socket – this could result in physical damage to the connection pins and malfunction of the system.

When refitting electrical connectors always ensure that they are pushed home fully to give the maximum protection from moisture and contamination.

When removing a wheel speed sensor do not pull on its cable.

When replacing a wheel speed sensor ensure that there are no sharp bends in the cable close to the sensor head. If using cable ties to secure the cable, these must not be pulled too tight as this can cause physical damage to the cable and possible short circuits. When replacing a wheel speed sensor always fit a new sensor bush and use the correct lubricant between the sensor and the bush. The sensor should slide in the bush using only manual pressure.

When refitting any electrical cabling that is protected by corrugated tubing ensure that the tubing is guided such that any water entering it will drain away from any electrical connector.

Should heavy corrosion be found on the pins of an electrical connector the cable assembly should be replaced. When fitting the replacement cable assembly, ensure that the weatherproofing of the connector plug and socket combination has not been reduced by any physical damage to either.
Before refitting any plug and socket, check that the mating electrical connections are not damaged, misaligned or elongated (see Fig. 11) and have no contamination present which might cause a short circuit.

When testing a pressure modulator valve, if an external voltage is applied to the solenoids this should not exceed 17 Volts for a valve rated at 12 Volts or 33.5 Volts for a valve rated at 24 Volts. The applied voltage should not be left in place for more than a few seconds. Prolonged application of an external supply will result in overheating and damage to the insulation of the solenoid.

On the completion of any work on the ABS ensure that the complete braking system is tested before the vehicle is used on the public highway.

1.3.3 Dos and Don’ts for ABS pneumatic components and pipework

- Before commencing work on a vehicle, always chock the wheels to prevent the vehicle rolling when the brakes are released.
- Never connect or disconnect a hose or line containing air pressure, it may whip as air escapes. Never remove a device or pipe plug unless you are sure that all system pressure has been depleted.
- If any modifications are made to the vehicle that require any increase in the length of the pipework between the pressure modulator valves and the service brake actuators then any increase must be kept to a minimum. Any additional piping must have an internal diameter of at least 10 mm. 90° elbow fittings must not be used. There must be no kinks in the pipework and the piping must have a smooth flow under all conditions of suspension travel and steering movement.
- When screwing a fitting or brake hose into a valve, ensure that the threads are clean and undamaged and do not exceed the recommended tightening torque (see Section 2.7 on Voss fittings).
- On the completion of any work on the ABS ensure that the complete brake system is tested before the vehicle is used on the public highway.
1. General Information

1.4 Troubleshooting and Fault-finding

1.4.1 Normal Operation

If the system is working normally and there are no faults then, when the ignition is switched on, the ABS warning lamp on the dashboard will illuminate and then go out. It will not illuminate again while the ignition remains switched on unless there is a problem with the system.

1.4.2 Start-up Check

The Electronic Control Unit (ECU) used in the ABS 6 system contains two interconnected microprocessors. Each microprocessor checks the function of the other and in the event of a malfunction the faulty microprocessor will be shut down with the remaining microprocessor continuing to provide the ABS function. The ECU also has the ability to check the operation of the other components in the system and the integrity of the system cabling. When the ABS 6 system is first switched on the ABS warning lamp is switched on for 2 seconds by the ECU while it carries out a ‘static’ check of the system components and cabling. This start-up check also shows that the ABS warning lamp is operating correctly. If the ABS warning lamp does not illuminate when the system is first switched on, the bulb and the electrical supply to the ECU should be checked.

1.4.3 Fault Detection

Once the static check is complete, providing no fault was found, the ABS warning lamp is switched off. Should the ECU detect any malfunction or problem during the static check then it will leave the ABS warning lamp switched on and shut down, either partially or completely, the operation of the ABS. If the ECU had detected a fault with any wheel speed sensor when it was last powered up, then the ECU will leave the ABS warning lamp switched on until the vehicle is driven and the ECU can detect acceptable signals from all wheel speed sensors. When acceptable signals are detected the ECU will switch off the ABS warning lamp.

The ECU continuously monitors the condition of the ABS components while the vehicle is in use. If the ECU detects any malfunction or problem (either with the brakes released or applied) it will switch on the ABS warning lamp and shut down, either partially or completely, the operation of the ABS.

Once the ABS warning lamp has been switched on to signify that a fault exists in the system the nature and location of the fault must be identified as soon as possible by one of two methods:

- Use of the Blink Codes
- Use of PC Diagnostics

The vehicle should be driven to the nearest service centre for correction of the fault.

1.4.4 Using Blink Codes

The ABS warning Lamp is used not only to display the fact that a fault exists but also to display blink codes.

The blink code function within the ECU can be used to display two types of blink code:

- Configuration Blink Codes showing the system configuration of the ECU programming.
- Fault Blink Codes giving information on faults detected and stored by the ECU.

Blink codes are triggered by operating the blink code switch, which is located in the vehicle’s electrical compartment and the codes will be displayed by short periods of illumination (“blinks”) of the ABS warning lamp on the dashboard. The number of ‘blinks’ is counted and the blink code can be interpreted from tables below. The blink code switch is used in the following manner:
In the following descriptions the operation of the blink code switch and the illumination of the ABS warning lamp are shown diagrammatically.

**Operation of the Blink Code Switch**

The condition of the blink code switch is represented by a step in a graph with time as its base (see Fig. 12).

The blink code displayed by the ABS warning lamp is represented in two ways. Firstly, with a pair of symbols, one representing the lamp ‘off’ and the other representing the lamp ‘on’ (illuminated) and secondly by a step in a graph with time as its base (see Fig. 13).

**Note:**

The ABS warning lamp will illuminate to show that the blink code switch is pressed.

---

**1.4.5 Configuration Blink Codes**

- With the ECU powered (ignition switched on) wait at least 1 second, then press the blink code switch twice in quick succession and release. The transmission of the configuration blink code is triggered.
- The blink code will be displayed as short illuminations (blinks) of the ABS warning lamp.
- The blink code is divided into two blocks, each block comprising two numbers. For each number the series of ‘blinks’ will be approximately half a second long with half a second pause between them.
- Count the first series of blinks to establish the 1st Number and, after a pause of approximately 1.5 seconds, a second series of blinks should be counted to give the 2nd Number of the first block (see Fig. 14).
- After another pause of approximately 4 seconds a third series of blinks should be counted to give the 1st Number of the second block. There will then be a pause of approximately 1.5 seconds after which a fourth series of blinks should be counted to give the 2nd Number of the second block (see Fig. 14).
- Using the chart on the following page the configuration of the ECU can be established.
- The transmission of the configuration code can be terminated at any time by pressing the blink code switch again.
Configuration Sequence

![Configuration Sequence Diagram](image)

**Fig. 14**

Configuration Blink Codes

<table>
<thead>
<tr>
<th>Block</th>
<th>Number</th>
<th>Blinks</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st</td>
<td>1</td>
<td>12 Volt</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>24 Volt</td>
</tr>
<tr>
<td>2</td>
<td>2nd</td>
<td>2</td>
<td>4S/4M</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td>Invalid config.</td>
</tr>
<tr>
<td>2</td>
<td>1st</td>
<td>1</td>
<td>J1939 CAN link and endurance braking system (exhaust brake / retarder) relay not fitted.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>J1939 CAN link fitted, endurance braking system (exhaust brake / retarder) relay not fitted.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>J1939 CAN link not fitted, endurance braking system (exhaust brake / retarder) relay fitted.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>J1939 CAN link and endurance braking system (exhaust brake / retarder) relay fitted.</td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>2</td>
<td>Traction Control not installed</td>
</tr>
</tbody>
</table>

**Note:**

With the ABS 6 Standard system there are no extra features and so only the above configuration blink codes should be displayed. If any other codes are displayed and the correct ECU is fitted to the vehicle then contact your nearest service centre as soon as possible.
1.4.6 Fault Blink Codes

- With the ECU powered (‘ignition on’), wait at least 1 second then press the blink code switch once and release. The transmission of the fault blink code is triggered.
- The blink code will be displayed as short illuminations (blinks) of the ABS warning lamp.
- The blink code for a fault is split into two series of ‘blinks’ - the first series of blinks (approximately 0.5 seconds each) should be counted to give a “1st Number” and, after a pause of approximately 1.5 seconds, a second series of blinks (approximately 0.5 seconds each) should be counted to give a “2nd Number” (see Fig. 15). Using the charts on the following pages, it is possible to identify the component and its fault. If there is more than one fault, the next blink code will start approximately 4 seconds later.
- The ABS ECU is able to store specific codes for every fault detected. The memory can store a maximum of 16 faults.
- Fault codes for failures that are most recently detected are displayed first and oldest detected faults are displayed last.
- The blink code sequence, i.e. one blink code per fault, can be repeated by pressing the blink code switch again at the end of the sequence. Note that pressing the blink code switch during the sequence will terminate the transmission of the blink codes.
- During output of the blink codes, normal operation of the ECU is disabled (i.e. no ABS function).

Fault code sequence

Fig. 15
# Fault Blink Codes

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No fault found</strong></td>
<td></td>
<td>No faults recorded by the ECU.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Air gap too big (see Section 2.4 for guidance).</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Missing speed sensor signal at drive off, (see Section 2.4 for guidance).</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Damaged/contaminated tooth on sensing ring, erratic signal from speed sensor, check sensing ring alignment and wheel bearing adjustment (see Sections 2.3 and 2.4 for guidance).</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Unstable signal from speed sensor, check sensing ring alignment and wheel bearing adjustment, check wiring for possible source of interference (see Sections 2.3 and 2.4 for guidance).</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Loss of speed sensor signal (see Section 2.4 for guidance).</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>Sensor wires shorted or broken (see Section 2.4 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
</tbody>
</table>

**Wheel speed sensor, front axle, left side**

| 3 | 1 | Air gap too big (see Section 2.4 for guidance). |
| 3 | 2 | Missing speed sensor signal at drive off, (see Section 2.4 for guidance). |
| 3 | 3 | Damaged/contaminated tooth on sensing ring, erratic signal from speed sensor, check Sensing ring alignment and wheel bearing adjustment (see Sections 2.3 and 2.4 for guidance). |
| 3 | 4 | Unstable signal from speed sensor, check Sensing ring alignment and wheel bearing adjustment, check wiring for possible source of interference (see Sections 2.3 and 2.4 for guidance). |
| 3 | 5 | Loss of speed sensor signal, (see Section 2.4 for guidance). |
| 3 | 6 | Sensor wires shorted or broken, (see Section 2.4 for guidance and Section 3 for X2 Plug layout). |

**Wheel speed sensor, front axle, right side**

<p>| 4 | 1 | Air gap too big (see Section 2.4 for guidance). |
| 4 | 2 | Missing speed sensor signal at drive off, (see Section 2.4 for guidance). |
| 4 | 3 | Damaged/contaminated tooth on Sensing Ring, erratic signal from speed sensor, check Sensing Ring alignment and wheel bearing adjustment (see Sections 2.3 and 2.4 for guidance). |
| 4 | 4 | Unstable signal from speed sensor, check Sensing Ring alignment and wheel bearing adjustment, check wiring for possible source of interference (see Sections 2.3 and 2.4 for guidance). |
| 4 | 5 | Loss of speed sensor signal (see Section 2.4 for guidance). |</p>
<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>Sensor wires shorted or broken (see Section 2.4 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
</tbody>
</table>

**Wheel speed sensor, rear axle, right side**

| 5          | 1          | Air gap too big (see Section 2.4 for guidance). |
| 5          | 2          | Missing speed sensor signal at drive off, (see Section 2.4 for guidance). |
| 5          | 3          | Damaged/contaminated tooth on sensing ring, erratic signal from speed sensor, check sensing ring alignment and wheel bearing adjustment (see Sections 2.3 and 2.4 for guidance). |
| 5          | 4          | Unstable signal from speed sensor, check sensing ring alignment and wheel bearing adjustment, check wiring for possible source of interference (see Sections 2.3 and 2.4 for guidance). |
| 5          | 5          | Loss of speed sensor signal (see Section 2.4 for guidance). |
| 5          | 6          | Sensor wires shorted or broken (see Section 2.4 for guidance and Section 3 for X1 Plug layout). |

**Pressure modulator valve, front axle, left side**

| 8          | 1          | Release solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 2          | Release solenoid - shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 3          | Release solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 4          | Valve ground wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 5          | Hold solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 6          | Hold solenoid – shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 7          | Hold solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 8          | 8          | System configuration error, check valve and system wiring and check ECU configuration (see Section 1.4.5). |

**Pressure modulator valve, front axle, right side**

| 9          | 1          | Release solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 9          | 2          | Release solenoid - shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 9          | 3          | Release solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
| 9          | 4          | Valve ground wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout). |
## 1. General Information

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure modulator valve, front axle, right side (continued)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>Hold solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>Hold solenoid – shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>Hold solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>System configuration error, check valve and system wiring and check ECU configuration (see Section 1.4.5).</td>
</tr>
<tr>
<td><strong>Pressure modulator valve, rear axle, left side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Release solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>Release solenoid - shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>Release solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Valve ground wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>Hold solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>Hold solenoid – shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>Hold solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>System configuration error, check valve and system wiring and check ECU configuration (see Section 1.4.5).</td>
</tr>
<tr>
<td><strong>Pressure modulator valve, valve common ground</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Shorted to battery, remove X2 Plug from ECU and check for voltage on valve ground connections, replace wiring if necessary (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Shorted to ground not through ECU or internal valve defect, remove X2 Plug and check resistance between valve ground connections and chassis ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td><strong>Pressure modulator valve, rear axle, right side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>Release solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>Release solenoid - shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>Release Solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>1st Number</td>
<td>2nd Number</td>
<td>Fault Description</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Pressure modulator valve, rear axle, right side (continued)</strong></td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>Valve ground wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>Hold solenoid – shorted to battery (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>Hold Solenoid – shorted to ground (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>Hold Solenoid wire broken (see Section 2.6 for guidance and Section 3 for X2 Plug layout).</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>System configuration error, check valve and system wiring and check ECU configuration (see Section 1.4.5).</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>ECU internal failures</strong></td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>Internal microprocessor fault, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>Internal microprocessor fault, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>ECU data error, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>ECU not programmable, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td>Internal microprocessor fault, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>Internal microprocessor fault, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>Internal microprocessor fault, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>Invalid configuration in ECU, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>Internal relay not switching, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>Internal relay permanently switched on, erase fault memory (see Section 1.4.7), if this fault code is still present then replace the ECU</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>ABS software not compatible with hardware, check system installation and ECU configuration</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Power supply</strong></td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>Battery supply – temporary over voltage, check alternator/voltage regulator</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>Battery supply – temporary low voltage/low voltage during ABS control, check condition of battery and terminals</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td>Battery supply – broken wire</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>Supply voltage – power line noise/temporary power line noise</td>
</tr>
</tbody>
</table>
## 1. General Information

### Power Supply (continued)

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>9</td>
<td>Ignition supply – temporary over voltage, check alternator/voltage regulator</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>Ignition supply – temporary low voltage, check condition of battery and terminals</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
<td>Ignition supply – low voltage during ABS control, check for corrosion on battery terminals.</td>
</tr>
</tbody>
</table>

### Endurance Braking Device (Engine Exhaust Brake or Drive Line Retarder)

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>1</td>
<td>Relay controlling endurance braking device shorted to battery, check wiring to endurance braking device.</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>Relay controlling endurance braking device shorted to ground or broken wire, check wiring to endurance braking device.</td>
</tr>
</tbody>
</table>

### Tyre size alignment

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>5</td>
<td>Front to rear out of range, check that correct tyre sizes are fitted and that tyre pressures are correct.</td>
</tr>
</tbody>
</table>

### Warning lamp

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>10</td>
<td>Warning lamp ground shorted to battery or broken wire, or warning lamp supply shorted to ground or broken wire, check warning lamp wiring (see Section 3 for X1 Plug layout).</td>
</tr>
</tbody>
</table>

### Wheel Speed Sensors

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>12</td>
<td>Wheel speed sensor failure in previous ‘power on’ cycle (will be displayed only after a wheel speed sensor fault has been cleared from the ECU memory). Drive vehicle to 20 km/hr, if ABS warning lamp goes off then problem is fixed, if lamp stays on then stop vehicle and check the fault blink codes again.</td>
</tr>
<tr>
<td>17</td>
<td>13</td>
<td>Wheel speed sensors incorrectly wired (left to right) on front axle or rear axle, check wiring of X1 and X2 plugs (see Section 3 for X1 and X2 Plug layouts).</td>
</tr>
</tbody>
</table>

### J1939 CAN Data Link

<table>
<thead>
<tr>
<th>1st Number</th>
<th>2nd Number</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>3</td>
<td>CAN-Bus off, check CAN-Bus connections and terminating resistor.</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>Timeout or invalid data on ERC1, check CAN-Bus connections and the ECU which is generating the ERC1 message.</td>
</tr>
</tbody>
</table>
1.4.7 Erasing Fault Codes from the ECU memory

To erase all fault codes from the memory of the ECU:

- Press and hold the blink code switch.
- Switch on the ignition.
- After approximately 3 seconds release the blink code switch.

Notes

- The ABS warning lamp will illuminate when the blink code switch is pressed if the ignition is already switched on. In this case the ECU memory will not be erased.
- If any of the faults erased from the ECU memory were related to wheel speed sensors then the ABS warning lamp will illuminate on the next power up of the system and will stay illuminated until the vehicle is driven to a speed of approximately 20 km/hr. Once driven to this speed, providing the ECU detects good signals from the relevant wheel speed sensors, the ECU will switch off the ABS warning lamp (see Section 1.4.3).

1.4.8 PC Diagnostics

A computer based program ECUtalk® - ABS Diagnostics is available and provides several functions:

- Assists workshop diagnosis of ABS problems.
- Enables system check after servicing of the ABS system.
- Includes a database to enable storage and retrieval of information relating to customer, vehicle and test results.

- Knowledge base covering the function and servicing advice for ABS systems and their components, wiring diagrams and a software manual for the program.

Workshop Diagnostic Testing

This section of the program leads the operator through step-by-step testing of the ABS components, instructing him at each stage how to carry out checks and take measurements. At the end of the test a full report can be printed out from the program and the results can be stored in the database for subsequent retrieval.

End of Line (EOL) Testing

This section of the program provides a guided semi-automatic process for testing the ABS system and its components following any servicing of the system. At the end of the test a full report can be printed out from the program and the results can be stored in the database for subsequent retrieval.

Database Management

The database section of the program provides the facility to store records of the workshop’s customers, the customers’ vehicles and the results of any Workshop Diagnostic or EOL tests carried out on those vehicles.

The program has a user-friendly interface for the addition and maintenance of the records held within the database.

For more details on this program see Product Information Y032175-EN-000 “ABS Diagnostics” Diagnostics and Database Program for ABS 6 Standard.
2. System Components

2.1 Electronic Control Unit (ECU)

The Electronic Control Unit (ECU) should be found mounted in a protected environment (in the cab) as it is not weatherproofed and it also needs to be mounted where it will not be subjected to any electromagnetic radiation. The ECU should be supplied with power through a circuit breaker or fuse and the wiring to the ECU should be arranged so that there is no possibility of water running along the cables into the ECU.

The ECU used in the ABS 6 system contains two interconnected microprocessors. The ‘control’ microprocessor controls the ABS function of the system and the ‘monitoring’ microprocessor continuously checks the function of the ‘control’ microprocessor. If the ‘monitoring’ microprocessor detects a malfunction of the ‘control’ microprocessor, it will switch on the ABS warning lamp and shut down the ABS function of the system.

The ECU is the ‘brains’ of the ABS. It receives the input data from the wheel speed sensors, processes the information and during a service brake application it decides upon any action necessary. Having made such a decision the ECU will instruct the relevant pressure modulator valve to take the appropriate action and will then monitor the affect of this action and make any corrections necessary.

In addition to carrying out its functions during a brake application, the ECU monitors the condition of the system components initially when the system is first powered up and then continuously as long as the system is powered:

- When the system is first powered up the ECU switches on the ABS warning lamp on the vehicle dashboard to demonstrate that the bulb is functioning and the lamp stays on for approximately 2 seconds while the ECU carries out a “static” test of the system. During this static test the ECU sends test pulses to the wheel speed sensors and to each of the solenoids in the pressure modulator valves to check electrical continuity and to ensure that the solenoids energise and de-energise. If the ECU finds that the system passes this static test it will turn off the ABS warning lamp. If a problem is found, or if there was a fault recorded by the ECU when it was last switched off, the ECU will keep the ABS warning lamp switched on to indicate that there is a problem that needs attention. If a wheel speed sensor fault was present when the ECU was last switched off and it has since been corrected, the ABS warning lamp will remain switched on. The lamp will stay on until the vehicle is driven to a speed of approximately 20 km/hr and the ECU has established that there is an acceptable signal being received from that sensor. Once the presence of an acceptable signal has been established the ECU will switch off the lamp (see Section 1.4 “Troubleshooting and Fault-finding”).

- Following the static test, even when there is no brake application made, the ECU will continue to monitor the electrical continuity in all circuits of the ABS using test pulses as well as checking the quality of the signal from the wheel speed sensors. If a problem is detected then the ECU will shut down the ABS, either partially or totally, and switch on the ABS warning lamp to indicate that a fault has been found (see Section 1.4 “Troubleshooting and Fault-finding”).

Once a fault has been detected the ECU will store information on the nature of the fault, even when not powered, until the fault memory is erased (see Section 1.4 “Troubleshooting and Fault-finding”).

If a malfunction occurs in the ‘control’ microprocessor of the ECU then the ‘monitoring’ microprocessor will switch on the ABS warning lamp in the same way as other faults are indicated. ECUs are not serviceable and must be replaced if faulty.
2.2 ABS Warning Lamp

The ABS warning lamp is mounted in the vehicle dashboard and is used to signal the presence of a fault with any of the ABS components.

When the ABS is powered (ignition switched on) the ABS warning lamp should illuminate for 2 seconds while the ECU carries out a static test of the system and it should then go out. If the ABS warning lamp does not illuminate when the ignition is first switched on, the condition of the bulb should be checked immediately and it must be replaced if found to be faulty. If the bulb is found to be satisfactory then check the power supply to the ECU.

If the ABS warning lamp fails to go out, or if it has gone out after 2 seconds and then illuminates again, this is an indication of a malfunction of the system. This should be investigated as soon as possible (see Section 1.4 Troubleshooting and Fault-finding).
2.3 Sensing Ring

The sensing ring is a toothed ring rigidly mounted to the axle end so that it rotates with the wheel.

The sensing ring rotates relative to the wheel speed sensor, which in turn provides a sinusoidal electrical signal to the ECU. This signal can be used to measure the rotational speed of the wheel (see Section 2.4 “Wheel Speed Sensor”).

For the wheel speed sensor to provide a good signal to the ECU it is important that the teeth of the sensing ring are clean and in good condition. If the gaps between the teeth become filled with any magnetic material, such as wear debris from the brake itself, or if any of the teeth become chipped (see Fig. 16), then the ECU will recognise that the signal received from the wheel speed sensor is of poor quality (not true sinusoidal form). When this happens the ECU will indicate a malfunction by switching on the ABS warning lamp and it will shut down the ABS on the affected axle. If the gaps between the teeth have become filled then the debris should be removed carefully ensuring that the cleaning process does not damage the teeth. If the teeth of the ring become damaged or corroded then the sensing ring must be replaced.

For the wheel speed sensor to produce a consistent sinusoidal output it is essential that the sensing ring rotates parallel to the face of the sensor, therefore, maintaining the wheel bearing adjustment to the manufacturer’s specification is vital. In all cases the run-out of the sensing ring must not exceed 0.2 mm.

Following the correction of any fault associated with a sensing ring the ECU fault memory should be cleared (see Section 1.4.7).

![Fig. 16](image)
2.4 Wheel Speed Sensor

The wheel speed sensor is mounted, using a spring-loaded bush, in a housing on the axle in such a position that the end of the sensor is as close as possible to the teeth of the sensing ring. The wheel speed sensor contains an internal permanent magnet whose magnetic field extends a short distance beyond the end of the sensor case. A coil is wrapped around a soft iron core, which is attached to the magnet. This coil is connected to the output cable.

When a wheel rotates, the teeth of the sensing ring pass in turn through the magnetic field of the sensor magnet and disturb the field thereby creating an induced voltage in the sensor coil. This voltage is monitored by the ECU via the output cable. The voltage generated takes the form of a sine wave with both the voltage and frequency increasing as the rotational speed of the wheel increases (see Fig. 17). The ECU requires a minimum voltage before it recognises the signal from the wheel speed sensor and thereafter it uses the frequency of the signal to monitor the rotational speed of the wheel.

The voltage generated by the coil is dependent not only on the rotational speed of the wheel but also on the gap between the end of the wheel speed sensor and the teeth of the sensing ring: the larger the gap the lower the generated voltage. It is important, therefore, that the gap is kept as small as possible to ensure that sufficient voltage is generated to allow the ECU to recognise the signal.

Under normal conditions this gap should result in a generated voltage of >100 mV at 5 km/h (see Fig. 18).

Note:

If a rolling road is not available then a speed of approximately 5 km/h can be simulated by jacking up a wheel and rotating it by hand at a speed of 1 revolution every 2 seconds (0.5 rev/sec).

The quality of the sine wave generated by the wheel speed sensor is important and this can be degraded by damage to the teeth of the sensing ring. Damage, such as ‘chipped’ teeth can cause an unstable signal to be generated by the wheel speed sensor which will not be accepted by the ECU. Should this occur the ECU will switch on the ABS warning lamp and shut down the ABS function. Similarly, ‘brake squeal’ can cause an unstable signal from the wheel speed sensor with possibly the same result.
2. System Components

The spring-loaded sensor bush is used to hold the wheel speed sensor whilst allowing easy adjustment of the gap between it and the teeth of the sensing ring. The wheel speed sensor can slide in the sensor bush, so the gap between the wheel speed sensor and the teeth of the sensing ring can be set by manually pushing the sensor gently into contact with the teeth and then turning the wheel by hand. After pushing the wheel speed sensor into contact with the sensing ring, with the system not powered up (i.e. ignition is turned off), the wheel should be rotated by hand. Any run-out of the wheel bearings will cause the teeth of the sensing ring to push away the wheel speed sensor thereby setting the air gap between the two parts.

The wheel speed sensor and its extension cable can be checked as follows:

- Consult the wiring diagrams in Section 3 to establish which plug (X1 or X2) and which connectors are connected to the wheel speed sensor/sensor extension cable to be tested.

- Connect a multimeter (set to read AC voltage) to the appropriate contacts of the plug (see example in Fig.19).

- Rotate the relevant vehicle wheel at approximately 1 revolution every 2 seconds.

- If the gap between the wheel speed sensor and the sensing ring is set correctly, the multimeter should show a generated voltage of at least 0.1 Volts (100 mV) AC.

- The resistance of the sensor coil can also be checked while the multimeter is connected to the plug. The coil should have a resistance of 1750 +/- 175 Ohms.

- If a problem is found with either of these readings, disconnect the wheel speed sensor from the sensor extension cable and repeat the measurements having connected the multimeter to the connector on the sensor output cable (see Fig. 20). This will establish whether the problem lies with the sensor or the extension cable.

NOTE: the correct contacts for testing should be established from Section 3 Wiring Diagrams.
If a wheel speed sensor or sensor extension cable is found to be faulty then it must be replaced.

When removing a wheel speed sensor do not pull on its cable.

When replacing a wheel speed sensor the bore of the housing should be cleaned, a new sensor bush should also be fitted and the sensor should be greased with the special lubricant provided.

When fitting the sensor it should be pushed gently into contact with the teeth of the sensing ring and the vehicle wheel should be rotated by hand to set the correct gap. If the sensor does not slide in the bush under manual pressure then the housing should be inspected for damage. Do not attempt to adjust the gap by moving the sensing ring.

If cable ties are used to secure the output cable from the wheel speed sensor they should never be placed close to the sensor and they should never by tightened excessively as the insulation of the cable can become crushed and a short circuit could result.

Following the correction of any fault associated with a wheel speed sensor the ECU fault memory should be cleared (see Section 1.4.7).

If a wheel speed sensor fault has been corrected as a result of the ABS warning lamp illuminating then, after the ECU fault memory has been cleared, when the system is next powered up, the ABS warning lamp will again illuminate. It will stay illuminated until the vehicle is driven to a speed of approximately 20 km/h. Once driven to this speed, providing the ECU detects a good signal from the wheel speed sensor, the ECU will switch off the ABS warning lamp.

If a vehicle has been put back into service following correction of a fault caused by too large a gap between the wheel speed sensor and the sensing ring then, within a few days of operation, the same sensor fault re-occurs this is likely to be due to excessive run-out of the wheel bearing or incorrect fitting of the sensing ring. If the wheel bearing is faulty then it should be serviced and adjusted to within the vehicle manufacturer’s specification. In all cases the run-out of the sensing ring must not exceed 0.2 mm.
2.5 Sensor Extension Cable

The sensor extension cable is used to connect the wheel speed sensor to the ECU. The connector on the wheel speed sensor output cable is designed to join with the sensor extension cable and provide a weatherproof seal. It is therefore important that the connectors are inserted correctly and are fully engaged.

See Section 2.4 for details concerning the testing of the wheel speed sensor and extension cable.

If a sensor extension cable is replaced and it is secured with cable ties then they should never be tightened excessively as the insulation of the cable can become crushed and a short circuit could result.
2.6 Pressure Modulator Valve

The pressure modulator valve is rigidly mounted on the vehicle chassis as close as possible to the brake actuator that it controls. The valve is part of the service brake system, its inlet port (labelled ‘1’) is supplied with air pressure from the foot valve when the brake is applied and the delivery port (labelled ‘2’) supplies air pressure to the service brake actuator. Both ports are machined to take Voss System 230 push-in pipe fittings (see Section 2.7). The electrical cables connecting the pressure modulator valve should always be routed so that moisture does not run along the cables into the connector on the valve.

The valve is connected electrically to the ECU, enabling it to control the operation of the two internal solenoids ‘C’ and ‘D’ (normally de-energised). The valve has two internal non-return valves ‘A’ and ‘B’ held closed by light springs (see Fig. 21).
Description of the function of the pressure modulator valve under ABS operation is given below. Refer also to Section 1.2.2.

1) Under normal braking operation, when the driver makes a service brake application, air pressure flows from the foot valve into the inlet port ‘1’ of the pressure modulator valve. This air pressure pushes open the non-return valve ‘A’, and air flows through the body of the valve and through the open solenoid ‘D’ onto the spring side of non-return valve ‘B’ holding it closed. The air pressure also flows out of the delivery port ‘2’ to the service brake actuator (see Fig. 22). When the driver releases the service brake the air flows back from the service brake actuator through the pressure modulator valve and out of the open exhaust of the foot valve. If a relay valve or quick release valve is fitted between the foot valve and the pressure modulator valve the air will exhaust through one of these valves instead of flowing back to the foot valve. When the service brake operates under these circumstances the application and release are unaffected by the pressure modulator valve. If the pressure modulator valve delivery is connected to a large volume (service brake actuator of Type 30 or bigger) then, if the driver releases the foot valve rapidly, it is probable that the pressure on the spring side of non-return valve ‘B’ will drop sufficiently to allow the actuator pressure acting on the other side to open the non-return valve. Under these circumstances air pressure from the service brake actuator will be exhausted through the pressure modulator exhaust.

2) During an application of the service brake if the ECU detects from the wheel speed sensor signals that the slip of one of the wheels starts to increase and there is a rapid change in deceleration of that wheel, i.e. it is in danger of locking, then the ECU will energise the ‘Hold’ solenoid ‘C’ and ‘Release’ solenoid ‘D’. The energisation of solenoid ‘C’ allows air pressure to flow to the spring side of non-return valve ‘A’ forcing it to close. When this happens the service brake actuator becomes effectively disconnected from the foot valve and any further build up in pressure from the foot valve will not be transferred to the service brake actuator. The energisation of solenoid ‘D’ exhausts the pressure on the spring side of non-return valve ‘B’ and the pressure on the other side pushes the valve open and allows the air pressure in the actuator to reduce by escaping through the

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**Fig. 22**

**Pressure Modulator Valve - normal service brake application**
exhaust of the pressure modulator valve. (See Fig. 23). The action of reducing the pressure in the service brake actuator will generally prevent the wheel from locking.

3) Releasing the brake on the locked wheel allows whatever adhesion is available between the tyre and the road to rotate and speed up the wheel. When the ECU detects from the wheel speed signal that the wheel has regained some rotational speed then the ECU will prevent any further reduction in pressure by de-energising the solenoid ‘D’. This will re-apply pressure to the spring side of non-return valve ‘B’ forcing it to close, thereby closing the connection between the service brake actuator and the exhaust of

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**2. System Components**

**Pressure Modulator Valve**
- service brake application
- ‘Hold’ solenoid energised

![Fig. 23](image37)

**Pressure Modulator Valve**
- service brake application
- ‘Hold’ and ‘Release’ solenoids energised

![Fig. 24](image37)
the pressure modulator valve. Solenoid ‘C’ remains energised and non-return valve ‘A’ remains closed (see Fig. 24).

4) As the wheel speed continues to increase the ECU will start to reapply the brake. The ECU will momentarily de-energise ‘Hold’ solenoid ‘C’. This will exhaust the pressure on the spring side of non-return valve ‘A’ allowing it to open and increase the pressure inside the valve and in the service brake actuator (see Fig. 25).

The momentary de-energising of the ‘Hold’ solenoid ‘C’ will cause a small step increase in pressure in the service brake actuator. When ‘Hold’ solenoid ‘C’ is re-energised air pressure will again be applied to the spring side of non-return valve ‘A’ forcing it closed and preventing any further pressure being applied to the service brake actuator. The ECU will continue to monitor the signals from the wheel speed sensor to establish the affect of the stepped increase in pressure in the actuator. If the ECU detects that there is no tendency for the wheel to lock, then it will momentarily de-energise the ‘Hold’ solenoid ‘C’ again allowing another small stepped increase in pressure in the service brake actuator. The ECU will continue to monitor the signals from all wheel speed sensors to establish if the wheel that was locked is still speeding up and if this is so a further increase in pressure in the actuator will be permitted.

If at any time the ECU detects that the wheel is showing a tendency to lock again it will revert to step 2 above and repeat the processes above until the tendency for the wheel to lock is no longer present or the vehicle has stopped.

5) Providing that there is no tendency to lock, the ECU will continue to increase the pressure in the service brake actuator in small steps until the pressure reaches the level of the pressure delivered by the foot valve or the speed of the wheel that was locked reaches the same speed as the other wheels on the vehicle. If the wheel that was locked still has a lower level of adhesion than the other wheels then the level of braking sustainable by that wheel will be less than those with the higher level of adhesion. So the level of pressure applied by the ABS to the service brake actuator on the wheel with low adhesion will be lower than the pressure delivered by the foot valve, but
will provide the maximum level of sustainable retardation for that wheel and the vehicle whilst also providing vehicle stability.

The functionality of the solenoids in the pressure modulator valves is checked by the ECU when the ABS is first powered (ignition switched on). Test pulses are sent to each solenoid as part of the ECU’s static test to check that they energise and de-energise. This operation can be used as a simple test for checking the pressure modulator valves:

- Start with the foot valve applied, the brake system pressurised and the ignition turned off.
- Turn on the ignition to power the ABS and a short blast of air should be heard coming from the exhaust of each pressure modulator valve as the ECU sends a test pulse to each solenoid in turn as part of the static check.

If a problem is suspected with a pressure modulator valve then the resistance of the solenoid coils should be checked with a multimeter (see Fig. 26). The resistance of each coil relative to ground should be between 4.7 and 5.7 Ohms for a 12 Volt system and between 12 and 19 Ohms for a 24 Volt system. If the resistance of the coils is correct then check the wiring between the pressure modulator valve and the ECU.
If an external voltage is applied to a solenoid of a pressure modulator valve in order to check its function then this should not exceed 17 Volts for a valve rated at 12 Volts and 33.5 Volts for a valve rated at 24 Volts. The applied voltage should not be left in place for more than a few seconds. Prolonged application of an external supply to the solenoid will result in overheating and damage to the insulation of the solenoid.

During the operation of the ABS function it is vital that the pressure modulator valve is able to exhaust the air pressure in the service brake actuator as quickly as possible and so the unrestricted flow of air through the exhaust of the pressure modulator valve is essential. The exhaust flap of the pressure modulator valve should be checked at regular service intervals to ensure that it is not becoming blocked by the accumulation of contamination thrown up by road wheels. If the exhaust of the valve should become blocked, even partially, then when the service brake has been released there is a possibility of the blockage causing pressure to be retained in the valve body, which in turn could cause a small amount of air pressure to be retained in the service brake actuator. This retained pressure may, in some cases, be sufficient to cause the brakes to ‘drag’ (see Fig. 27). If this situation is found then the exhaust flap and exhaust passageway should be cleaned taking care that no contamination enters the valve.

If there is any problem with a pressure modulator valve, apart from blockage of the exhaust, then the valve must be replaced, as it is a non-serviceable item. When replacing a pressure modulator valve ensure that the pipe fittings are installed in accordance with the Section 2.7 on Voss fittings, paying particular attention to the tightening torques. There is no need to use thread sealant of any type on these fittings.

Following the correction of any fault associated with a pressure modulator valve the ECU fault memory should be cleared (see Section 1.4.7).
2.7 VOSS plug connection system 230 (assembly instructions)

The VOSS plug connection system 230 permits the rapid fitting of nylon tubes; only a spanner is needed to undo the connector. It consists of four components (see Fig. 28): plug with fir-tree (2), male fitting (4), retaining clip (8) and spring element (9). The plug has a wide holding groove, in which the retaining clip (8) engages on assembly. Two other grooves accommodate O-rings. The first O-ring (5) seals the connector against the air pressure. The second O-ring (3) prevents the ingress of foreign matter. At the same time, the red colour of O-ring (3) serves as a visual check to indicate correct assembly.

The male fitting (4) is screwed tightly into the body of the device with the thread being sealed by O-ring (6). The plastic retaining clip (8) is open on one side and is opened by the tapered tail of the plug during assembly. After insertion of the plug this clip engages the holding groove. The retaining clip is self-centring.

The rubber spring element (9) is inserted into an annular space at the base of the formed bore in the device. The design of the spring element causes the plug to be placed under axial stress after the retaining clip (8) has engaged.

Removal/refitting of a connector

If a device using the VOSS 230 connectors needs to be changed, the connectors are removed by unscrewing the male fitting (4), noting the port number from which it is removed. The connector assembly remains attached to the nylon pipe.

Fit a new spring element (9) into the ports of the new device. Fit the connectors into the same ports on the new device as were used on the removed device. Fully tighten the male fitting (4) to a torque of 10 + 1 Nm.

Should a connector assembly need to be replaced follow the procedure below:

Cutting the nylon tube to length

The nylon tube must be cut off square. A saw must not be used for this purpose as the unavoidable formation of burrs jeopardises the sealing capability of the connection. For cutting the nylon tube to length, the VOSS tube cutting pliers can be used so that the tube is cut cleanly and at right angles. Reworking the cut surface, such as deburring, is not necessary.

Pressing the fir-tree into the nylon tube

The following is to be observed:

- Do not remove the protective cap from the plug.
- The pressing-in procedure is to be performed at room temperature
- The nylon tube must not be heated
- The fir-tree must not exhibit any damage otherwise the connection with the nylon tube will not be tight
- The fir-tree should be clean and free of grease
2. System Components

Assembly of the male fitting using VOSS assembly mandrel (see Fig. 29)

The male fitting (4) with greased O-ring (6), retaining clip (8) and spring element (9) are successively mounted onto the assembly mandrel. The assembly mandrel prepared in this way is screwed hand-tight into the connection bore in the device. The mandrel is withdrawn, the individual components remain in their position. The male fitting (4) is then tightened fully to a torque of 10 + 1 Nm.

Assembly of the male fitting without using the assembly mandrel (see Fig.30)

- The spring element (9) is inserted into position under the thread root of the connection bore (diagrams a and b).
- The retaining clip (8) is introduced so that it rests flat on the thread root (diagrams b and c). The spring element (9) and retaining clip (8) must be symmetrically positioned.
- The male fitting (4), pre-assembled with the pre-greased O-ring (6), is then screwed by hand into the tapped bore (diagram c), then tightened fully to a torque of 10 + 1 Nm.

Assembly of the plug with the male fitting

Remove the protective cap from the plug. Push the plug (with nylon tube fitted) into the male fitting until the retaining ring engages in the groove of the plug. The red O-ring (3) should not be visible. Check that the retaining ring has engaged by pulling the assembly against the direction of insertion.

Grease

Use grease II14525 Fuchs “Renolit” HLT2.
3. Wiring Diagrams
3. Wiring Diagrams

**X1 Plug Layout**

![X1 Plug Layout Diagram]

**X2 Plug Layout**

![X2 Plug Layout Diagram]