

Anti-Lock Braking Systems

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Abstract

During this assignment, Anti-lock Braking Systems were researched, and two different ABS systems tested and compared – the Bosch 2EH and the Teves Mk IV. Waveforms and voltage figures were collected during testing for analysis in this report. Based on the research and testing results, a diagnostic flowchart was also generated and presented.

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1. Introduction

Anti-lock Braking Systems (ABS) have been in use on passenger cars since the 1980's and have been a major contributor in improving road safety and in the development of active safety systems. ABS became mandatory on cars sold in Europe in 2002, and further developments of the system led to Traction Control Systems (TCS) and later on stability control systems (often known as ESP – Electronic Stability Programme) being developed.

In this report, the function of ABS will be defined, and diagnostic techniques will be researched and discussed. Two different ABS systems will be tested, analysed and compared – the Teves Mk IV and the Bosch ABS 2EH. A series of tests will be conducted on ABS rigs to acquire voltage values as well as waveforms throughout the electronic systems. The results will be presented and analysed, and a diagnostic flow chart generated based on them. This will be for a specific fault on one of the systems. The two systems will then be compared, and their strengths and weaknesses will be identified.

The aims of the assignment are to work effectively as part of a team to collect the required data, and to understand, analyse and compare the two different ABS systems.

2. Research

2.1 ABS Function

ABS is used as an active safety system. Its function is primarily to prevent accidents by allowing the driver to maintain control of the vehicle during hard braking. The system prevents wheels from locking up, therefore reduces braking distances and maintain steer-ability of the vehicle. ('How ABS Works', N.D.)

The system is made up of wheel speed sensors, solenoids, a hydraulic pump and an Electronic Control Unit. Under normal conditions, the pump only operates for a short period after the ignition is switched on. The ECU runs a self-test and ensures that the pump functions correctly and by operating it, prevents it from seizing. This is especially important as the pump is made up of some ferrous components and brake fluid contains moisture due to its hygroscopic properties ('Why is brake fluid important?', N.D.).

The sensors are mostly of two types: inductive and hall effect. Photo sensors have also been used in the past, but these proved unreliable due to the nature of the environment they have to work in. Inductive sensors are two-pin pulse generators producing an analogue sinusoidal waveform. Hall effect sensors are three-pin sensors requiring an input voltage and generating a digital square wave signal. These are more effective at low speeds than inductive sensors, as an inductive sensor will not generate enough voltage to register in the ECU at low speeds. Hall effect sensors also reduce processing time. Inductive sensors are aimed at toothed rings, generally attached to the drive shaft, and use a permanent magnet and coil to produce voltage. Hall Effect sensors use magnetic rings instead, often attached to the wheel bearing. ('ABS Sensors', 2017)

The brake pedal switch is also connected to the ECU. When the switch indicates that the driver is braking and a wheel starts to lock up, the ECU detects that the wheel is decelerating at a higher rate than the other wheels. Initially, the first phase is put into action – pressure hold. During this phase, the solenoid for the locking wheel moves a plunger back to close off the hydraulic circuit. This prevents any more pressure being applied on the caliper piston. If this is not enough to stop the wheel from locking up, the plunger is moved further back to allow the pressure to flow into a reservoir. The pump is connected to this reservoir and builds pressure for the last phase – pressure increase. At this point, the pressure needs to be reapplied to maintain braking. The ABS will cycle through these phases at a frequency between 15-25Hz. ('How ABS Works', N.D.)

Over time, ABS systems have developed to perform other active safety functions on vehicles. These include Traction Control Systems and stability control systems. When the relevant ECU detects wheelspin, it will apply brake pressure to the spinning wheel(s) to regain traction. On a vehicle with an open differential, this can allow drive to be transferred to the wheel with more traction. For stability control, individual brakes can be applied when the vehicle start to slide, to bring the car back into the driver's control. (Tracy, 2013)

Some manufacturers also use the ABS wheel speed sensors for tyre pressure monitoring (TPMS). The rolling radius of a tyre decreases when the pressure is low, therefore the wheel

speed will be higher for the same vehicle speed. As the ECU compares the wheel speeds of all four wheels, this will only work if only one tyre is underinflated. (Carley, 2014)

2.2 Diagnosing ABS

There are a number of diagnostic techniques available when investigating ABS faults. These range from visual inspections to On-Board Diagnostics fault code reading equipment, simple multimeter tests and oscilloscope tests.

The first step to diagnosing a fault is to confirm the present symptoms. This can be done by looking at the job card, visually or by speaking to the customer. The next step is to obtain more information by asking the customer specific questions about the vehicle and symptoms as well as learning about the vehicle model's common problems and how the system works, in order to gain an understanding of the particular system. All of this information then needs to be analysed and a logical test plan established. Some of the tests may include visual, such as checking for warning lights, blown fuses, leaks, damage to sensors, rings and wiring etc. An auditory test can be performed for the operation of the hydraulic pump. An OBD code reader can be connected to the Datalink connector of the vehicle to check for any fault codes stored in the ECU. This can give an indication of the problem, but more tests should still be performed to confirm the fault. These tests would involve using a multimeter and oscilloscope (more details in 2. Methodology, page 6). Once the fault has been rectified, all of the vehicle's systems should be checked to ensure full correct operation of the vehicle.

2.3 OBD System Development

On-Board Diagnostic systems have been fitted to road vehicles since the late 1960's, with the first generation OBD. These were different for every vehicle and required different equipment. OBD-II was introduced in 1994, with a standardised connector and Diagnostic Trouble Codes. This is the most up to date system used in the United States, while in the European Union, E-OBD was introduced in 2001. (Barreto and Ciolek, 2017)

Fault codes and data from the ABS ECU can also be accessed via OBD systems, which can be very useful in diagnosing faults.

2. Methodology

The testing will consist of static multimeter tests with both ignition on and ignition off, on all ECU pins and solenoids. Dynamic tests will also be carried out using the oscilloscope function of a Bosch Dedicated Digital Diagnostic Centre.

Before starting static tests, the battery voltage should be noted for reference, and to ensure sufficient voltage to carry out reliable testing. The multimeter should also be checked to ensure there is no resistance in the leads. Once a suitable earth point is found for the black lead, each ECU pin and solenoid pin will be probed and the voltage noted firstly with the ignition off, then again with the ignition on. This will be done on both systems, and care must be taken not to damage any of the wiring or plugs/pins.

Dynamic testing will be carried out using the Bosch oscilloscope. Before testing, the battery leads of the oscilloscope should be connected to the battery to ensure result accuracy. The probes need to be placed securely before running the rigs. The motors simulating the road wheels are AC motors powered by the mains supply, so there is no effect on the battery voltage.

During testing, safe working practices also need to be considered. Protective boots and lab coats should be worn at all times in the workshop. Care should be taken around cables and wiring, as it may present a trip hazard or may get caught in moving parts of the rig. Hands should be kept clear of all moving parts when the rigs are being run.

3. Results

3.1 Teves Mk IV

The following voltage readings were collected from the static tests of the Teves Mk IV system:

Pin Number	Teves ABS ECU Voltage (V)	
	Ign. OFF	Ign. ON
1	2.34	2.34
2	2.34	2.34
3	-	-
4	-	-
5	-	-
6	-	-
7	12.13	12.13
8	0	0
9	0	12.15
10	2.34	2.34
11	2.34	2.34
12	0	12.05
13	10.38	10.38
14	-	-
15	-	-
16	0	12.07
17	2.35	2.35
18	2.35	2.35
19	2.35	2.35
20	2.35	2.35
21	-	-
22	-	-
23	-	-
24	0	0
25	12.18	12.18

Pins 1, 2, 10 and 11 all show the same voltage as they are the earth return to each of the wheel speed sensors. Pins 17, 18, 19 and 20 are the signal pins for the sensors. The Teves system uses two pin inductive sensors.

The solenoids are ECU internal and therefore cannot be tested.

3.2 Bosch 2EH

The following table shows the static voltage results for the Bosch 2EH system. This testing had to be carried out on two plugs, a 15-pin and a 4-pin.

Pin Number	Bosch System 15 pin plug Voltage (V)	
	Ign. OFF	Ign. ON
1	0	11.83
2	0	0.2
3	-	-
4	0	0.34
5	0	0.2
6	0.34	0.34
7	0	0.2
8	-	-
9	0	11.88
10	0.34	0.34
11	-	-
12	0	10.68
13	0.34	0.34
14	0	0.2
15	0	0

Pin Number	Bosch System 4 pin plug Voltage (V)	
	Ign. OFF	Ign. ON
1	0	11.79
2	0	12.08
3	0	0
4	0	11.79

On the 15-pin plug, pin 1 connects to the ABS warning light, and will show battery voltage with the ignition on unless a fault is present, and the light is illuminated. This also applies to pin 9, as this connects to the brake light switch. A very low voltage can be expected at pin 15, as this diagnostic data. On the 4-pin plug, pin 3 is an earth connection hence showing no voltage.

Dynamic test scope patterns can be found in the Appendices on page 13.

4. Analysis

4.1 Results Analysis

The static testing shows that the Teves system may have a memory keep-alive function, as there is a direct live feed to the ECU. The Bosch system does not have this. This is due to the Bosch system using an early OBD system, while the Teves uses OBD-II.

Appendix 1 shows the earth return and signal pins of the nearside rear wheel speed sensor on the Bosch system. The lower voltage seen is the earth return. The two sinusoidal waves are offset – as the signal voltage rises, the earth return voltage drops. The ECU determines the wheel speed based on the frequency and amplitude of the signal wave.

Appendix 2 shows the voltage at pin 9 on the Bosch system, which is the brake light switch. This is to tell the ECU when the brakes are being applied by the driver. On the scope pattern, a drop in voltage is seen before gradually returning to battery voltage. This shows the current draw on the battery from the ABS hydraulic pump and would be seen across all of the vehicle's systems.

Appendices 3 and 4 show the voltage at the rear solenoid on the Bosch system in two phases. Appendix 3 shows the pressure hold phase while Appendix 4 shows the pressure release phase. The solenoid is switched on when the voltage drops, and the cycling through the phases can be seen in Appendix 4.

Appendix 5 shows a wheel speed sensor signal and earth return on the Teves system. Some fluctuations and imperfections can be seen in both sinusoidal waves – this is most likely due to the target wheels used on the rig. The original ABS rings are not utilised on the rig, and the target wheels used in their place may not run perfectly parallel with the sensor.

4.2 Diagnostic Flowchart

Appendix 6 shows a flowchart generated for diagnosing an ABS system fault – in this case the fault leads to a damaged ABS ring/sensor.

5. Comparison

The two systems are quite similar in their basic operation. They work using the same basic principles and both use inductive wheel speed sensors. They differ in their use of the solenoids and their OBD capabilities. The Bosch system uses just three solenoids – two for the front and a single solenoid for the rear. This means that the rear wheels cannot be controlled independently. On the Teves system, there are as many as ten solenoids. Each brake can be controlled independently. The solenoids on the Teves system are built in and not accessible.

In terms of On-Board Diagnostics, both systems feature a warning light to alert the driver of any faults present in the system. The Bosch system uses an earlier OBD system and illuminates the warning light briefly when the ignition is turned on. The Teves system uses a standardised OBD-II and has a 16-pin Data Link Connector.

6. Conclusion

In conclusion, the aims of the assignment were successfully met, as the necessary data was collected through effective teamwork and the two systems were analysed and compared. The Teves system's strengths are that it is capable of controlling each brake individually, therefore being more effective when a rear wheel locks up, and it uses OBD-II, which makes diagnosing faults much simpler due to the standardisation of the system. The main weakness of this system is that the solenoids are internal and cannot be directly tested. In comparison, the solenoids on the Bosch system can be directly tested, potentially giving a more accurate diagnosis of a problem. The weaknesses of this system are that it can be seen as more complex with multiple connector plugs, the limited OBD capability and using only three solenoids. A weakness of both systems is the type of wheel speed sensor they use – hall effect sensors would allow faster processing times and more accurate readings at very low speeds (Williams, 2005).

7. Bibliography

Anonymous (No Date) 'How ABS Works' *How a Car Works* Available at: <https://www.howacarworks.com/technology/how-abs-works> (Accessed: 4th January 2019)

Anonymous (No Date) 'Measuring an Inductive ABS Sensor' *TiePie Automotive* Available at: <https://www.tiepie-automotive.com/en/articles/abs-sensor-inductive> (Accessed: 4th January 2019)

Apec Braking (2017) *ABS Sensors* Available at: <http://www.apecbraking.co.uk/getattachment/f3d85f2b-a473-429e-aa60-d9ffa28e0456/ABS-Sensors.aspx> (Accessed: 4th January 2019)

Barreto V. and Ciolek P. (2017) 'What is OBD II? History of On-Board Diagnostics' *Geotab* [blog] 18th August. Available at: <https://www.geotab.com/blog/obd-ii/> (Accessed: 4th January 2019)

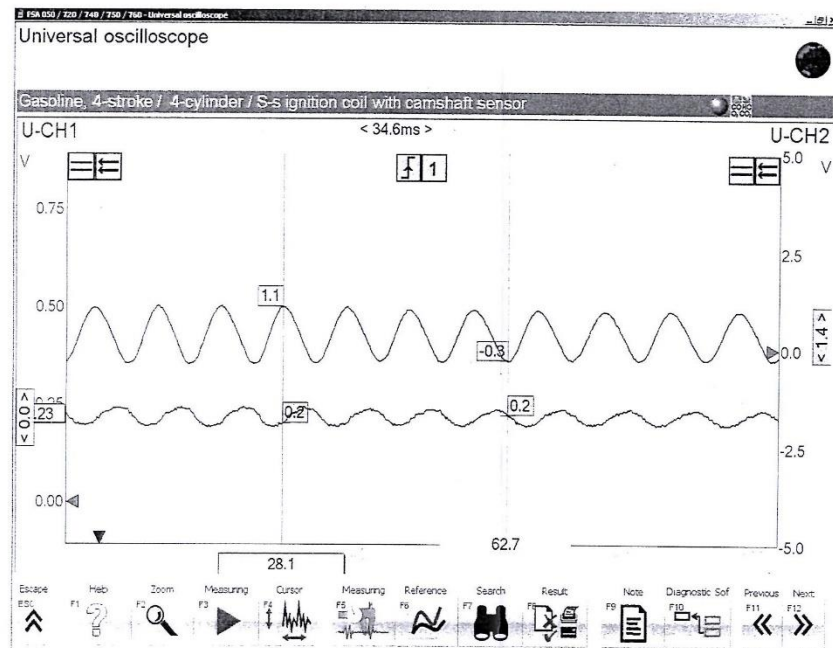
Carley L. (2014) 'Indirect Tire Pressure Monitoring Systems Making a Comeback on Some Imports' *Tire Review* [blog] Available at: <https://www.tirereview.com/indirect-tpms-imports/> (Accessed: 6th January 2019)

Kwik Fit (No Date) 'Why is Brake Fluid Important?' *Kwik Fit* Available at: <https://www.kwik-fit.com/brakes/information/why-brake-fluid-is-important> (Accessed: 6th January 2019)

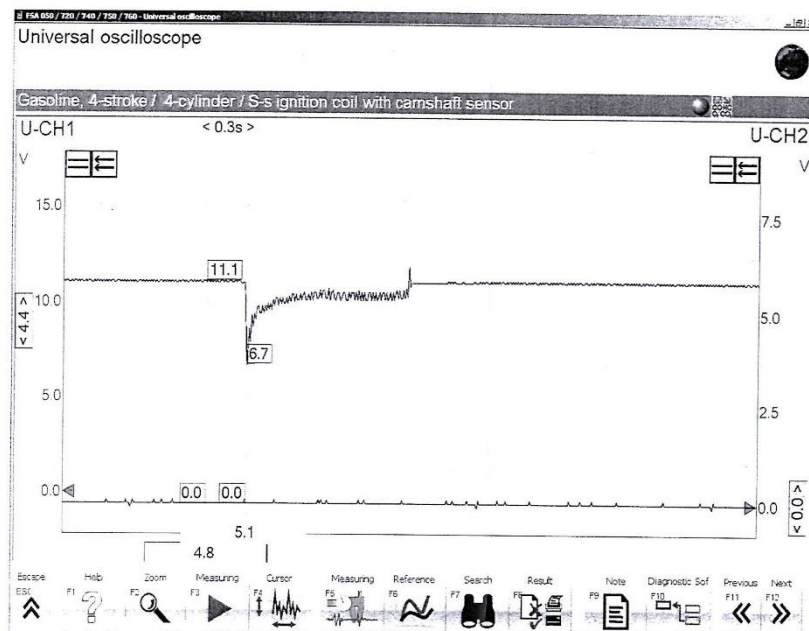
Tracy D. (2013) 'This is How ABS, ESC and Traction Control Work' *Jalopnik* [blog] 24th June. Available at: <https://jalopnik.com/this-is-how-abs-esc-and-traction-control-work-513807036> (Accessed: 6th January 2019)

Williams B. (2005) 'Diagnosis of Faulty ABS Systems' *Brake & Front End* [blog] 1st June. Available at: <http://www.brakeandfrontend.com/diagnosis-of-faulty-abs-systems/> (Accessed: 6th January 2019)

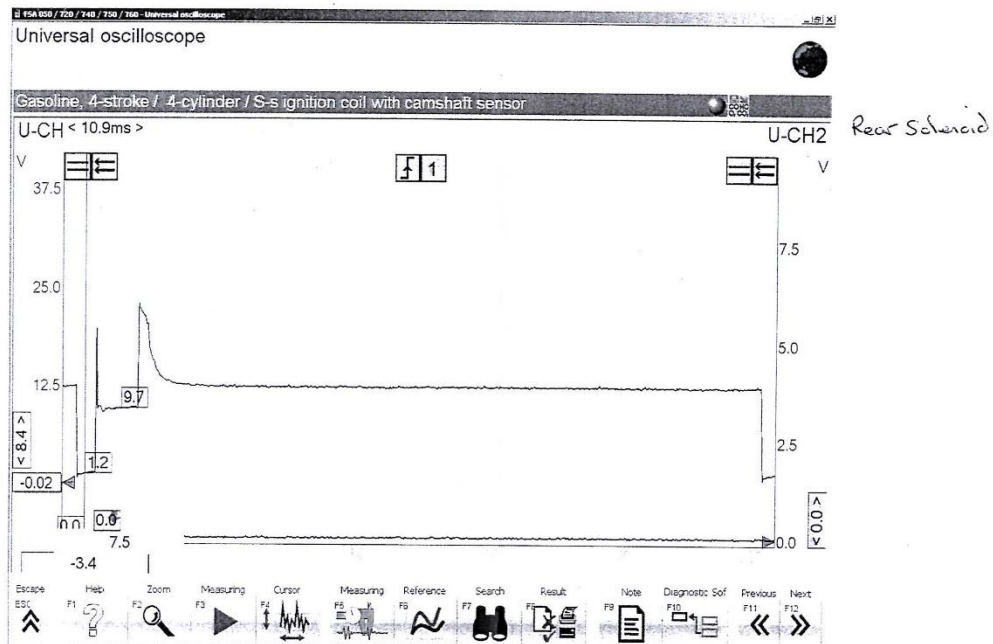
8. Appendices



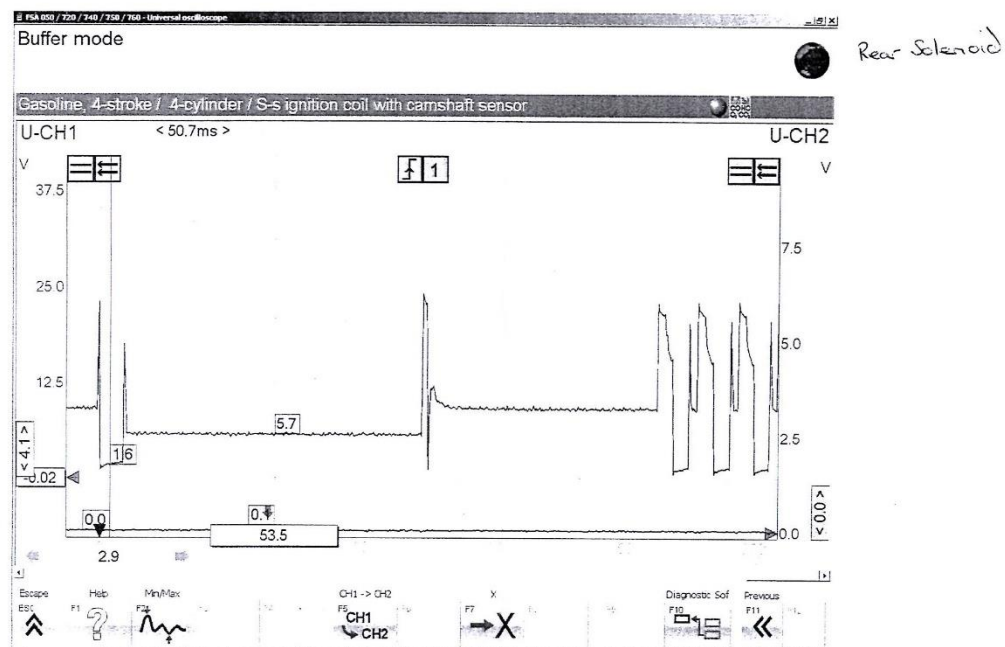
Appendix 1: Bosch wheel speed sensor signal and earth waveform (pins 2 and 4).



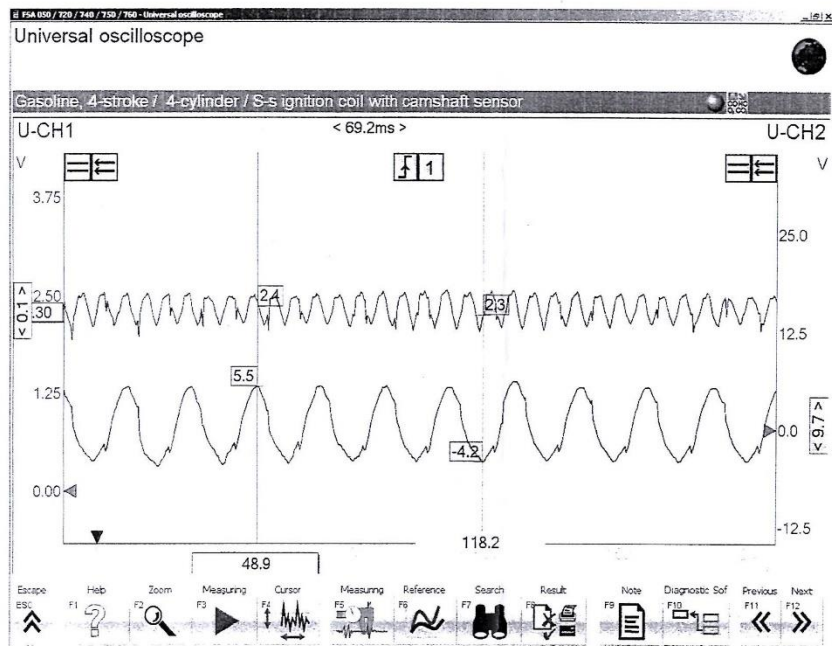
Appendix 2: Bosch brake light switch scope pattern showing voltage drop on pump actuation (pin 9).



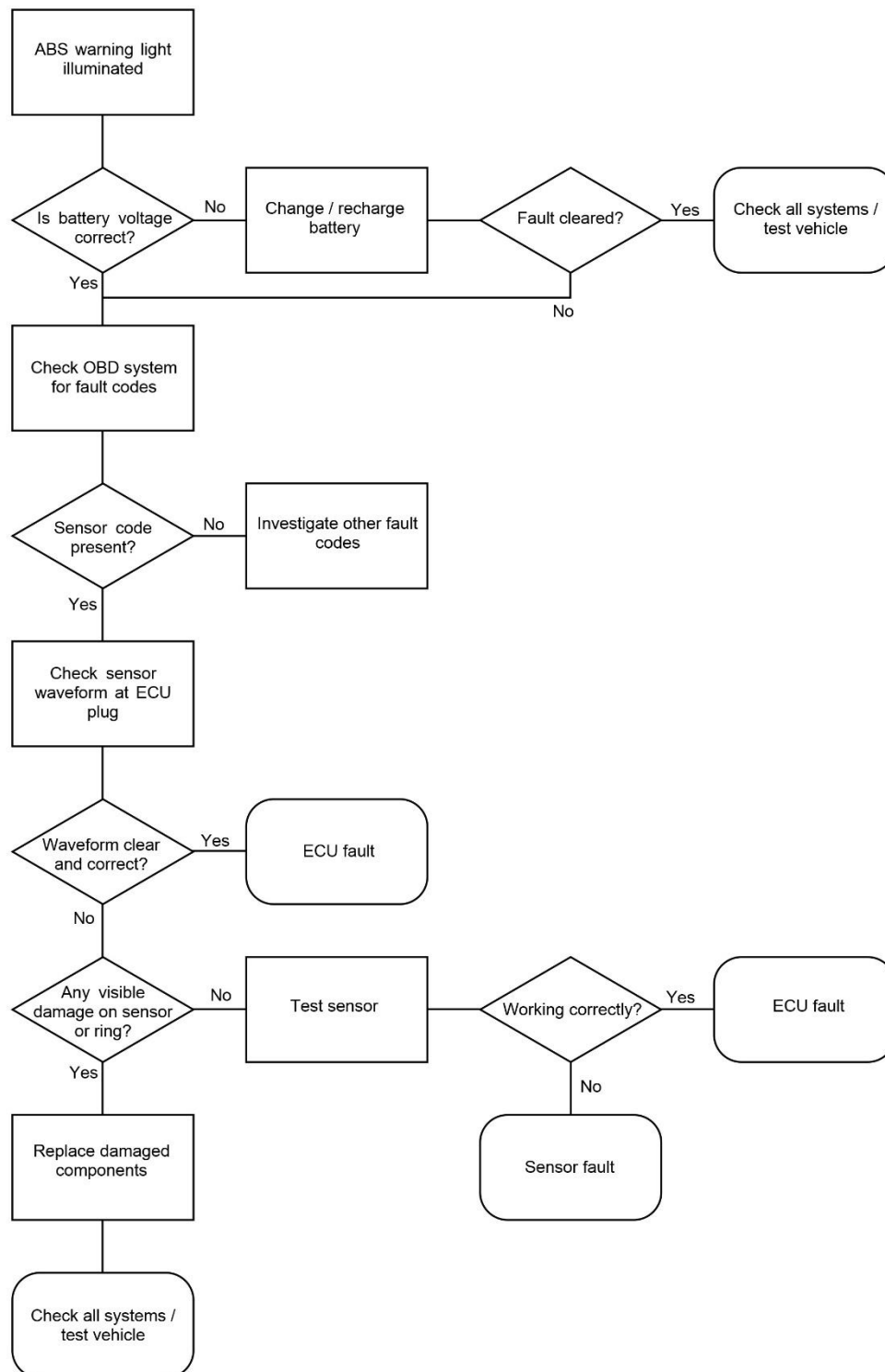
Appendix 3: Bosch rear solenoid waveform during pressure hold phase.



Appendix 4: Bosch rear solenoid waveform during pressure release phase.



Appendix 5: Teves wheel speed sensor signal and earth waveforms (pins 2 and 19).



Appendix 6: Diagnostic flowchart leading to damaged sensor / ring.