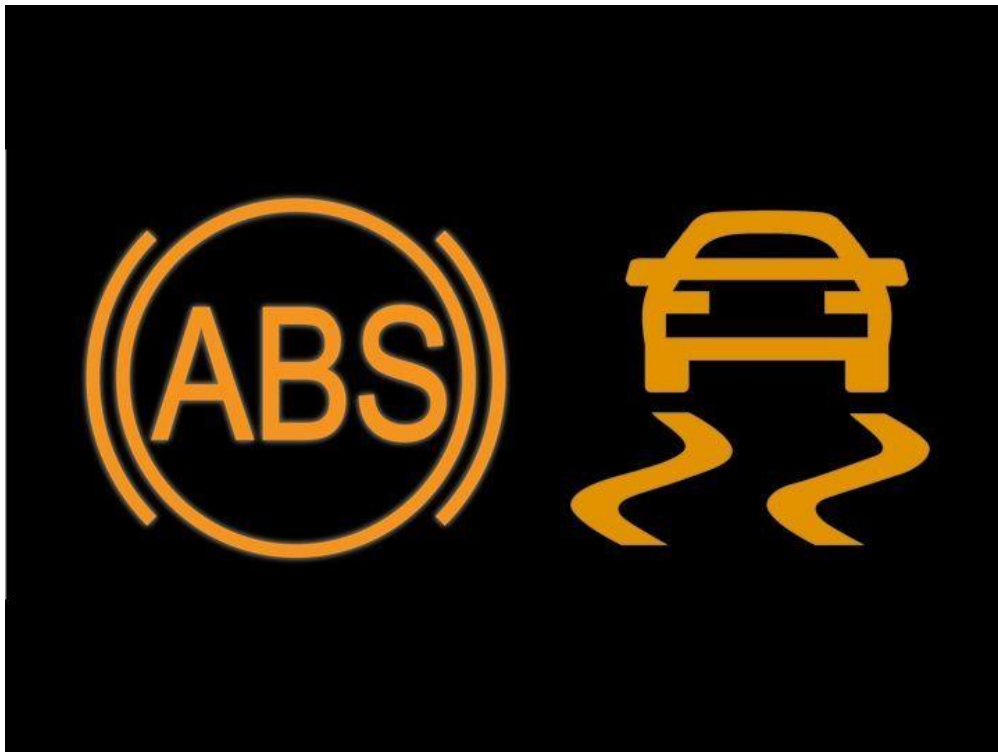

ANTI-LOCK BRAKING SYSTEMS

M5X02202



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2018/19

Abstract

This report will look into ABS (Anti-Lock Braking Systems), diagnostic techniques that can be applied when attempting to rectify a fault within an ABS system and compare two ABS systems from different manufactures. These ABS systems are the late 80's Bosch 2-EH and the mid 90's Teves Mk IV system. Data was collected and analysed via group testing to establish the key differences between the two systems and also to consider the strengths and weaknesses of both systems. It was found that, the Teves system allowed for better hydraulic control through the use of more solenoid valves, utilizing 2 for each wheel. The Teves system also incorporated traction control, as a further enhancement to the system. As time has progressed though ABS system design and control, ABS is forever advancing.

Contents

Abstract	1
List of Figures	4
1.0 Introduction	5
2.0 Research & Literature Review	6
2.1 Anti-Lock Braking Systems	6
2.1.1 Wheel Speed Sensors	6
2.1.2 ABS ECU	7
2.1.3 ABS Modulator	7
2.1.4 Valve block	7
2.2 The Bosch 2-EH ABS System	8
2.3 The Teves Mk IV ABS System	10
2.4 System Comparison	12
3.0 Equipment Used	13
3.1 Bosch 2-EH Test Rig	13
3.2 Teves Mk IV Test Rig	14
3.3 Bosch Diagnostic Centre	15
4.0 Methodology	16
5.0 Analysis	19
5.1 Bosch 2-EH ECU Data Plug Test Results	19
5.2 Bosch 2-EH 4-Pin Data Plug Test Results	22
5.3 Bosch 2-EH Solenoid Valve Data Test Results	23
5.4 Teves Mk IV Diagnostic Port Test Results	24
5.5 Waveform Analysis	27
5.5.1 Pin 4 & 2 Bosch 2-EH N/S/R Wheel Speed Sensor	27
5.5.2 Pin 9 Bosch 2-EH Brake Light Switch	29
5.5.3 Bosch 2-EH Rear Solenoid Valve	31
5.5.4 Bosch Rear Solenoid Valve, Higher Frequency	33
5.5.5 Pin 2 & 19 Teves Mk IV O/S/F Wheel Speed Sensor	34
5.6 Diagnostic Techniques and Procedures	35

6.0	Conclusion	36
7.0	Bibliography.....	37

List of Figures

Figure 1 Bosch 2-EH Schematic Diagram.....	9
Figure 2 Teves Mk IV Schematic Diagram	11
Figure 3 Bosch 2-EH Test Rig	13
Figure 4 Teves Mk IV Test Rig.....	14
Figure 5 Bosch Diagnostic Centre	15
Figure 6 Bosch 2-EH ECU	16
Figure 7 Bosch 2-EH ECU Data Plug	17
Figure 8 Bosch 2-EH ECU Data Plug Test Results	19
Figure 9 Bosch 2-EH 4-Pin Data Plug Test Results	22
Figure 10 Bosch 2-EH Solenoid Valve Data Test Results	23
Figure 11 Teves Mk IV Ecu Plug Test Results	24
Figure 12 Bosch N/S/R Wheel Speed Sensor waveform	27
Figure 13 Pin 9 Bosch 2-EH Brake Light Switch	29
Figure 14 Bosch 2-EH Rear Solenoid Valve	31
Figure 15 Bosch Rear Solenoid Valve, Higher Frequency	33
Figure 16 Pin 2 & 19 Teves Mk IV O/S/F Wheel Speed Sensor.....	34
Figure 17 Diagnostic Fault Tree	35

1.0 Introduction

The two ABS systems chosen for testing were the late 80's Bosch 2-EH system and the mid 90's Teves Mk IV system. Collection of data was obtained via group testing by Richard Osborne, Toby Marshall, Harrison Liddell, Dion Billing and Ashleigh Jones. Data was taken in the form of Voltages and Oscilloscope waveforms. The purpose of testing these two systems was to understand each systems operation and then to compare them to analyse their strengths and weaknesses. Diagnostic techniques will be utilized to produce a 'Fault Diagnostic Chart' that can be applied when attempting to rectify a fault within any given ABS system.

The two ABS systems were set up on a test rig to make data collection easier. All voltage readings were taken using a Bosch Oscilloscope Diagnostic Centre. The voltage readings were recorded by a member of the group (scribe) and were then entered into tables using Excel. The wave forms using the Bosch Oscilloscope Diagnostic Centre were printed off and scanned into the report with explanations analyzing the wave forms produced.

With all relevant data collected and both systems strengths and weaknesses considered, a broad understanding of ABS systems should be achieved. This will enable the ability to interrogate faults and create improvements to any given ABS system present or future.

2.0 Research & Literature Review

2.1 Anti-Lock Braking Systems

“This key safety feature is found on nearly all modern road cars. It was introduced in 1978 by Bosch and is now, in most instances, fitted as standard (mandatory in the EU from 2004)” as sourced from Hillier (2014, p.313)

The main purpose of ABS is to maintain steering response and vehicle stability at all times during heavy breaking or driver panic reaction regardless of road conditions. This allows the driver to steer away from an unanticipated obstacle safely while reducing speed rapidly. ABS systems make this possible by incorporating the use of numerous electronically controlled components. The main components are as follows.

2.1.1 Wheel Speed Sensors

As Hillier (2014) states, most wheel speed sensors use a magnetic pick up, attached to the hub, which reads the phonic wheel as it rotates. Each sensor takes a pulsed voltage reading which is sent back to the ECU. The ECU then converts this voltage reading into wheel speed so that it can determine whether a wheel is locking up. These analog sensors are gradually being replaced by Hall Effect sensors.

As Bauer, Beer and Cypra (1995, p.55) states “The ECU uses the signals (wheel frequencies) provided by the wheel-speed sensors as the basis for determining the wheels’ rotational speeds. The wheel-speed sensor’s pole pin with its external winding is located directly above the sensor ring, which is a type of pulse rotor joined directly to the wheel hub (wheel-speed sensor is also installed in the differential in some applications). The pole pin is connected to a permanent magnet producing an electrical field that extends outward to the sensor ring. As the ring turns, the pole pin is exposed to an alternating progression of teeth and gaps. This results in the magnetic field changing continuously so that a voltage is generated in the sensor’s winding, the frequency of which provides the precise index of the current wheel speed”.

2.1.2 ABS ECU

“This controls the system and is often found as part of a unit with the modulator. This makes constant calculations and commands the modulator to increase, decrease or maintain breaking pressure in order to use maximum breaking efficiency without locking the wheels” as stated by Hillier (2014, p.315)

2.1.3 ABS Modulator

The ABS modulator uses a series of solenoid valves. These valves can open or close hydraulic circuits between the master cylinder and brake calipers thus allowing pressure control in the brake lines. Internal reservoirs can enable pressure increases and decreases by holding fluid (Robert Bosch, 2007). These functions are pressure increase, pressure sustain and pressure release.

2.1.4 Valve block

This is where, governed by the ABS ECU, the pressure control takes place. The ECU uses information obtained via the frequency of pulse signal from the wheel speed sensor. This alerts the ECU if a wheel is locking or about to lock. The ‘pressure increase’ is achieved by the ECU sending a signal to the inlet valve solenoid in the Valve Block. This in turn opens the valve allowing hydraulic fluid to enter the pressurized line thus increasing brake pressure to that particular wheel. When the ABS ECU detects that the wheel is about to lock, the ECU sends a signal to the ‘Pressure Release’ valve solenoid. This then opens the pressure release valve and reduces the pressure in the hydraulic line. The wheel is then free to rotate once more. If the ECU receives a signal from the wheel speed sensor, during ABS intervention, that proves a sufficient reduction in wheel speed, the ECU will send a signal to the pressure increase solenoid to close the valve. This pressure will be held in the hydraulic line regardless of driver input until the system deems the vehicle speed safe enough to discontinue intervention, increase or reduce pressure, or if the driver releases the brake pedal. This is called ‘Pressure Sustain’. These actions take place in fractions of a second to maintain tyre grip while braking force is kept of the edge of wheel lock so to reduce the vehicle speed as quickly and safely as possible.

2.2 The Bosch 2-EH ABS System

“Thirty years ago, in June 1978, Bosch started series production of the ABS antilock braking system, laying the foundation for all active safety systems in the motor vehicle. The system prevents the wheels from locking, meaning that the vehicle remains stable even when braking hard, and the driver can take evasive action. With its electronic control, the system developed by Bosch was the first solution to be efficient and reliable enough to be used in vehicles.” As sourced from Bosch.co.jp (2019)

“After 14 long years of development, everything finally came into place in 1978: the system, known as ABS 2, went into series production at Bosch. It was first fitted as optional equipment in Mercedes-Benz's 'S-class' cars, and shortly afterwards in BMW's 7-series limousines.” As sourced from Bosch.co.jp (2019)

“The ABS function was further enhanced in 1986 by the TCS traction control system, and in 1995 by the ESP® electronic stability program - and once again, these systems were Bosch innovations. In 2007, more than three quarters of all new vehicles worldwide were equipped with ABS. At world market leader Bosch alone, some 21 million braking control systems will roll off the production lines in 2008.” As sourced from Bosch.co.jp (2019)

The Bosch 2-EH ABS system was most commonly found in Vauxhall vehicles of the late 80's and early 90's. These vehicles were the Astra F, the Calibra V6 and the Cavalier, all of which had the ABS systems updated around the early to mid-point of production to the Bosch generation 5.0 ABS system.

Below is an image of a Schematic Diagram of the Bosch 2-EH ABS Control System.

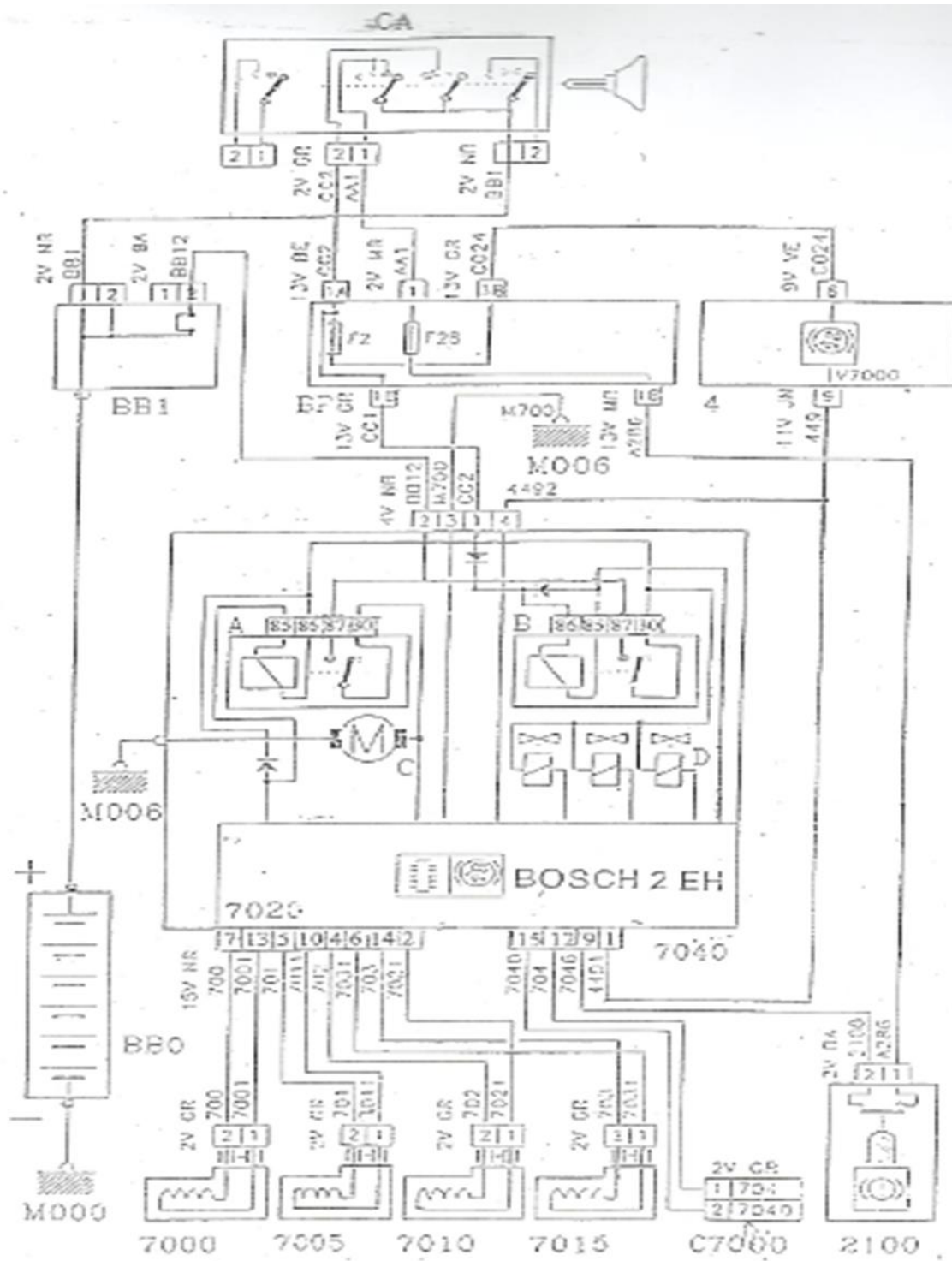


Figure 1 Bosch 2-EH Schematic Diagram

2.3 The Teves Mk IV ABS System

“The Mk IV system is similar in operation to the Mk II system and replaces it in many of the previous Mk II applications. However, this system uses a conventional master cylinder and power booster and a separate ABS solenoid and pump assembly to control the ABS hydraulic action. Like the Mk II the Mk IV ABS uses four input channels and three output channels.” As stated by Erjavec (2004, p.382)

“A TCS was added to the Teves Mk IV ABS on some GM cars in 1992. In 1993, Chrysler also began using LTCS with Teves Mk IV on some models. Unlike the Bosch systems, the Teves Mk IV with TCS controls the brakes only. Engine torque management is not used.” As stated by Owen and Eichhorn (2004, p. 279)

As Erjavec (2004, p.382) says “The low-speed traction control (LSTC) version of Teves IV includes two isolation valves or traction control valves. These are normally open, allowing flow and return of brake fluid from the master cylinder to the front calipers. When traction control is activated, the HCU delivers brake pressure to the caliper at whichever wheel is spinning. The isolation valve close to block the return of brake fluid to the master cylinder and allow brake pressure to build up at the spinning wheel.”

“Made by Continental/Teves (Teves was formerly owned by ITT Automotive), the Teves Mark 20 ABS system is the successor to the Teves Mark 4 ABS system, and features a more compact, integrated design that combines the electric pump, solenoid valves and controller into one assembly. The Mark 20 is 40 percent lighter than the Mark 4 system, has traction control capability and is less expensive to manufacture. It is a nonintegral ABS system that can be configured for either three- or four-channel operation on front- or rear-wheel drive vehicles.” As sourced from Aa1car.com (2019)

Below is an image of the Teves Mk IV ABS ECU Schematic Diagram.

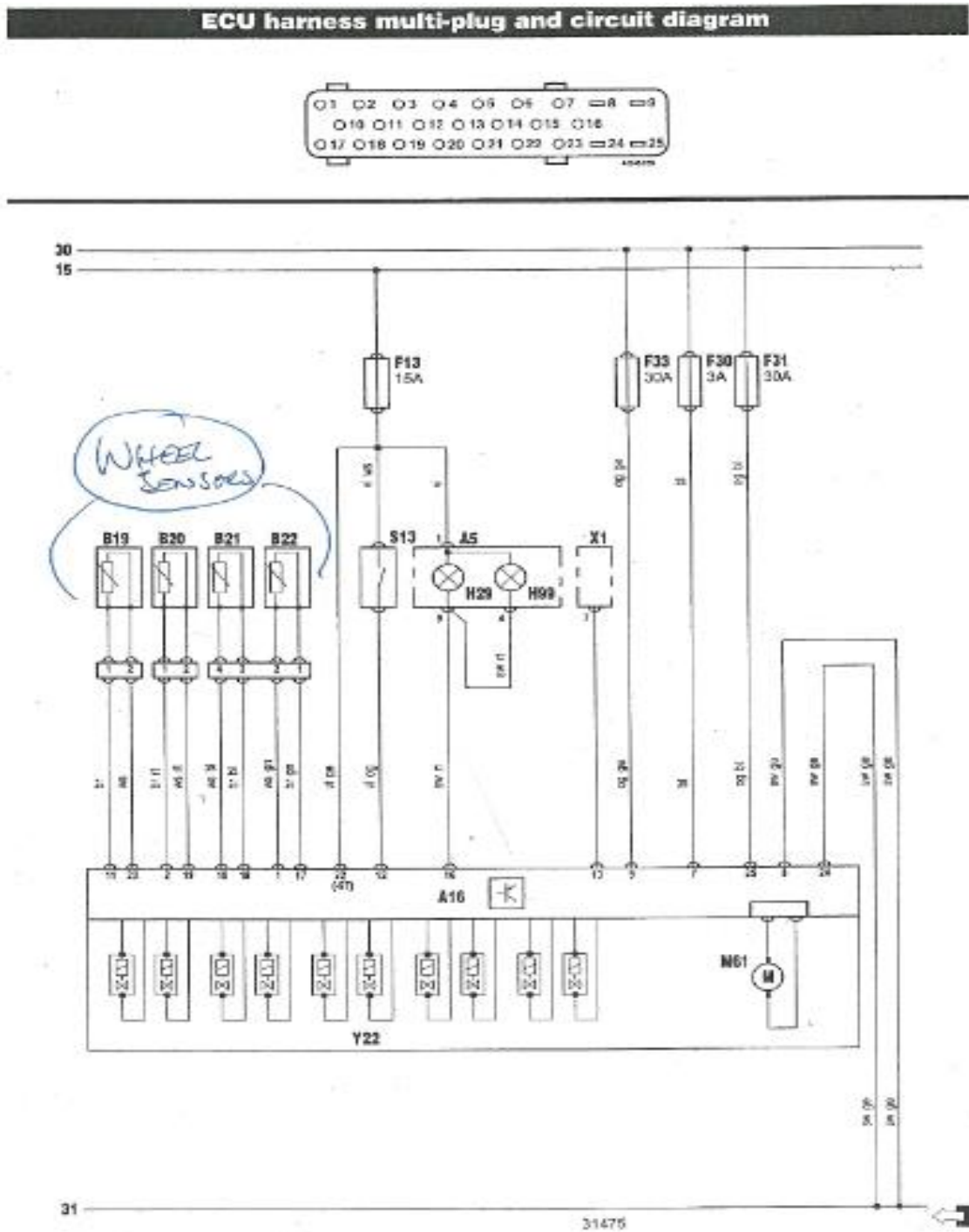


Figure 2 Teves Mk IV Schematic Diagram

2.4 System Comparison

The Bosch 2-EH ABS system uses 3 hydraulic solenoids as opposed to the Teves Mk IV system which uses 10. The 3 solenoids on the Bosch system uses only 1 solenoid to control both rear wheels, and the other 2 solenoids control 1 front wheel each. Although only 3 solenoids control the hydraulic system, it is a 4-channel system. As explained by Erjavec (2004, p. 442) channels are “Individual legs of the hydraulic system that relay pressure from the master cylinder to the wheel cylinder”, the need for this system to be 4-channel is due to the diagonal split of the braking system requiring independent wheel control. The 10 solenoids in the Teves system however, gives the system the advantage of better hydraulic pressure control, by using 2 solenoids per wheel cylinder and 2 isolation valves. These valves isolate the front brakes from the master cylinder and rear wheel circuit. This is because traction control is used in the Teves system, thus allowing a more efficient and effective means of increasing and reducing the vehicle speed safely and rapidly.

A disadvantage of the Teves system, is that it houses more of its components internally of the control module as opposed to the Bosch system. While this makes for a compact unit taking up less space in the engine bay, it also means that testing of solenoids is unachievable. This also results in the replacement of a complete module, instead of being able to fix or replace certain parts, which is deemed very costly in comparison the Bosch system.

The Teves system is compatible with OBD2, meaning that, the vehicles it was fitted to are equipped with Catalytic Converters and Lambda Sensors to reduce emissions. This, as found today, is a massively important factor to current and future vehicles being produced. The Bosch system was only compatible with OBD1 systems which did not house these emission reducing components. Unfortunatly this meant that a new form of ABS system had to be produced to work along-side ever changing emission laws.

3.0 Equipment Used

3.1 Bosch 2-EH Test Rig

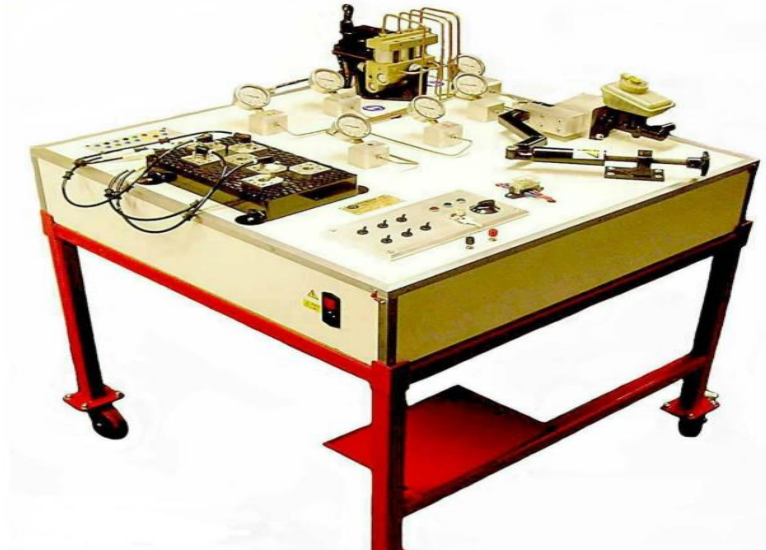


Figure 3 Bosch 2-EH Test Rig

A fully operational Anti-Locking Braking System Training Rig (ABS unit mounted on a trolley stand with castors) which allows the observation of a working Anti-Locking Brake system via pressure gauges in the brake circuit. It includes a Bosch 2EH system, complete with ABS pump, electronic control unit, wheel sensors, master cylinder, diagnostic socket and comes complete with 6 integral fault switches to aid diagnostic testing. It is self-contained, realistic and able to simulate, skid or wheel lock with road speeds up to 160KM/H.

Pin-Out facility on sensors and actuators.

(Agblock.co.uk, 2019)

3.2 Teves Mk IV Test Rig



Figure 4 Teves Mk IV Test Rig

A fully operational Anti-Locking Braking System Training Rig (ABS unit mounted on a trolley stand with castors) which allows the observation of a working Anti-Locking Brake system via pressure gauges in the brake circuit. It includes a Teves Mk IV system, complete with ABS pump, electronic control unit, hall effect wheel sensors, master cylinder, diagnostic socket and comes complete with 6 integral fault switches to aid diagnostic testing. It is a self-contained, realistic and be able to simulate, skid or wheel lock with road speeds up to 160KM/H.

Pin-Out facility on sensors and actuators.

(Agblock.co.uk, 2019)

3.3 Bosch Diagnostic Centre



Figure 5 Bosch Diagnostic Centre

The Bosch Diagnostic Centre provides versatile and reliable fault diagnosis. It is a complete system with measurement module and PC system in trolley. The Bosch FSA 740 comes equipped with around 50 pre-set component tests, a high-performance oscilloscope and exhaust gas modules for gasoline and diesel vehicles can also be added if needed.

It has a convenient display of actual values from control unit diagnosis in FSA software in combination with KTS module and the software has test steps and component tests for checking vehicle electronic and electrical systems. It also has optional testing of electrically driven and hybrid vehicles in combination with FSA 050. The menu is concise and clearly arranged, quick and easy software routines (thanks to test steps) with optional vehicle-specific reference values. It also saves time in situ checking of components.

(Uk-ww.bosch-automotive.com, 2019)

4.0 Methodology

The system testing was carried out in groups of 5 and both of the systems were tested on the same day. Each system was setup on a training rig to allow for easy, efficient and accurate testing of the systems. The first of the systems tested was the Bosch 2-EH.

Before the commencement of any testing, health and safety precautions had to be adhered to. All students participating in live testing activities had to be wearing appropriate PPE (personal protective equipment). This consisted of a pair of safety boots with steel toe caps and a dust coat. Any loose clothing or jewelry had to be removed as well as tying back long hair.

With all students correctly obeying the Health & Safety rules, the Bosch Oscilloscope Diagnostic Centre was set up. Both ABS systems were earthed via an earth strap located on the side of each test rig, the Bosch oscilloscope was earthed by connecting its own earth lead (black/ground) to this strap.

When the testing was ready to be carried out, the tasks required needed to be understood fully. Voltage readings were to be taken from the ABS ECU Plug, the 6 Solenoid valve Terminals and the 4-Pin Data Plug, all located on the body of the ABS ECU. The image below shows the ECU plug to the right, the 6 terminals for the 3 solenoid valves on the left and the 4-pin data plug connection at the bottom left. There is also a list to the right-hand side labeling the image.

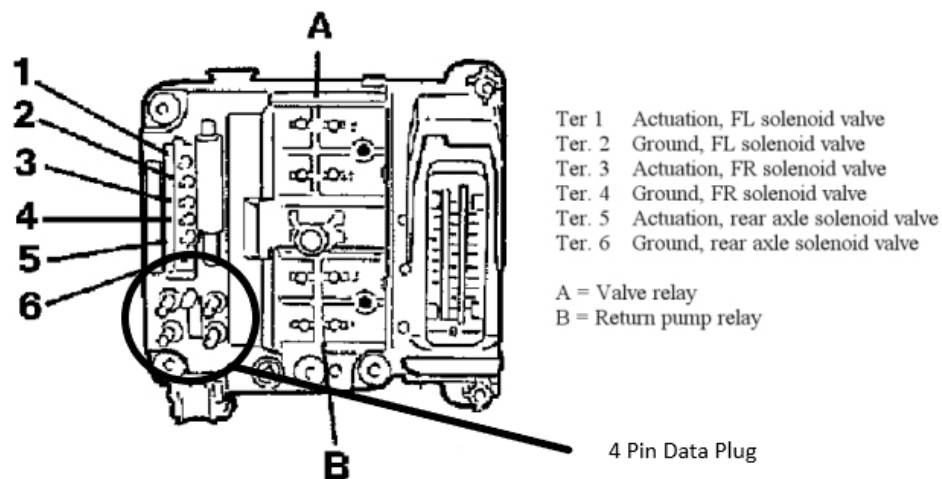


Figure 6 Bosch 2-EH ECU

(Clubcalibra.net, 2019)

The image shown below displays the wiring harness connector plug on the left, and to the right is a list of data found at each pin location 1-15.

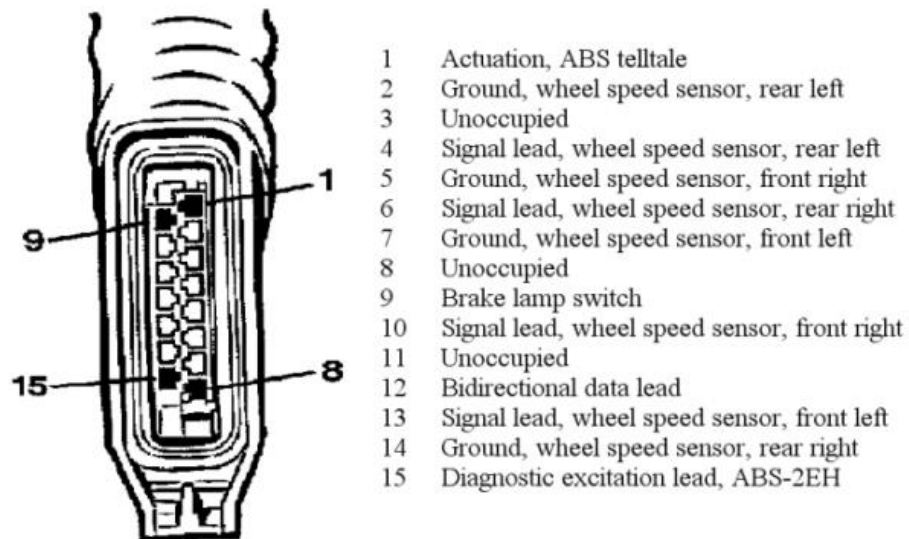


Figure 7 Bosch 2-EH ECU Data Plug

(Clubcalibra.net, 2019)

Using the Bosch Oscilloscope diagnostic Centre and a paper clip (attached via crocodile clip) it was possible to probe through the different pin locations on the plugs and terminals.

Using the live test lead (red) the various points of the ABS ECU could be tested, one at a time, this job was carried out by Harrison Liddell. Each voltage reading was recorded on paper by Dion Billing (Scribe) in three forms: Ignition Off, Ignition On and system running. This allowed for the full ABS system's data to be analysed at a later date.

Toby Marshall was given the job of activating the ABS systems at different key positions (Ign off, on, system running) while Ashleigh Jones assisted in observing voltage data retrieved and oscilloscope waveforms visible on the monitor. As the data was being obtained through the different system activations, Richard Osborne was also observing and reporting voltage readings and when the ABS systems were running, adjusted the system brake pedal pressure.

With all relevant data collected from the 3 key areas of the Bosch ECU, the testing of the 2nd system, Teves Mk IV, could begin.

The Teves Mk IV ABS system was tested in the same way as the Bosch 2-EH system with fewer places to collect data from. The Teves system is an all in 1 built in ABS module meaning that all of the relevant data could be collected from the 1 ECU plug located on the body of the ABS Module. The Teves system had a 25 pin ECU plug as opposed to the Bosch system's 15.

5.0 Analysis

5.1 Bosch 2-EH ECU Data Plug Test Results

The first point of the Bosch 2-EH ABS System to be tested was the Main ECU Plug. This plug housed 15 pin locations (Fig. 7). If no fault is present in the ABS system, the MIL light will come on with the ignition and once the system is running it will turn the MIL light off. The table below shows the recorded testing data obtained.

Pin Number	Ignition On (V)	Ignition Off (V)	Running (V)
1	11.88	0	11.75
2	0.2	0	0.25
3			
4	0.29	0	1.25
5	0.2	0	0.25
6	0.2	0	1.25
7	0.2	0	0.25
8			
9	11.88	0	11.75
10	0.2	0	1.25
11			
12	10.68	0	10.51
13	0.2	0	1.25
14	0.2	0	0.25
15	0.2	0	0.25

Figure 8 Bosch 2-EH ECU Data Plug Test Results

The 'Ignition Off' column shows that all pin locations register 0v. This is because with the Ignition off, the system is receiving no power.

- Pin 1 – ABS MIL Light – With both the ignition on and system running, the table shows that there is a voltage supply. This is to ensure that any faulty information received by the ECU will instantly put the MIL light on to warn the driver that a fault is detected in the system.
- Pin 2 – N/S/R wheel speed ground – At all 'Wheel Speed Sensor Ground' pin locations, it was found that the voltage reading was 0.2v with ignition on and 0.25v

with the system running. A voltage is sent to the sensor from the ECU via the signal wire. This voltage passes through the wheel speed sensor and returns to the ECU as a system check (with ignition on). The higher voltage created as a result of the magnetic field produced within the sensor (system running) is then returned to the ECU. After the ECU has received the return voltage and calculated the wheel speed the voltage is then grounded.

- Pin 3 – Unoccupied
- Pin 4 – N/S/R wheel speed signal – The voltage recorded at Pin 4 displays a slightly higher reading than the other signal voltages, 0.29v, with the ignition on. This could be due to early signs of a failing wheel speed sensor. As a result, a higher resistance could be occurring within the wheel speed sensor itself. In this case the ECU could be sending a higher signal voltage to overcome the higher resistance in the wheel speed sensor. With the system running, the voltage increases to 1.25v. This is because of the magnetic field created within the wheel speed sensor as the vehicle speed increases.
- Pin 5 – O/S/F wheel speed ground – Same as Pin 2
- Pin 6 – O/S/R wheel speed signal – The voltage measured at Pin 6, and the other signal wire pin locations, was 0.2v with ignition on and 1.25v with the system running. This higher voltage, with the system running, is due to the speed of the trigger wheel (wheel speed) creating a larger magnetic field in the wheel speed sensor and therefore creating a higher voltage signal.
- Pin 7 – N/S/F wheel speed ground – Same as Pin 2
- Pin 8 – Unoccupied
- Pin 9 – Brake Light Switch – The voltage recorded at Pin 9 was battery voltage. This is 11.88v with the ignition on and a slight drop to 11.75v as the system is running. The slight drop in voltage is due to the drain on the battery created by running the system. Battery voltage is found here due to the brake light switch having 2 purposes. Firstly, it has to complete the brake light circuit and illuminate the rear lights. Secondly, it sends a voltage to the ABS ECU to alert the system that the brake pedal is being depressed.
- Pin 10 – O/S/F wheel speed signal – Same as Pin 6
- Pin 11 – Unoccupied
- Pin 12 – Serial Data Wire – At Pin 12 with the ignition on, 10.68v was measured. With the system running, this voltage dropped slightly to 10.51v. This is because

of the transferring of data. The Serial Data Wire sends measured and calculated voltages to the other vehicle control units to inform them of what is happening within the system. The engine ECU, ABS ECU, Dash Panel and various other control units talk to each other constantly. This form of communication system is called the 'Data Bus'.

- Pin 13 – N/S/F wheel speed signal – Same as Pin 6
- Pin 14 – O/S/R wheel speed ground – Same as Pin 2
- Pin 15 – Diagnostic Excitation Lead – The voltage measured here, at Pin 15, was 0.2v with the ignition on and 0.25v with the system running. This is the data link for diagnostic tools when connecting suitable diagnostics to the vehicle when attempting to interpret a fault in the system.

5.2 Bosch 2-EH 4-Pin Data Plug Test Results

Another component for testing, is the 4-Pin Data plug. This data plug was used as communication line to the dash board to alert the driver to a fault within the system. The table of results below indicates what was found at the time of test.

Pin Number	Ignition On (V)	Ignition Off (V)	Running (V)
1	11.79	0	11.75
2	12.04	0	12
3	0	0	0
4	11.79	0	11.79

Figure 9 Bosch 2-EH 4-Pin Data Plug Test Results

- Pin 1 - Key/Ignition - It can be seen that with the ignition on and when the system was running, near battery voltage was displayed. This is showing that the system is active.
- Pin 2 - Battery - Battery Voltage is shown here displaying the live feed to the system is sufficient.
- Pin 3 – Earth – This shows 0v in all aspects of testing proving no resistance in the systems grounding.
- Pin 4 – Communication Line/MIL Light – The voltage shown at Pin 4, in both the ignition on and system running stages, indicates a strong connection with no loss of voltage. This indicates that there is no resistance in the communication line between the ABS ECU and the Dash Panel, meaning that, as soon as a fault in the system is found, the driver will know about it. This voltage would ground if a fault was present, turning on the MIL light.

5.3 Bosch 2-EH Solenoid Valve Data Test Results

The Bosch 2-EH ABS system used for testing, had 3 Solenoid Valves, 1 for each front wheel and 1 for **both** rear wheels. The system was a 4-channel system, meaning that, there was a wheel speed sensor fitted at each wheel. A 3-channel system would commonly be found on a vehicle with a differential on the rear axle and therefore would incorporate 1 speed sensor for the rear, mounted on the diff.

6 solenoid terminals (2 for each solenoid), were found separate to the main ABS ECU plug. The wires to these terminals consisted of, 1 green, 2 yellow and 3 black wires, in sequence of green-black, yellow-black, yellow-black. The first pair of wires tested (green-black) were for the solenoid acting for the rear wheels and the other combinations of wires tested were for the 2 solenoids working at the front wheels (fig. 6).

The table below shows the data obtained from the solenoid terminals. The reason there are 2 solenoids for the front, is to aid the larger braking effort that occurs due to the sudden weight distribution shift to the front wheels under heavy braking. Also, it is because of the 2-EH systems reliance on the front wheel speeds to govern ABS intervention and maintain the steering response and stability.

Wire Colour	Ignition On (V)	Ignition Off (V)	Running (V)
Green	12.08	0	12.04
Black	12.08	0	11.96
Yellow	12.08	0	11.96
Black	12	0	11.96
Yellow	12	0	11.96
Black	12	0	11.96

Figure 10 Bosch 2-EH Solenoid Valve Data Test Results

The voltages obtained throughout this test provides evidence that with the ignition off there is no power getting to the ABS unit. While with the Ignition on/system running the voltages are relatively consistent throughout. The minor drops in voltage are due to the battery usage with the ignition on/system running. On a whole, the ABS system proves ready and willing to intervein whenever the driver calls for it.

5.4 Teves Mk IV Diagnostic Port Test Results

The table below shows the test results recorded from the Teves Mk IV ABS System.

Pin Number	Ignition On (V)	Ignition Off (V)	Running (V)
1	0	0	0.25
2	0	0	0.25
3			
4			
5			
6			
7	12.2	12.2	12.2
8	0	0	0
9	12.2	12.2	12.2
10	0	0	0.25
11	0	0	0.25
12	11.99	0	11.99
13	9.28	9.28	9.28
14			
15			
16	11.99	0	11.99
17	0	0	1.25
18	0	0	1.25
19	0	0	1.25
20	0	0	1.25
21			
22			
23			
24	0	0	0
25	12.2	12.2	12.2

Figure 11 Teves Mk IV Ecu Plug Test Results

The voltages found at each pin location are as follows.

- Pin 1 – Pins 1, 2, 10 & 11 are for all wheel speed sensor grounds. The voltage readings obtained during testing were 0v with ignition on and 0.25v with the system running. The 0v reading with ignition on is because, although the ABS ECU is getting a voltage via terminal 15 (ignition) (Fig. 2), it is not sending a test voltage to any of the wheel speed sensors. The system self-test carried out by the Teves

ABS system is performed with the system running. This will cause the ABS and Traction Control warning lights to appear on the dash panel momentarily when the vehicle starts up. Once the system has satisfied its requirements with no faults detected, the warning lights will disappear from the dash panel. This normally takes around 3 seconds.

- Pin 2 – O/S/F wheel speed sensor ground
- Pin 3 – Unoccupied
- Pin 4 – Unoccupied
- Pin 5 – Unoccupied
- Pin 6 – Unoccupied
- Pin 7 – Pin 7, when tested, was showing battery voltage of 12.2v. This is because this pin location, along with Pin 9 & Pin 25, is a permanent live feed from terminal 30 (Battery +) (Fig. 2). This ABS system has permanent live feeds so that it can store a fault memory and maintain a data link between other control units throughout the vehicle. This permanent voltage is present in all forms of testing (ignition on/off/system running).
- Pin 8 – Ground/Battery -
- Pin 9 – Permanent live
- Pin 10 – N/S/R Wheel speed sensor ground
- Pin 11 – N/S/F Wheel speed sensor ground
- Pin 12 – Pin 12 is representative of the Brake Pedal Position (BPP) Switch or brake light switch. The voltages obtained at this pin location were 11.99v (ignition on), 0v (ignition off) and 11.99v (system running). This is so that as soon as the driver is in the car and pressing the brake the brake lights work and more importantly, the ABS system knows at its earliest possible point that the brake pedal is being operated.
- Pin 13 – Pin 13 shows 9.28v throughout all stages of testing. A permanent voltage is required for this pin location as it is power to the Data Link Connector (Diagnostic port). This voltage assists in powering up the diagnostic equipment and also it is its serial data link between the ABS ECU and the diagnostic machine.
- Pin 14 – Unoccupied
- Pin 15 – Unoccupied
- Pin 16 – The voltage reading taken at Pin 16 was 11.99v. This voltage was recorded in the ignition on and system running stages. No voltage was found with the

ignition off. This is due to this pin location being the link between the ABS ECU and the Dash Panel. This connection is a means of data link to illuminate the ABS and Traction Control warning lights when a fault is found within the system.

- Pin 17 – Pins 17,18,19 & 20 are the wheel speed sensor signals. The voltages found at these sensors with the ignition on and off are 0v, but with the system running the voltages obtained are 1.25v. This is due to the voltage received via the ABS sensor and, as stated before (5.1), this voltage will increase with wheel speed (trigger wheel) speed.
- Pin 18 – N/S/R wheel speed sensor signal
- Pin 19 – O/S/F wheel speed sensor signal
- Pin 20 – N/S/F wheel speed sensor signal
- Pin 21 – Unoccupied
- Pin 22 – Unoccupied
- Pin 23 – Unoccupied
- Pin 24 – Ground/Battery-
- Pin 25 – Permanent live

5.5 Waveform Analysis

In this section, each waveform shows what is occurring at each point throughout the testing. Each of these points will be explained. The lack of waveforms produced by the Teves ABS system is due to the components being internal of the ecu restricting the vast measurements.

5.5.1 Pin 4 & 2 Bosch 2-EH N/S/R Wheel Speed Sensor

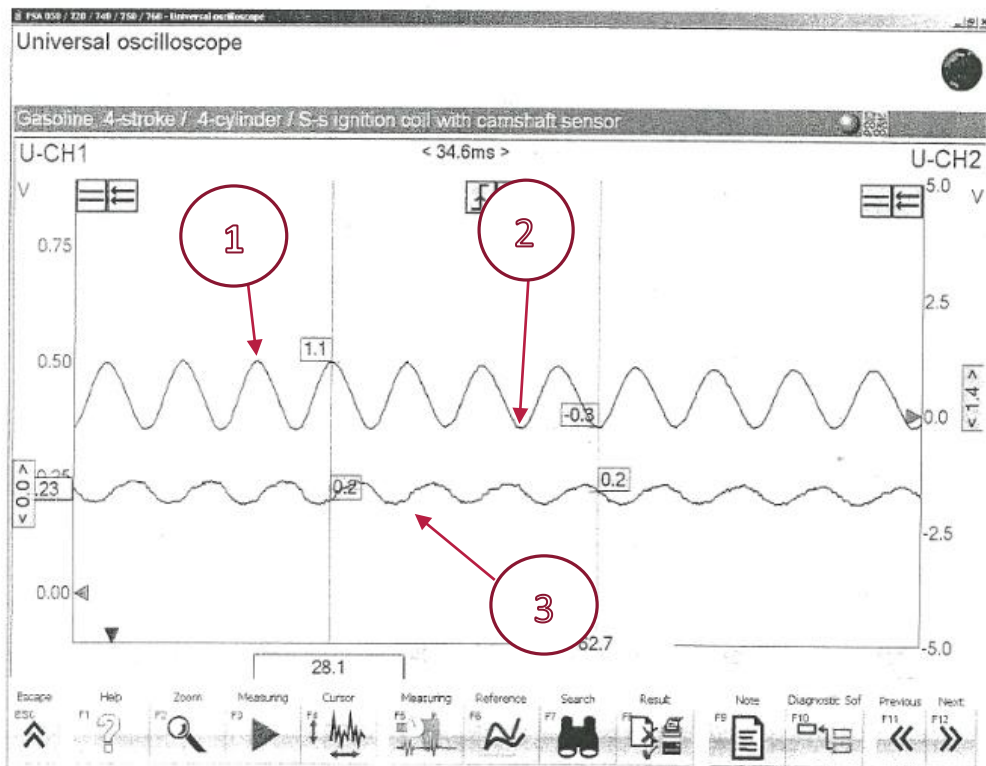


Figure 12 Bosch N/S/R Wheel Speed Sensor waveform

This waveform shows the signal received by the oscilloscope during testing of the Near-Side Rear (N/S/R) Wheel Speed Sensor on the Bosch 2-EH ABS System (Fig. 12). As can be seen, there are 2 waveforms appearing in the graph. The upper, larger, waveform was measured at the ECU from the 'Signal' wire of the sensor. This is, therefore, the wheel speed sensor signal received by the ECU. It is apparent that the voltage is increasing (point 1, 1.1V) and decreasing (point 2, -0.3V) continually. This is because this inductive pulse sensor runs on an 'Alternating Current' (AC) circuit and displays an AC voltage. This AC voltage is occurring due to the 'Electric Magnetic Field' (EMF) constantly growing and reducing inside the sensor. This happens because the reading taken by the sensor is from the Reluctor Disc/Phonic Wheel (Toothed wheel consisting of 'teeth and gaps' re-occurring) attached to the drive shaft or wheel bearing. As a tooth on the Reluctor Disc passes the sensor, the EMF increases (point 1, Fig. 12). As this tooth passes and the air gap becomes present (point 2, Fig. 12), the EMF decreases. If the vehicle were to speed up, the frequency of these voltage changes would increase, meaning that, the rise and fall of voltage would occur a lot more in the wave form provided.

Point 3 (Fig. 12) on the waveform is the signal from the ground/Earth wire from the sensor. It displays a voltage reading of 0.2V.

5.5.2 Pin 9 Bosch 2-EH Brake Light Switch

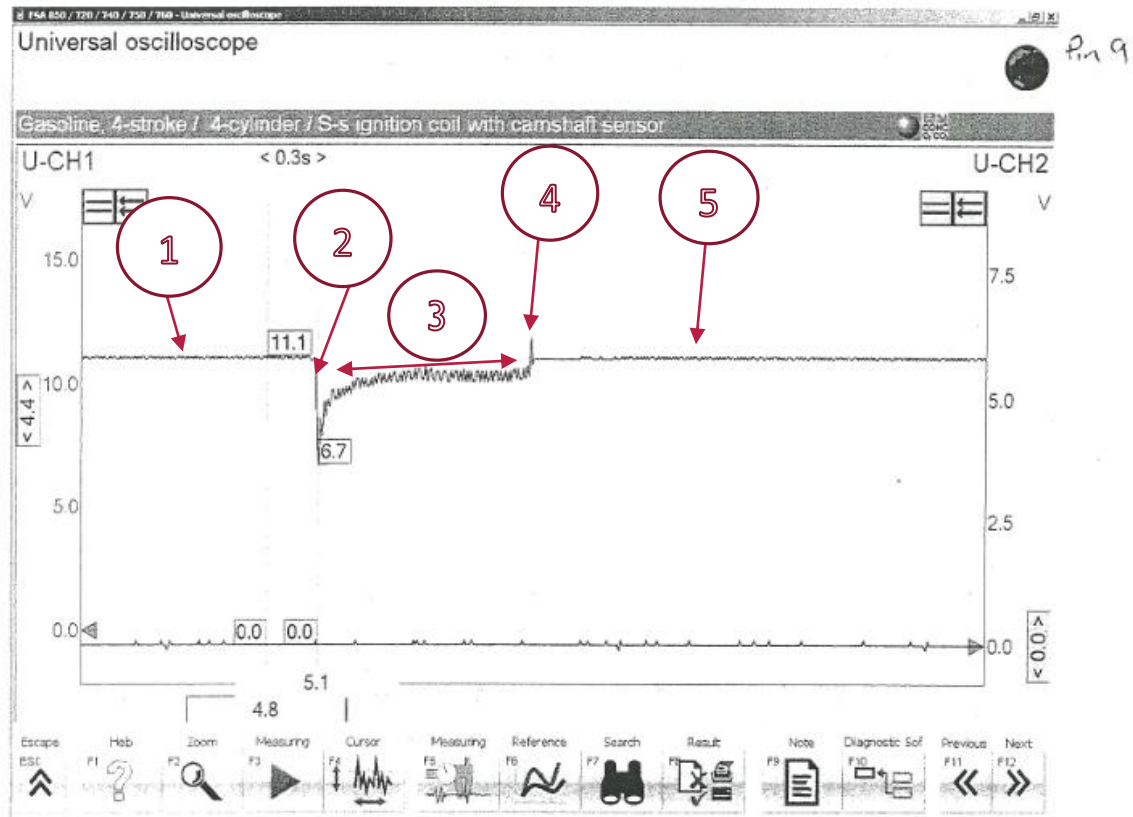


Figure 13 Pin 9 Bosch 2-EH Brake Light Switch

A Brake Light Switch maintains an open circuit until the brake pedal is depressed. At this point the contacts in the circuit are connected, completing the circuit, the brake lights illuminate, and a signal is sent to the numerous ECU's that require this information to act if required, such as, the ABS, Cruise Control and so on.

At point 1, a potential voltage can be seen of 11.1V. At point 2, the brake pedal has been depressed causing a small loss in voltage from 11.1v, down to 6.7v, this is due to the sudden completion of the circuit. Point 3 Shows the oscillations that have occurred as part of this shock and the time that the brake pedal has been held for. At point 4 the brake pedal has been fully released and at point 5 voltage has settled back to potential voltage.

An Oscilloscope is not normally required to test a brake light switch because it is a relatively simple component to test. This can be done using a normal multi-meter or a test light. Brake light switches normally only have 2 wires going to them, one of which will show voltage in and the other should show 0V coming out. When the brake pedal is depressed, completing the circuit, the voltage should pass through the sensor and a voltage should be shown at each pin location on the connector. If using a test light to check this sensor, the test light should illuminate on both pins with the brake pedal depressed, if not, the sensor is faulty due to the circuit not being completed by the brake light switch.

5.5.3 Bosch 2-EH Rear Solenoid Valve

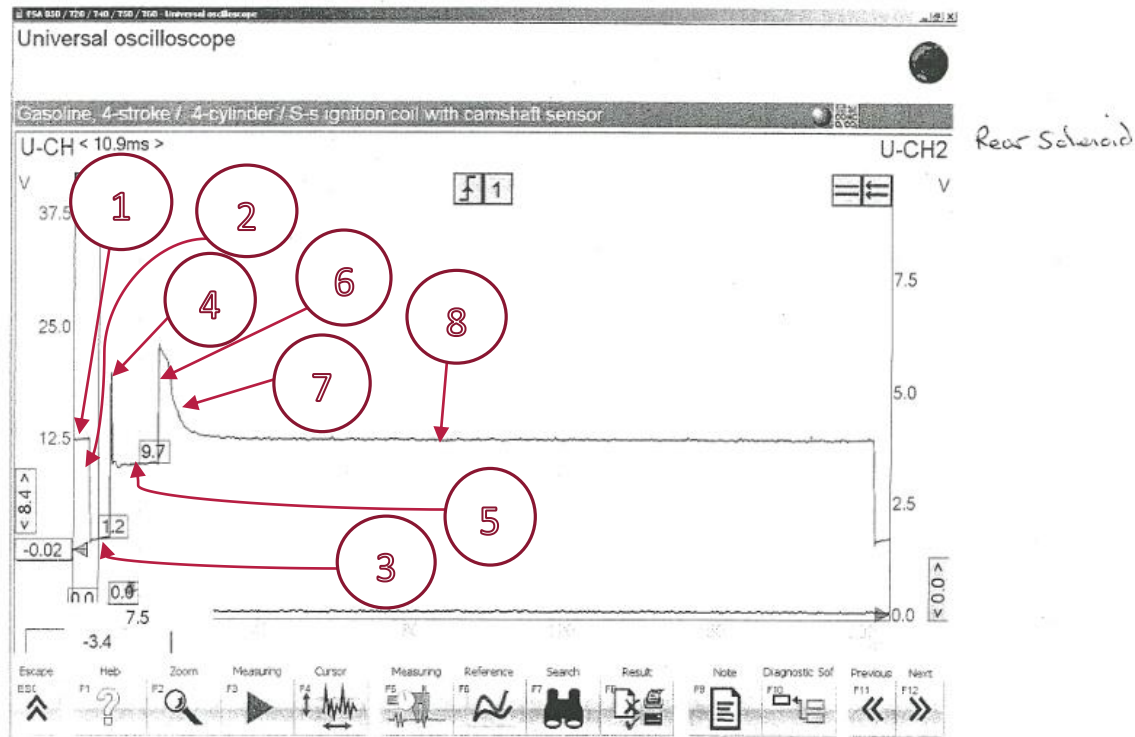


Figure 14 Bosch 2-EH Rear Solenoid Valve

This waveform displays a single pulse of the solenoid acting for the rear wheels in the Bosch 2-EH system. The capturing of this pulse, being close to the left-hand side, makes it difficult to see properly but, at point 1, it can just about be seen that there is a potential voltage of 12.5V. At point 2, this voltage has been grounded by the ECU, turning on the solenoid and energizing the internal coil. At point 3, the solenoid is on, causing the internal coil to create a magnetic field, opening the valve and allowing hydraulic fluid into the system. While the solenoid is on it is pressurizing the hydraulic system. This is due to ABS intervention under initial heavy braking. At point 4, the solenoid is shut off creating a back EMF of around 20V. This is caused by the collapse of the magnetic field that was generated during the solenoid on time. At point 5 the voltage can be seen to level out, but below the potential voltage. This is known as pressure sustain, where the ECU has decided to hold this pressure caused in the pressure increase stage of points 2,3 & 4. At

point 6 the solenoid is shut down again, this creates another back EMF of around 23V. This, in-turn, releases the high pressure in the hydraulic line allowing the wheels to turn freely once again. At point 7, it can be seen that the voltage is returning to potential voltage as can be seen at point 8.

5.5.4 Bosch Rear Solenoid Valve, Higher Frequency

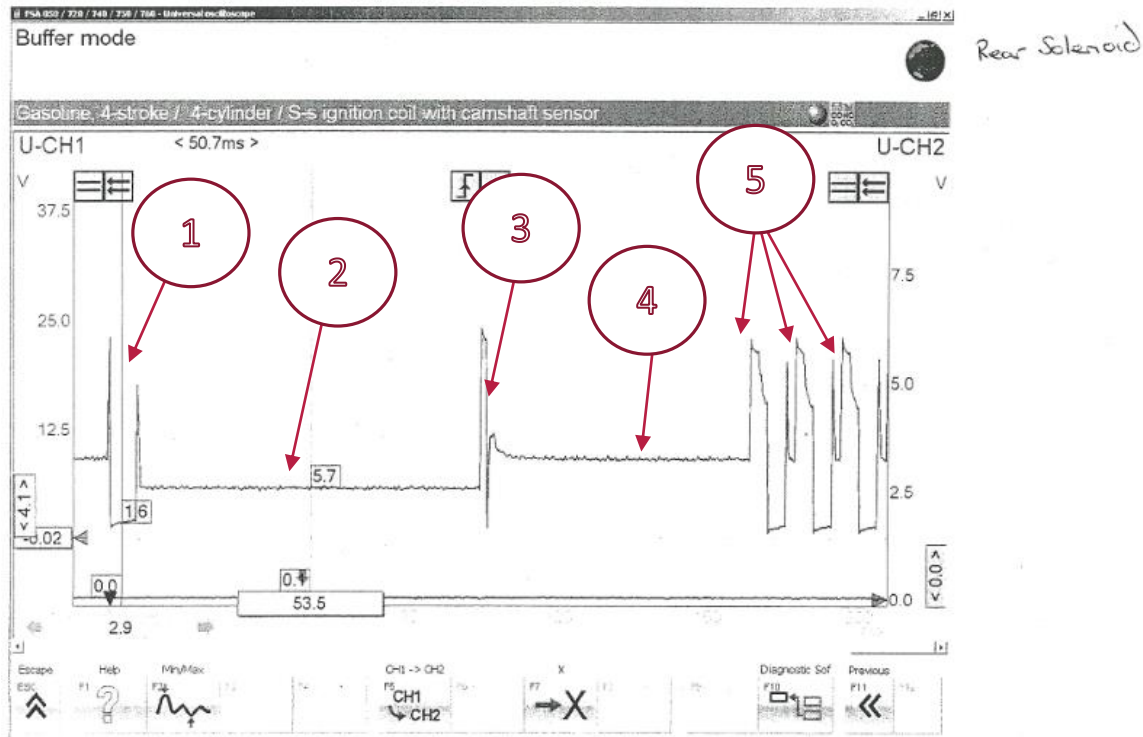


Figure 15 Bosch Rear Solenoid Valve, Higher Frequency

As can be seen in this waveform, the solenoid for the rear wheels is being activated continuously. This is displaying that the ABS intervention is occurring for a longer period than in the previous waveform. At point 1, the first pulse of the rear solenoid is occurring. At point 2, the pressure sustain time is longer, lasting 5.7 milli seconds (m/s). At point 3, the solenoid is switched off, point 4, potential voltage resumes and at point 5, multiple pulses are occurring. This waveform shows the various pulses in operation to maintain wheel rotation on the edge of wheel lock up. As Hillier (2014, p. 313) suggests “The cycle will occur over and over to maintain grip and stability with the pressure release-apply-release-apply sequence occurring up to 16 times per second.”

5.5.5

Pin 2 & 19 Teves Mk IV O/S/F Wheel Speed Sensor

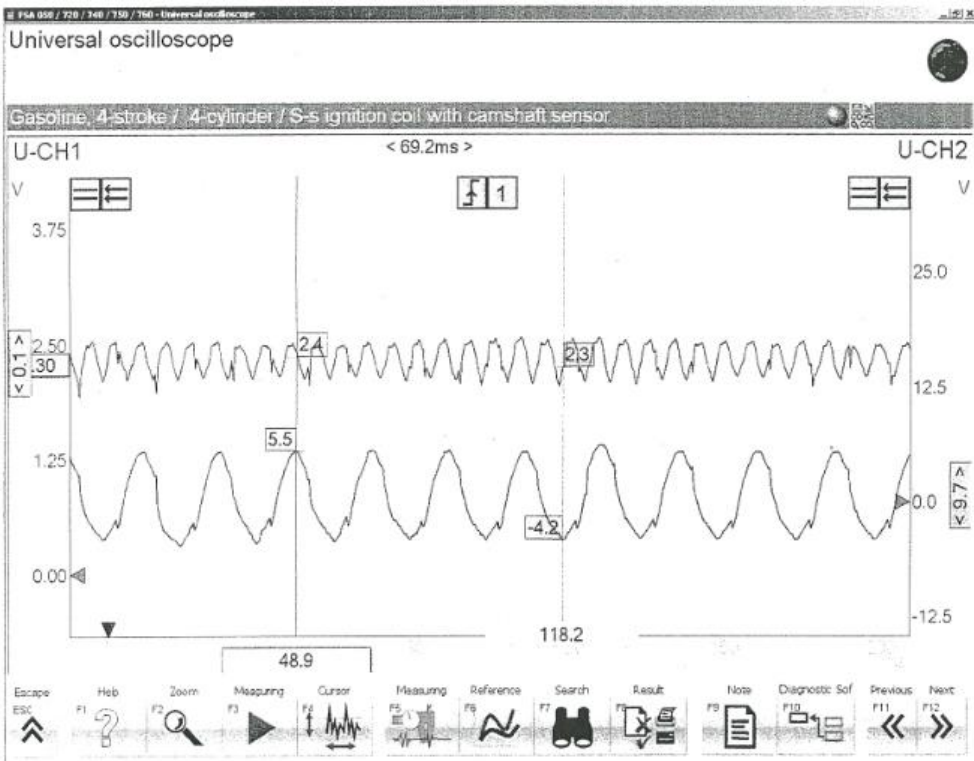


Figure 16 Pin 2 & 19 Teves Mk IV O/S/F Wheel Speed Sensor

This waveform shows the Off-side Front Wheel Speed Sensor output measured at pin2 & 19 of the Teves ABS ECU. This waveform is much the same, in appearance, as the Bosch waveform of the N/S/R wheel speed sensor, the key differences being the measurement was obtained at a slightly higher frequency and the ground frequency being higher than the signal.

5.6 Diagnostic Techniques and Procedures

Before carrying out any form of diagnostic checks, it is imperative that a general knowledge is understood of the systems being worked upon. Along with this, a visual inspection of relevant system components should be carried out to insure the overlooking of obvious faults doesn't occur. This can be deciphered by warning lights on the dash and customer complaint.

Below is a Diagnostic Fault Tree that shows the processes that can be adhered to, on ABS Systems, in the challenge to obtain correct and quick diagnosis of system faults.

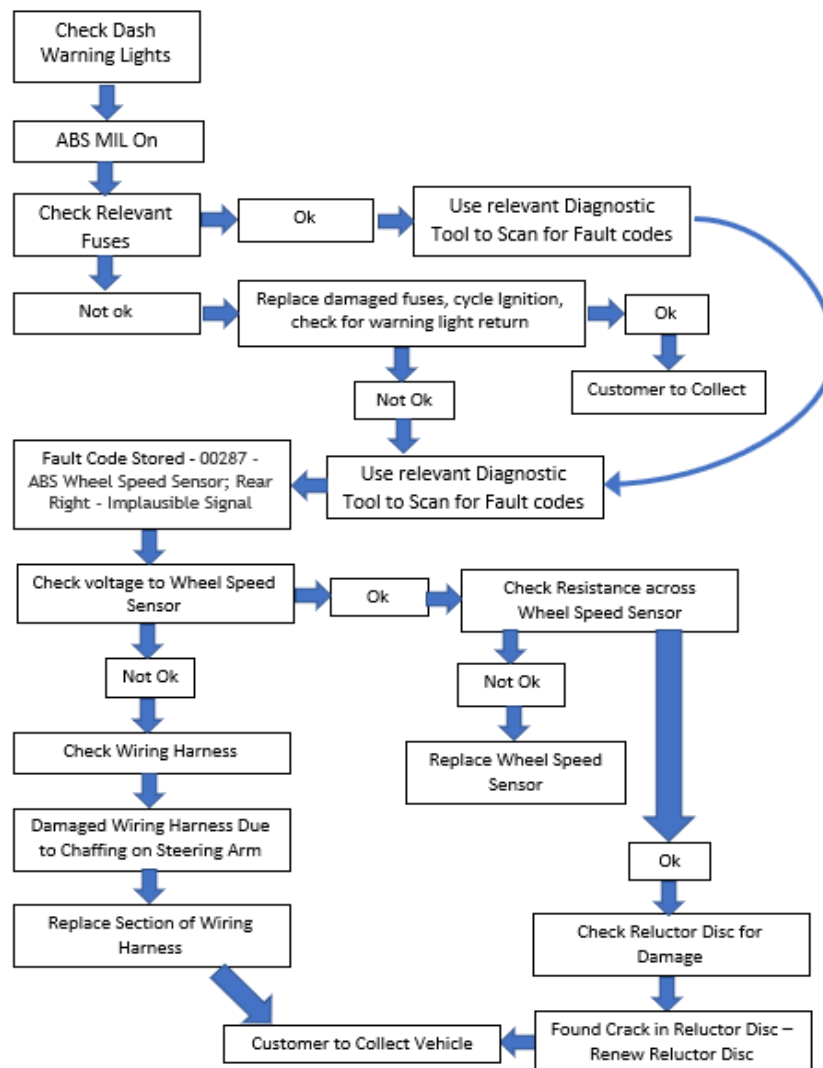


Figure 17 Diagnostic Fault Tree

6.0 Conclusion

It was found that the Bosch 2-EH ABS system was primitive in comparison to the Teves ABS system. This is evident in its capability of hydraulic pressure control and presentation/appearance. Unfortunately, direct measurements of solenoid activation are unachievable on the Teves system, due to them being housed within the compact ABS unit, thus being unable to obtain an accurate waveform measurement for comparison within the report. That being said, having only three solenoids to maintain system function (Bosch) is inefficient in comparison to the ten solenoids used within the Teves system.

Production cost is less with the Teves system than the Bosch system, but unfortunately, if a fault occurs within the Teves ABS Module, it will require a whole new unit. Whereas with the Bosch system, repairs are able to be carried out on multiple points within the system.

During live testing, it was evident, that the Bosch ABS system is time-consuming in comparison to the Teves, as there are more components to obtain information from. The Teves system has one-point for data collection, in comparison to the Bosch' three. It is also noticeable that the up to date components used by Teves, operate differently to the Bosch system. This is due to the use of OBD2 and the introduction of higher emission control with Teves, thus having a higher number of control units that require constant communication back and forth.

ABS systems of 2018/19, are far advanced to the two systems compared throughout this report. Both systems have long been obsolete but both systems, and manufactures, have played an integral part in the evolution of all forms of modern control systems. Bosch is world known and covers a huge variety of component production and innovation, not only in the automotive sector but also home appliances and tools etc.

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