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Abstract

ABS systems improve the vehicles steerability and control of the vehicle at the point that wheel lock is about to happen, The Bosch 2EH and the Teves MKIV systems were tested at the university workshop and the test results are shown within this report, both systems have advantages and disadvantages however the Teves being the later model has the added option of applying traction control alongside the ABS. Emissions are taking into consideration when it comes to ABS and traction control, including the evolution of OBD to improve the emission control parameters. When an ABS or traction control fault occurs, the diagnostic procedure can be assisted by a fault flow chart although experience and knowledge allows the flow chart steps to be jumped if the technician is familiar with the fault.

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2. Introduction

The following report will be based on two separate anti-lock braking system, the oldest system known as the Bosch 2EH and the second being the Teves MKIV which is the later of the two systems. An insight into how ABS system operates including the three stages that happens during ABS intervention. Test results will be provided within the report from both systems, including information regarding the evolution, operation and purpose of the On-board diagnostic.

Information regarding the effectiveness of diagnosing ABS related faults using a fault flow chart, including the effectiveness and the complications that can be found with following a fault flow chart step by step, a fault flow chart will be produced relating to a specific fault code that could be found within relating to an ABS fault. The methods taken to complete the testing will be discussed including relevant images of the connection plugs the voltage readings were taken from. The results will be analysed along with waveforms produced displaying the voltage from the solenoids and the plug pins from both systems.

3. Antilock braking system

3.1. ABS purpose and requirements

The Antilock braking systems operate in a closed-loop, it was introduced to vehicles to prevent locking the wheel up and skidding while braking. Fitting ABS to a vehicle enhances the control of the steerability and stability of the vehicle. When ABS prioritises the steerability and stability of the vehicle over the braking distance, as confirmed (Bauer, 1996) and reported by (Austin and Morrey, 2000)

The first ABS system began production in 1978 and was known as ABS 2S, its operation consisted of monitoring the wheel speed using sensors at both front wheels, and the differential or both rear wheels. When one of the wheels is about to lock during braking the wheel speed sensor outputs a signal to the ABS ECU determining that the wheel is approaching lock and therefore actuates the solenoid for that brake line circuit in the hydraulic modulator. The braking pressure however isn't released completely but controlled by rapidly going through the three stages of ABS. This information can be clarified by (Bauer, 1995).

The three stages to the ABS system, the actuation of these stages are controlled by the ECU and the stages are as followed:

1. Build-up – The pressure builds up by allowing the brake fluid to travel from the brake master cylinder and to the modulator by activation of the solenoid valve.
2. Hold – The pressure is held by separating the wheel brake cylinder from the return line and master cylinder by closing the valve and trapping the pressure between the wheel brake cylinder and the modulator.
3. Release – The pressure is released by opening the valve to the return line whilst keeping the valve closed between the master cylinder and modulator allowing the pressure to leave the modulator via the return pump which connects back to the master cylinder.

This information is confirmed by (Bauer, 1995).

3.2. Teves

The Teves MKIV originally went into production in 1989 which was compatible with traction control systems, as reported by (Kolbe, 1990). The system is a four-channel ABS system as it has a wheel speed sensor at all four corners, and ten solenoids within the modulator. The solenoids are within a sealed casing; therefore, it is not possible to test the solenoids directly. The Teves uses an electronic brake control module (EBCM) or if traction control is added to the vehicle then it uses an EBTCM.

The control module processes the data received by the inductive wheel speed sensors and compares them to the data stored in the modules memory to determine one or more wheels are approaching lock. The Teves is available with and without traction control, the ABS only modulator contains eight solenoids and the traction control version comes with two isolation valves and a pressure switch. The isolation valves isolate the front brakes from the master cylinder and rear brakes.

In 1994 traction control was further enhanced, in addition to applying the front brakes the ABS and traction control module (ABSTCM) can improve traction by signalling the powertrain control module (PCM) to reduce engine torque output, this is accomplished by retarding the ignition and stopping fuel injection, this reduces the emissions marginally due to the decrease in fuel consumption during traction control intervention.

3.3. Bosch

The first generation made an appearance in 1978, and the second generation appeared in 1983. The Bosch 2EH system is a four-channel system like the Teves system as it has four wheel speed sensors monitor wheel speed at all corner of the vehicle and it consists of three solenoids. The reasoning for fitting wheel speed sensors to both rear corners is because there is no rear differential fitted to that vehicle, this also allowed the system to operate a diagonal split braking method to improve braking and steerability control. The ABS can be switched off with the use of a brake force regulator that would be fitted to the rear axle. The Bosch system isn't compatible with a traction control system, but the solenoids are visible and not sealed therefore making them more accessible for testing and receiving voltage readings compared to the Teves system.

3.4. Strengths and weaknesses of both systems

Bosch strengths:

- The solenoids are accessible and can be tested.

Bosch weaknesses:

- isn't compatible with traction control.
- operates using OBD1 which is not as efficient in controlling emissions due to the absence of a catalytic convertor and lambda sensors.
- Repairs are not permitted on the hydraulic modulator

Teves strengths:

- Compatible with traction control.
- Used in conjunction with OBD2 and can be applied to more efficient modern cars that also have OBD2 which monitors and aids in the control of emissions.

Teves weaknesses:

- The solenoids are enclosed within the modulator casing and cannot be tested.
- The modulator is not serviceable, if there is a fault detected with any parts inside the modulator the repair would be to replace the whole modulator.

4. Onboard Diagnostic Evolution

4.1. OBD

In 1988 OBD1 was known as OBD before the release of OBD2, OBD became a legal requirement in the United States, this was to diagnose open and short circuits faults. This can be confirmed by (King and Burnham, 2012).

4.2. OBD2

OBD2 was a legal requirement introduced in the United States in 1994, it was applied to all vehicles that would be manufactured and sold in the United States from 1994, as confirmed by (King and Burnham, 2012). The main purpose OBD2 was produced and became a legal requirement was to improve the engine and emission control by monitoring added sensors and increased actuator responses as confirmed by (King and Burnham, 2012). OBD2 is an improved version of the original OBD1 system which was originally known as OBD before the release of OBD2, it has the capability to monitor misfires and the efficiency of the catalytic convertor with the use of a lambda sensor monitoring the emissions prior the catalytic convertor and also a lambda sensor situated after the catalytic convertor to determine the emissions entering the atmosphere, as confirmed by (Chen, 2009). If a fault occurs or a component becomes defective an engine management light (EML) must illuminate to alert the driver that there is a fault and it needs to be fixed in order to minimise the pollution caused by the fault, this was expressed by (King and Burnham, 2012).

4.3. EOBD

European on-board diagnostic was released and legally required to be applied to European vehicles that were built and released in the UK from 2001 for petrol fuelled vehicles and 2004 for diesel fuelled vehicles, its purpose and functionality is the same as the OBD2 except it is used in Europe to comply with the European legal requirements regarding emissions. EOBD2 and OBD2 provides improvements regarding the control of the emissions by increasing the parameters and data monitored, this includes additional sensors fitted to the vehicle that is constantly being monitored by the ECU to aid in the control of emissions. The use of a catalytic convertor and lambda sensors have been introduced into the OBD2 program allowing an increase in control over fuel injected and the emissions produced before and after the catalytic convertor.

The emissions are constantly monitored by the ECU with the use of the lambda sensor. The ECU can alter the injection duration and advancing or retarding the ignition based on the values received from the lambda sensor. The use of a knock sensor allows the ECU to monitor if detonation happens within the cylinders while the ignition timing is constantly altering to maintain a balance of reducing emissions and providing protection against detonation. Generic diagnostic scanners can monitor the live data that the engine management control unit monitors, including any trouble codes stored, but other control units around the vehicle depending on the manufacturer can only be observed or accessed with original manufacturers equipment.

5. Diagnosing an ABS system fault

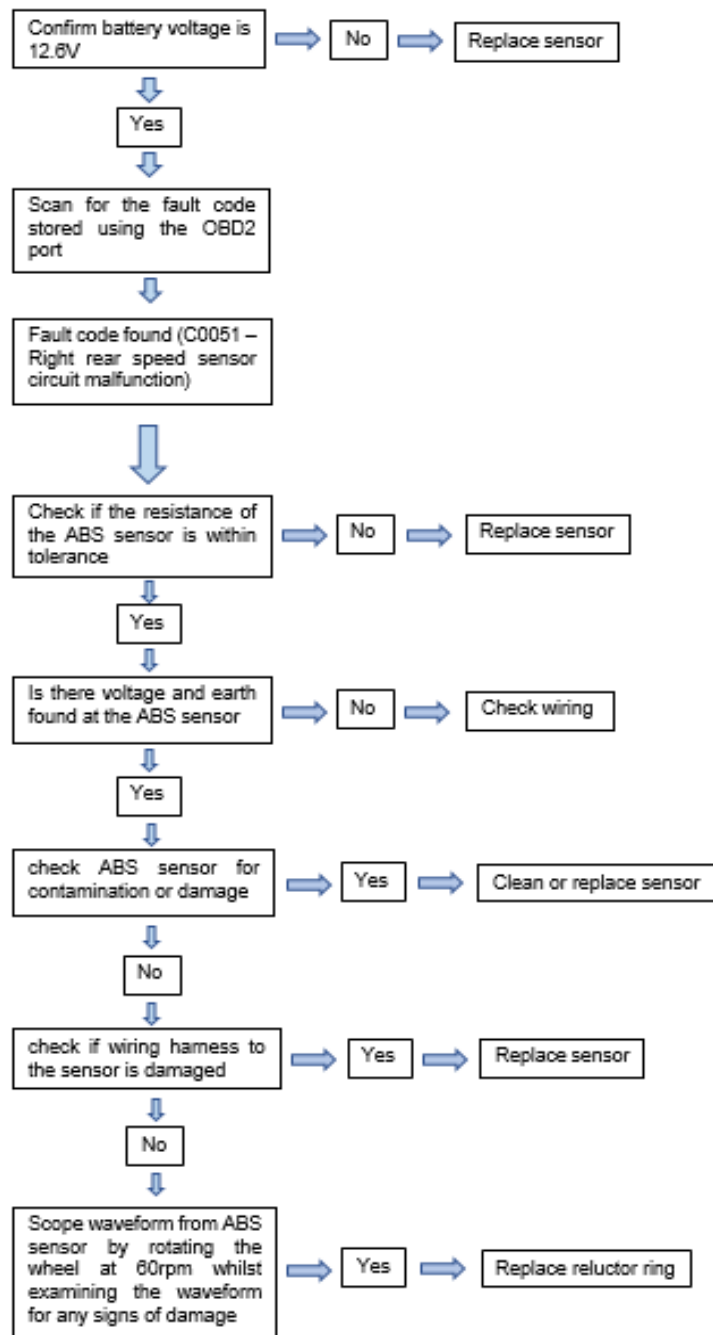
5.1. Introduction to diagnostics

There are two requirements to successfully diagnose an automotive fault, the first requirement is having the knowledge and understanding of the system that the fault has developed on and secondly having the ability to apply a logical diagnostic procedure to successfully diagnose the fault, this was expressed by (Denton, 2000). The more experience a diagnostic technician has, the quicker and easier the diagnostic procedure becomes, this is due to the technician being familiar with the system and may have had similar faults previously and therefore certain steps in a fault flow chart can be skipped as the technician would have an idea of what the fault would more likely be.

The use of a generic diagnostic procedure by the means of a fault flow chart was expressed by (Bonebrake, 2011) where the fault was not found when the diagnostic procedure ended on the diagnostic flow chart, there for the knowledge and understanding is also extremely important in aiding the diagnostic process alongside with the assistance of a fault flow chart. However, a fault diagnosis flow chart is not always the quicker option to diagnose the fault if there is a fault code stored as this would have an impact on the order of testing and eliminating a large amount of diagnosing procedures that would have been made without a fault code stored.

5.2. Diagnostic procedure

The use of a fault flow chart can be used to guide you on a pathway to find the fault, below is a fault flow chart relating to a possible ABS fault.



6. Group Testing

6.1. Health and safety in the workshop

It is a compulsory requirement by the university to wear steel toe cap footwear and overalls or a laboratory coat when in the workshop. All watches, rings and jewellery must be removed.

6.2. Equipment used

- Bosch diagnostic centre was used to scope the waveforms using the live voltage reading found at the connector plug, the monitor was then frozen to view a captured waveform.
- Multi-meter was used to record the voltage at found at the connector plug during ignition off, ignition on and during ABS intervention.

6.3. Testing procedures

The testing was carried out on two ABS systems, the Bosch 2EH and a Teves MKIV. The first system tested was the Bosch 2EH, which started by using a multi-meter to record the voltage found with the ignition off at all fifteen pins in the connector plug of the control unit. Once all the voltage results were captured and recorded on to the premade results table the voltage was then recorded at the back of the connection plug powering the three solenoids, each solenoid has a voltage supply and a ground.

The final voltage readings with the ignition off were taken from the four-pin connection block that consists of the ignition live fed from the ignition key, earth return, relay and the brake light switch. The same testing procedure was made during the ignition on stage and during ABS intervention and the results can be found in figure 5, 6 and 7.

The Teves MKIV system was then tested, but due to the solenoids being enclosed within a sealed unit it was not possible to record the voltage values found at the solenoids like the Bosch 2EH. Voltage measurements were taken from the ABS control unit that consists of twenty-five pins, measurements were recorded with the ignition off, ignition on and during ABS intervention. The results can be found in figure 3.



Fig 1 Bosch 2EH - Connection plug to the control modulator.



Fig 2 Bosch 2EH - Connection plug to the solenoids (left). Square 4 pin connection plug (right).

7. Results and Analysis

7.1. Teves test results

Below is the results table for the Teves system.

1	Wheel Speed Ground				Same as pin 2
2	Wheel Speed Ground	0v	2.3v	2.6v	AC output
3					
4					
5					
6					
7		12.6v	12.6v	12.57v	Permanent Memory live
8	Earth	0v	0v	0v	Earth
9		0v	12.6v	12.6v	Ignition live
10	Wheel Speed Ground				Same as pin 2
11	Wheel Speed Ground				Same as pin 2
12		0v	12.6v	12.6v	Ignition live
13		9.86v	9.86v	9.7v	Data link
14					
15					
16		0v	12.6v	12.6v	Lamp
17	Wheel Speed Signal				Same as pin 19
18	Wheel Speed Signal				Same as pin 19
19	Wheel Speed Signal	0v	2.3v	2.6v	Speed reading changes up and down voltage in dynamic
20	Wheel Speed Signal				Same as pin 19
21					
22					Not included in this system
23					
24	Earth	0v	0v	0v	Earth
25		12.6v	12.6v	12.6v	Permanent live

Fig 3 Teves MKIV test results obtained

During testing it was not required to record the voltage measurement at all wheel speed sensors as the results would be identical to pin 2 and 19. The wheel speed sensor provides an AC voltage output of 2.3 volts while the ignition is on, this sends a voltage signal back to the ECU to confirm that the sensor is operating as it should and that the wheel speed is zero. Once the wheel speed begins to increase the voltage output increases to the sensor and returns the voltage back to the ECU, during testing the voltage found at pin 19 would be rapidly increasing and decreasing during ABS intervention as the ABS attempts to control the braking through its three stages.

Pin 7 is the permanent memory live to the ECU, as it is a permanent live battery voltage was found with the ignition off and on. At pin 8 and 24 there is no voltage found as there is no live supply feed as the testing probes were both connected to earths. Pin 12 is the brake pedal position switch that is connected to the ignition live circuit, the switch is mounted at the back of the brake pedal and when the brake pedal is pressed the voltage found should be battery voltage and when it is depressed the circuit is open and there should be no voltage found at pin 12. Pin 13 is the data link that is powered by a permanent live, this is to allow a diagnostic scanner to be powered by the OBD2 port, the voltage decreases as the wheel speed increases in the dynamic stage as data is being sent. Pin 16 is showing a potential voltage to the ABS warning lamp, once a fault occurs the circuit is grounded and the warning lamp illuminates.

7.2. Teves waveforms

Below in figure 4 is an analogue signal waveform produced from the wheel speed sensor by recording the live voltage found at pin 2 and 19 of the connector plug to the ABS control module. As the wheel rotates the reluctor ring rotates at the same speed, the wheel speed sensor is a permanent magnet with a coil winding that is supplied a voltage. The reluctor ring is made of steel which is a ferrous metal, as the reluctor ring rotates on the drive shaft it passes the magnetic poles of the sensor and increasing the magnetic field and reducing the reluctance. When the sensor is between the gapped section of the disc the reluctance increases and the intensity of the magnetic field decreases as air is more permeable than steel, this can be confirmed by (Hillier, 2014).

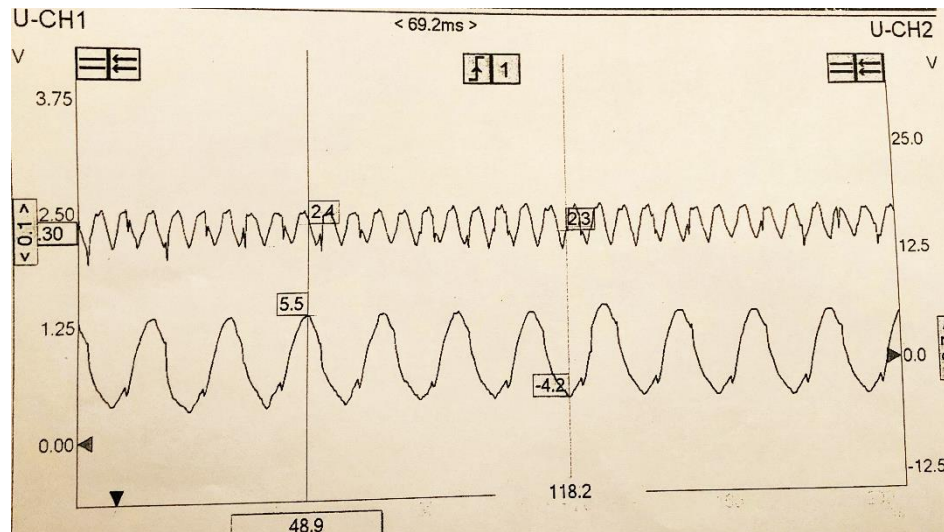


Fig 4 Teves MKIV pin 2 and 19 waveforms

The waveform appears to be rough and jagged, this could be due to poor condition of the teeth reluctor ring. As the voltage decreases on the waveform the abs sensor is passing the gapped section of the reluctor ring, and as the reluctor ring rotates the toothed section increases the magnetic field and in turn increasing the voltage, the frequency of the waveform would increase as the reluctor ring rotates with the wheel.

7.3. Bosch test results

Pins	Label	Ignition off	Ignition on	Dynamic	Note
1	ABS Warning Lamp	0v	12.5v	12.25v	Not changing but grounded if a fault occurs
2	Wheel Speed Ground	0v	0.22v	0.23v	AC signal output
3					
4	Wheel Speed Signal	0v	0.35v	0.35v	Looks for speed signal from wheels, causes ABS intervention if changes
5	Wheel Speed Ground				Same as pin 2
6	Wheel Speed Signal				Same as pin 4
7	Wheel Speed Ground				Same as pin 2
8					
9	Brake Light Switch	0v	12.3v (brake applied)	12.3v	Under Abs intervention voltage drops to 8.9v. This is supply to brake light and system
10	Wheel Speed Signal				Same as pin 4
11					
12	Serial Data Wire	0v	11.13v	11.09v	Data is the voltage line, draw decrease is due to sending data.
13	Wheel Speed Signal				Same as pin 4
14	Wheel Speed Ground				Same as pin 2
15	Diagnostic Lead	0v	0.25v	0.36v	The peaks on the voltage line are data.

Fig 5 Bosch 2EH test results obtained from modulator connection plug

The ABS warning lamp is supplied a potential voltage which is shown at pin 1, it becomes grounded if a fault occurs illuminating the ABS warning lamp on the instrument cluster. At pin 9 the brake light is supplied a voltage while the brake is applied, and during dynamic the voltage remains the same as the brake is still applied, the voltage during ABS intervention decreases to 8.9V as the voltage supply to the brake switch is also supplied to the ABS system, the voltage demand from the ABS system

increases causing a voltage draw from the brake switch. Pin 12 is the serial data wire, which decreases in voltage while wheel speed increases, this voltage decrease is the data being sent to the diagnostic

Pins	Label	Ignition off	Ignition on	Dynamic
1	Ignition key	0v	12.37v	12.37v
2	Over Arch Relay	0v	12.6v	12.6v
3	Earth	0v	0.04v	0.04v
4	Light	0v	12.33v	12.3v

Fig 6 Bosch 2EH ignition key, relay, abs light and an earth return

Below in figure 7 is the voltage measurements taken from the live supply and the earth return of all three solenoids.

Pins		Ignition off	Ignition on	Dynamic	Note
black	Front	0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v
Yellow		0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v
black	Front	0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v
Yellow		0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v
Black	Rear	0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v
Green		0v	12.5v	12.5v	At stage 1 Abs intervention 9.5v @stage 2 Abs intervention 5.5v

Fig 7 Bosch 2EH voltage readings found at the solenoid connection plug obtained

During the first stage of ABS intervention the voltage decreases to 9.5V, this can be seen in the waveform on figure 10. During the second stage the voltage is shown to decrease to 5.5V, this can be found on the waveform in figure 11.

7.4. Bosch Waveforms

Below is an analogue signal waveform displaying the wheel speed sensor voltage signal on channel 1 (top) and the earth on channel 2 (bottom).

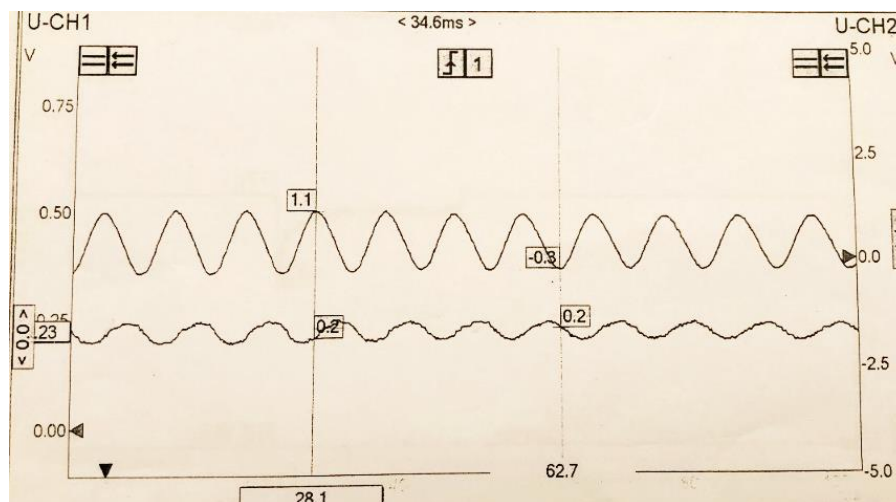


Fig 8 Bosch 2EH waveforms produced at pin 2 and 4

The waveform produced above in figure 8 displays the voltage signal supply and earth as shown previously in figure 4 displaying the wheel speed sensor waveform for the Bosch system, however the smoothness in the waveform is showing that the reluctor ring is in good condition. Both the earth waveform and voltage signal waveform have the same frequency showing eleven waves although the earth is returning a lower amount of voltage due to the resistance it must overcome as the magnetic field is increased within the sensor.

Below is a waveform produced scoping the voltage at pin 9 for the brake switch.

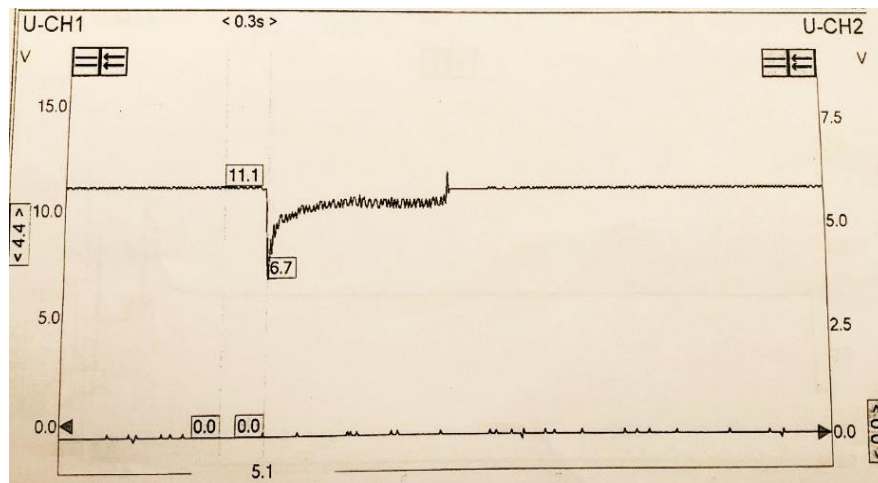


Fig 9 Bosch 2EH waveform produced at pin 9

It is shown in the waveform in figure 9 that the voltage drops from 11.1V to 6.7V when abs intervention happens, this is because the voltage demand to ABS system increases during the operation of ABS as the brake switch is on the same circuit, this is the reasoning behind the decrease blip in the voltage found at pin 9.

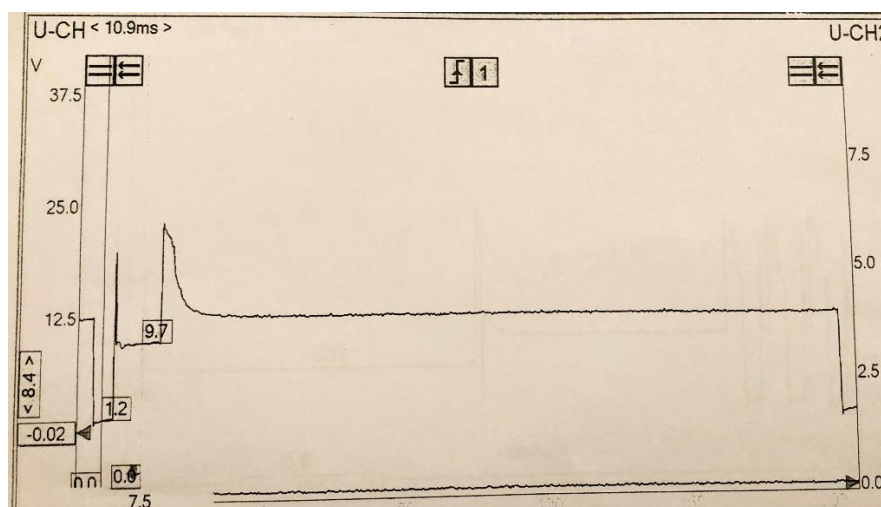


Fig 10 Bosch 2EH waveform produced from the rear solenoid during stage 1 of ABS

Figure 10 is showing the waveform produced from the rear solenoid of the Bosch 2EH system as the dual action solenoid moves to stage one. The voltage drop to 1.2V is the solenoid being actuated into stage one then producing a back EMF and the 9.7V is showing that the solenoid maintains in stage one, the solenoid then leaves stage one and returns to battery voltage.

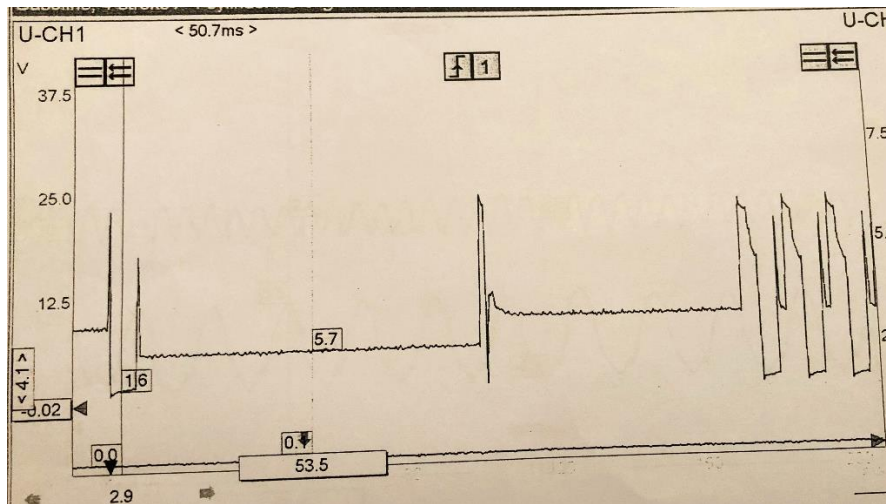


Fig 11 Bosch 2EH Waveform produced from the rear solenoid during stage 2 of ABS

Figure 11 is displaying the waveform produced from the rear solenoid of the Bosch 2EH as the dual action solenoid moves into stage two from stage one. The solenoid is showing 9.7V during stage one as shown in figure 10 and at the beginning of the waveform, then the voltage drops 1.6V to enter stage two. The 5.7V maintains the solenoid in stage two for approximately 20ms, then the solenoid moves back to stage one and holding at 9.7V.

8. Conclusion

The testing went successfully, the data that was received was as predicted. The waveform produced from the Teves wheel speed sensor shows that the reluctor ring is in poor condition resulting in a jagged waveform. The history and function anti-lock braking systems were explained including both system that were tested, and a fault flow chart has been produced with information about the reliability and effectiveness of flow charts. The emissions have been considered during the report, including the on-board diagnostics purpose. The test results have been produced including the waveforms from the testing.

9. Evaluation

The testing could have been made more reliable if more tests were carried out on both systems, during testing there was no change in voltage at the wheel speed sensor on the Bosch system from ignition on to constant wheel speed, where other groups had recorded a voltage increase. During testing of the Bosch system, it was not required to record the voltage measurement at all wheel speed sensors as the results would be identical for all the sensors, although this is assuming that all other wheel speed sensors are functioning correctly and are not defective. The testing could have been extended to record the voltage at the supply signal and ground of the other three sensors, this would increase the data retrieved and confirming all sensors functionality.

10. References

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