

Anti-Lock Braking Systems
Emissions Control & Diagnosis (M5X02202)

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1. Synopsis

This report has been put together to define and test two ABS systems showing differences in mechanical and electrical operations, fault diagnostic operations and various Assets and Liabilities.

2. Abstract

Using background research of ABS systems an explanation of what ABS does, how it does it and the main electrical and mechanical operations have been made. Fault diagnostics and On Board Diagnostics have been explained while highlighting fundamentals, uses and improvements made between generations such as OBD, OBD II and EOBD. The Teves Mk IV and the Bosch 2EH ABS systems are given a simplified explanation before conducting testing. The procedure carried out during the test has been provided, with considerations to safety such as PPE and the rigs and testing equipment used. Testing had been carried out while systems were off, on and dynamically with explanations to the results and changes of results during ABS intervention. Results of the testing come in data such as oscilloscope graphs and tables which have been explained in detail.

Throughout the report differences between the two ABS systems can be seen. These differences have been analyzed to determine which system has the greater assets and the lesser limitations. Areas and knowledge to improve the greater system has been put forward. The emissions side of ABS has been demonstrated showing links between micro plastic and concerns for human health. Further area such as OBD 3 and advanced ABS sensors have been outlined.

3. Contents

1. Synopsis	2
2. Abstract	2
3. Contents	3
4. Introduction.....	5
5. Literature Review.....	6
6. Safety and Equipment	11
7. Methodology	12
8. Results.....	13
9. Analysis.....	19
10. Conclusion	21
11. Evaluation	21
12. References.....	22
13. Appendix.....	23

3.1 Table of Figures

(Image 1, Type A OBD II DLC).....	8
(Image 2, Type B OBD II DLC).....	8
(Image 3, fault diagnostic flowchart for Teves Mk IV, L Standing, 2018)	9
(Table 1, Bosch 2-EH 15 pin results, 2018).....	13
(Table 2, Bosch 2-EH 4 pin results, 2018).....	14
(Table 3, Bosch 2-EH Solenoid results, 2018).....	14
(Table 4, Teves Mk IV 25 pin results, 2018)	15
(Graph 1, Bosch 2EH Pins 2 & 4, 2018).....	16
(Graph 2, Bosch 2EH Pin 9, 2018)	16
(Graph 3, Bosch 2EH Rear Solenoid, 2018).....	17
(Graph 4, Bosch 2EH Rear Solenoid, 2018).....	17
(Graph 5, Teves Mk IV Pins 2 & 19, 2018).....	18
(Figure 1, Bosch Wiring Diagram.)	23
(Figure 2, Teves Mk IV wiring diagram).....	24
(Figure 3, Bosch Automotive handbook).....	25

4. Introduction

In this report I aim to show understanding of ABS systems, specifically the Teves Mk IV and the Bosch 2EH. To do this firstly a definition of ABS will be given. Then ABS components and operations will be explained and linked to the two systems. The systems are in rigs and these will be defined showing what they are and the pros and cons of being rigs. During this report tests will be carried out on the two systems in a workshop environment. Personal Safety and workshop etiquette will be outlined alongside the procedure of testing being undertaken. The data gathered after testing will be discussed and analyzed. This data along with the research will help analyze which system is superior by demonstrating the assets and liabilities of each system in terms of operation and design. The chosen system will be demonstrated with possible further enhancements based on knowledge gathered from personal research.

In conjunction the diagnostics of these systems will be explained from fault diagnostics and flow chart to OBD (On Board Diagnostic) generation showing the advancements between them, also the limitations of the older systems. In this a diagnostic flow chart will be shown as what OBD improved upon. Then future OBD will be outlined. The link between OBD and emissions will be demonstrated.

5. Literature Review

5.1 ABS (Antilock Braking System) is a system in a vehicle that *“Provides significant improvement to overall vehicle safety. By prevention of wheel lock-up, ABS enables the driver maintain steering control during emergency braking and can also reduce stopping distance on some slippery surfaces”* (Burton, Delaney, Newstead, Logan & Fildes 2004)^[1]. Or simply, ABS *“Retains steerability and driveability under braking and Locking of the wheels is prevented”* (H. Meerkamm 2014)^[2]

These statements defines what ABS does by preventing the brakes on a vehicle from locking up in an emergency braking scenario. This allows the driver to maintain control of steering in this scenario and reduces the stopping distance hence it's a Safety system.

The maximum friction between the wheels and the road surface during deceleration is achieved just before friction becomes too much and the wheels lose grip and lock up/skid. By preventing the wheels on a vehicle locking up this maintains the highest level of friction between the tyre contact patch and the road surface when the brakes are applied. With this the high friction reduces the stopping distance and maintains the grip to the road to provide steering control. This point is explained by Burton, Delaney, Newstead, Logan & Fildes (2004)^[1] as, *“When the driver applies the brake, brake slip increases and at the point of maximum friction between tyre and road surface the limit between stable and unstable range is reached. At this point any increase in brake pressure will not increase the stopping force; as further brake pressure is applied the friction reduces and the wheels tend towards skidding”*

5.2 The process of how an ABS system operates is best described as *“When the ABS system senses that a wheel is about to lock up the braking force is regulated in two stages. Stage 1 is pressure maintenance. In this phase the system prevents the pressure in the wheel cylinder from increasing by blocking the hydraulic pipe running between the brake master cylinder and the wheel cylinder in question. If that is insufficient to prevent the wheel locking up then stage 2 is initiated – pressure reduction. The pressure in the wheel cylinder is reduced in this phase by hydraulic fluid being withdrawn from the wheel cylinder.”* (Trouble-Shooting - ABS Teves MK IV, 2012)^[3]

These two stages of intervention are the same for both the Teves MK IV and the Bosch 2-EH systems however the mechanical and electrical, structures and operations of these two systems are different.

5.3 An ABS system can be broken down in to several major parts; ABS Control Unit (ECU), Modulator valves, Wheel speed sensor (ABS sensor), Sensor ring (tooth wheel/exciter), ABS warning lamp and Diagnostics.^[4]

The ABS Control Unit (ECU) is the central hub on the ABS system. It processes all the data received from the wheel speed sensors in the form of voltage peaks as the Sensor rings rotate with the wheels. Using the data the ECU can determine whether a wheel/s are starting to lock/skid. Once the ECU determines a wheel/s is locking up it can control the Modulator valves on when to activate the solenoids and to which stage of ABS intervention they need to be activated to. The ECU also activates the ABS warning lamp when ABS is engaged, and when the diagnostics finds a fault in the system. Faults are able to be read from the ECU via a DLC (Data Link Connector).^[4]

The wheel speed sensors is located at each of the wheels and sends data to the ECU when the Sensor ring passes by the speed sensor. The Sensor ring is a ring with notches in it and the ring rotates at the same speed as the wheel. As the notches on the sensor ring pass the speed sensor the data is sent to the ECU to determine the rate on acceleration or deceleration. Comparing this data in the ECU to all wheels a locking wheel can be found. ^[4]

The modulator valve is activated by the ECU during ABS intervention. The ECU tells the Modulator valve to what stage of intervention what wheel has to be regulated to. This consists of controlling solenoids to the same description as mentioned in 5.2.

The Warning Lamp is located in the dashboard of the vehicle and as previously mentioned it illuminates when ABS is in use or a fault is found by the diagnostics (OBS see 5.5).

5.4 The Bosch 2-EH ABS system follows the two stages of intervention. This system is the first generation OBD of a 4 channel ABS and was first developed in 1978 with a joint effort between Mercedes and Bosch (Daimler, 2008) ^[5]. This system has 4 channels which are basically the four individual sensors monitoring each wheels' speed. This system regulates the braking forces to each wheel under ABS intervention via a three solenoids. Two of these intervene on the front wheels independently while the third intervenes on both the rear wheels. One limitation with this is if one of the rear wheels required intervention then both the rear wheels will experience it. The three solenoids mentioned are two stage solenoids.

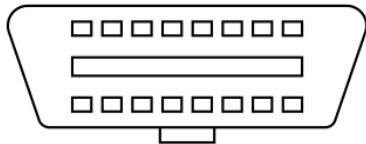
The Teves Mk IV ABS system follows the two stages of intervention as previously explained. This system is a second generation OBD (OBD II) of a 4 channel abs system. Unlike the Bosch system this system has 10 solenoids. Each wheel has two solenoids, one for each stage of ABS intervention (8 for wheels, 2 for ASR see 9.3). This allows the system to detect and implement ABS intervention on all fours wheels, unlike the Bosch system which has to implement abs on the rear wheels collectively.

5.5 OBD (On-Board Diagnostics) has been mentioned in both abs systems. OBD is a system on a vehicle that monitors each component that can contribute to emissions and if a problem occurs informs the driver via a warning light. The system runs diagnostic routines on the hardware and software, the results get checked compared to a database in the system for what tolerances are acceptable and then the system determine the diagnosis. If a sub-system is faulty on the vehicle it would bring up a warning light on the dashboard.

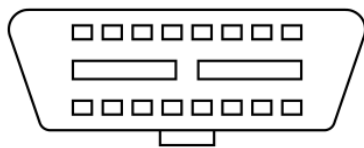
First generation OBD (OBD I) was mainly monitored by the manufacturer. In OBD I there was little standardization in what was supposed to be monitored and how the information was accessible. Different manufacturers had their own Diagnostic Link Connectors (device to connect to OBD to read Diagnostic Trouble Codes) to the OBD systems on vehicles. Also Diagnostic Trouble Codes (DTC's) were not standard between manufacturers or even models in some cases. CARB (California Air Resources Board) defines it as *"OBD I systems were not fully effective because they were limited to monitoring only a few of the emission-related components, and the monitors were not calibrated to a specific level of emission performance"* (California, Air Resources Board. 2015) ^[6]

Due to the downfalls of OBD I, OBD II came in to demand as emission regulations became more prominent. As explained in this extract from the Bosch Automotive Handbook (2002) ^[7] *"Due to the demands of the Californian Environmental Protection Agency, an expanded diagnosis system (OBD II; adapted for Europe: EOBD) monitors all those components which if they fail could result in a*

significant increase in noxious emissions (fault indication with diagnosis lamp)”. OBD II diagnosis can detect issues within the “Air-mass meter, ETC throttle-valve actuator, Combustion misses, Catalytic converter, Lambda sensor, Fuel supply, Tank system, Secondary-air injection and Exhaust-gas recirculation (EGR)” (Bosch Automotive Handbook, 2002)^[7]. As well as emissions it monitors ABS and other sub-systems on the vehicle. OBD II gave a standardized DLC (Diagnostic Link Connector) across all manufacturers.^[8]



(Image 1, Type A OBD II DLC)



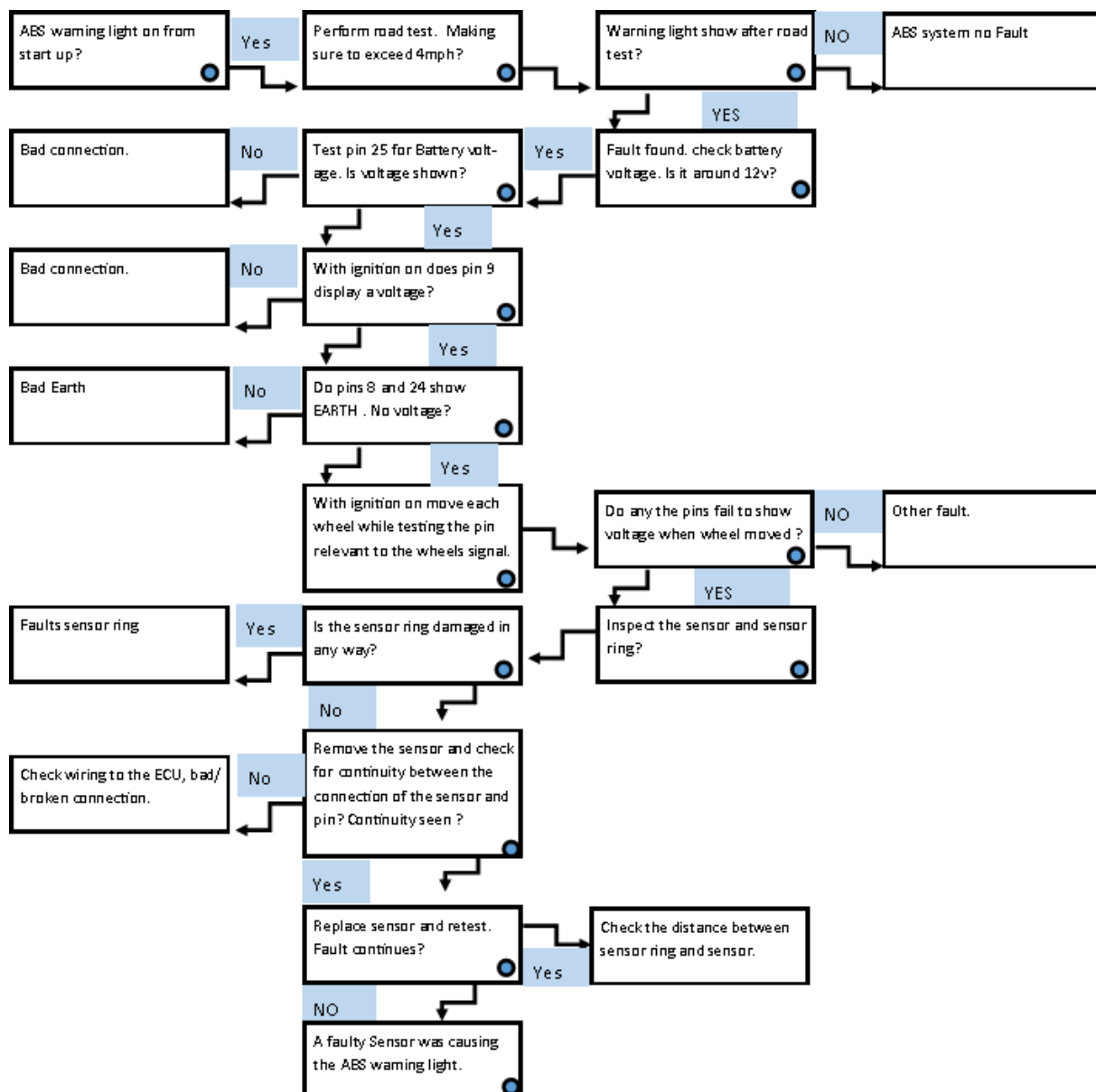
(Image 2, Type B OBD II DLC)

Image 1 and Image 2 both show the standardized 16 pin DLC that is used on the OBD II systems. The difference between the two DLC's in the images is that the Type B has a middle section remaining. This is due to Type A being for 12volt systems and Type B is for 24volt systems^[9]. With the middle section remaining this prevents a Type A plug (OBD II reader) going in to a Type B socket hence preventing potential damage to tool (OBD II reader) and injury to user.

EOBD is the European equivalent of the OBD II system. “EOBD is essentially the same as OBD-II, with the same SAE J1962 diagnostic link connector and signal protocols being used.”^[9]

Further specification of EOBD and OBD II (ISO 15031, SAE j1962)^[10].

5.6 Prior to OBD systems fault diagnostics would have been conducted on a vehicle with a limited number of tools such as multi-meters. A single fault could be caused by any number of possible issues hence a fault diagnostic flowchart was a useful tool. The fault diagnostic flow chart below shows the detection of a wheel speed sensor at fault from the warning light shown on the dash. The fault chart is for use with the Teves system and the pin layout can be seen in figure 2 in the appendix.



(Image 3, fault diagnostic flowchart for Teves Mk IV, L Standing, 2018)

This fault flow chart seen in image 3 shows the pathway to the resolution of the fault via the blue dots in the corner of each box. Sections without the blue dot shown in the flowchart are given a small description to a possible fault or the next section that would be looked at along the pathway. Starting at the beginning the ABS warning light being on shows the fault. Performing the first step concludes two things. If the ABS light goes off then the system was waiting to test the speed sensors and exceeding 4mph would test this. Also if the vehicle can start up then this would lead me to believe the battery is operational hence no fault with the battery.

By establishing no fault with battery then pin 25 can be tested if this shows battery voltage then the system is getting voltage. Same as pin 9 however if both of these show the correct voltage then we know the system is getting the right voltage. Next would be the earths as we have confirmed it's not a lack of voltage. Hence by this point we can test one of a few things defective ECU, brake switch or wheel sensors. The brake switch could be tested by pin or visually by looking at the brake lights hence why the option of moving each wheel while testing for voltage was put in. An ECU is more expensive than a sensor to replace therefore if all the sensors were faulty or none of them this would lead me to

believe it's an ECU problem. However no voltage was seen on one of the sensors when tested. The next part to inspect would be to look at the sensor ring, a visual inspection of the rings can show any missing or damaged section without removing it from the vehicle. Before changing the sensor continuity is checked this makes sure that the cables between the sensor and ECU are not broken. One thing before changing the sensor would be to remove the sensor on the other side and test it on the side where the fault occurred. This can prove the sensor is faulty or the alternative of the sensor being miss-aligned or too far from the sensor ring to receive a signal.

5.7 OBD 3

The future of OBD is plausible in the form of OBD 3 as it would consist of the diagnostics on the vehicle being monitored and sent to roadside governments which would monitor it. The strengths to this system is if OBD doesn't have a fault you won't have to have an emissions test. If you did have a fault the governing body can send memos or even fines to people who don't resolve the issues causing increased emissions after extended periods of time. Some of the draw backs to this are infrastructure and privacy. For this system to work a cellular network capable of handling this would need to be installed causing a massive cost. Also as everyone would be connected on the network it could be used for spying or maliciously by hackers. ^[6]

6. Safety and Equipment

6.1 PPE (Personal Protective Equipment) such as dust coats and steel toe boots was used during static and live testing. Dust coats are wore during testing for protection from harmful chemicals, materials and fire. These are made from durable materials that can prevent small foreign objects penetrating the wearer and deflects the material away from them. For fire the dust coats have mild flame retardant capabilities allowing the wearer to vacate or put out fire, allowing user possibility to prevent serious injuries. Steel toe boots prevent injury due to falling objects. These injuries are likely in a workshop environment and can be subject to the user and the occupants in the workshop hence why steel toe boot are essential. (Health and Safety Executive, 2013)^[11]



(Image 3, A G Block Engineering Bosch 2EH ABS Rig)

6.2 The two abs systems are mounted in rigs (Image 3) improving accessibility to components compared to a standard vehicle. During testing the rigs have moving parts hence they are fitted with a mesh cover to prevent injury. The moving parts mentioned is the sensor ring (also known as a tooth wheel or exciter) which has to move past the ABS sensor to determine wheel speed. The test rigs operate on battery power and were maintained by a mains supply, therefore no gaseous emissions are produced in the area of test.

6.3 To attain waveforms from each of the systems being tested an oscilloscope was used. The Bosch BEA 850 was used as it was available at the time and having the operation of creating real time oscilloscope graphs that could be printed for review.

7. Methodology

7.1 After taking in to account safety considerations static testing began. During static testing the group was going to be taking readings from pins on the ABS systems. The Bosch 2-EH system was the first tested and began by measuring the voltage of the battery on the system. Then with the ignition off the group tested for voltage in the 15 pin plug, 4 pin plug and at each of the 3 solenoids. (see figure 1)

This testing of the pins and solenoids was then repeated for the ignition on and no movement at the sensor ring on the rig. In reality this would simulate the vehicle running at idle but not moving. The testing was repeated again with movement at the sensor ring this time, this simulates the vehicle at constant speed and no braking. Lastly testing during ABS intervention was caused on the rig, simulating the vehicle braking and one wheel locking up.

Hence the group would have a set of data for the Bosch system with ignition off, ignition on, dynamic and at ABS intervention. After taking these readings the oscilloscope (Bosch BEA 850) was used to produce graphs of the some of the pins output during dynamic and ABS intervention stage (See results 8.2).

7.2 The testing outlined in 7.1 was repeated for the Teves Mk IV system. There was some differences for testing the Teves Mk IV system such as enclosed solenoids. On the Bosch system the solenoids are accessible however on the Teves system they are enclosed therefore data for this was unobtainable. The Teves system does not have the same 15 pin plug and 4 pin plug as the Bosch system but instead has a 25 pin plug.

8. Results

8.1.1 Bosch 2-EH results.

Pins	label	Ignition off	Ignition on	Dynamic	Note
1	AB 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	Peaks on the voltage line are data.

(Table 1, Bosch 2-EH 15 pin results, 2018)

Table 1 above shows the results from the ABS testing on the 15 pins in the Bosch 2EH system. The table gives each pin the label of what it monitors and/or controls and shows the data collected. Please note that the table doesn't have a separate column for ABS Intervention data, instead any data that was collected during ABS is in the Note section in the table, or if caused the intervention it will be mentioned. Pins 5, 7 and 14 don't show data as these pins would have the same values as pin 2 unless they were locking up therefore causing the ABS to intervene. Pins 6, 10 and 13 follows the same values as pin 4 alike to the pins previously mentioned and characteristics. Pins 3, 8 and 11 are blank/empty.

Pin 1 shows the voltage for the ABS warning lamp. The voltage shown in Table 1 for ignition on and dynamic is the voltage waiting to be grounded if a fault occurs on the system or if ABS is in use.

Pins 2 and 4 show a low voltage 0.22v and 0.35v respectively in both ignition on and dynamic testing. As Pin 2 is the ground on this system and therefore is the reference voltage for the signal shown from pin 4. The voltage shown being grounded is the voltage used to operate magnetic reluctance sensor for wheel speed.

Pin 9 voltage under ignition on and dynamic shows the voltage to the brake light. As the brake would have to be applied to show voltage the brake was applied in ignition on test. The 12.3v shown goes to brakes but under ABS intervention this decreases to 8.9v. This is due to the extra voltage required to power the solenoids (see 5.3), therefore this causes the brake lights on the vehicle to dim.

Pin 12 shows voltage for the data wire (DLC) and between ignition on and dynamic testing the voltage decreases slightly due to the ECU sending data. Part of this voltage would be used if an OBD reader was connected as the voltage would power the OBD reader.

Pin 15 is the diagnostic lead data wire voltage shown on data being sent though the data wire (DLC).

Notice on Table 1 there is no voltage supplied to any of the pins when the ignition is off. Therefore it can be determined that the Bosch 2-EH system does not have a memory as there are no permanent live seen.

8.1.2

Pins	label	Inginition off	Inginition 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

(Table 2, Bosch 2-EH 4 pin results, 2018)

Table 2 shown above shows the testing results from the 4 pins on the Bosch 2-EH system. Pin 1 shows the voltage from the ignition key to the ABS ECU. At ignition off there is no voltages and this supports the fact there is no memory on this system as previously mentioned.

Pin 2 shows the voltage from the overarch relay. This overarch relay is not included on the system, if included it would provide protective control of the control relays (See figure 1).

Pin 3 provides an earth to the system (pump motor also has earth). At the 0.04v shown is proves the system tested has a relatively good earth.

Pin 4 is the light to the dashboard showing ABS fault or intervention. This voltage is provided and waiting to be grounded by Pin 1 of the 15 pin side of the ABS ECU (Table 1).

8.1.3

Pins	Position	Inginition off	Inginition 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

(Table 3, Bosch 2-EH Solenoid results, 2018)

Table 3 shows the results taken from the solenoids on the Bosch 2EH system. Notice all the values are the same across both fronts and the rear solenoids. The voltage remains the same at both ignition on and dynamic at 12.5v. At stage 1 intervention the voltage drops to 9.5v as this is used to move the solenoid and maintain its position. At stage 2 intervention the voltage drops further to 5.5v showing more voltage required move the dual action solenoids to the second position.

See figure 1 in analysis for wiring diagram of the Bosch 2EH system.

8.2 Teves Mk IV results.

Pins	label	Ignition off	Ignition on	Dynamic	Note
1	wheel speed ground				same as pin 2
2	wheel speed ground	0v	2.3v	2.6v	AC output
3					
4					
5					
6					
7	Memory Perminant live	12.6v	12.6v	12.57v	Perminant live to retain memory
8	EARTH	0v	0v	0v	EARTH
9	Ignition live	0v	12.6v	12.6v	Ignition live
10	wheel speed ground				same as pin 2
11	wheel speed ground				same as pin 2
12	Brake switch	0v	12.6v	12.6v	at battery voltage when brakes applied
13	Data link	9.86v	9.86v	9.7v	Data link
14					
15					
16	warning light	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	P.live	12.6v	12.6v	12.6v	perminant live

(Table 4, Teves Mk IV 25 pin results, 2018)

This table (Table 4) shows all the results available for the Teves Mk IV System. Out of the 25 pins on the ABS ECU 8 were blank/empty (pins 3,4,5,6,14,15,21 and 23) and pin 22 is not included on this system. Note that pins 1, 10 and 11 have the same values as pin 2, in addition pins 17, 18 and 20 have the same values as pin 19 (unless the wheel is under ABS intervention or faulty). Pins 8 and 24 are Earths and can be seen as good condition.

Pin 2 is the wheel speed ground and pin 19 is the wheel speed signal. Hence the data to the ECU comes from pin 19 and with the reference of what the ground is from pin 2. Dynamic voltage in both pins higher than ignition on as the addition voltage is part of the data. The dynamic voltage is dependent on wheel speed.

Pin 7 shows a permanent live to the ECU even with ignition off this would be for the system memory to retain faults in the system to be read by an OBD II reader.

Pin 9 shows the same values as pin 7 however doesn't show voltage during ignition off hence this is an ignition live feed to the ECU. This would engage OBD diagnostic during start up in the ECU.

Pin 12 has been labeled as brake switch. This shows battery voltage at pin 12 when the brake pedal is depressed, when released this shows 0v. This supply voltage would then power the brakes lights.

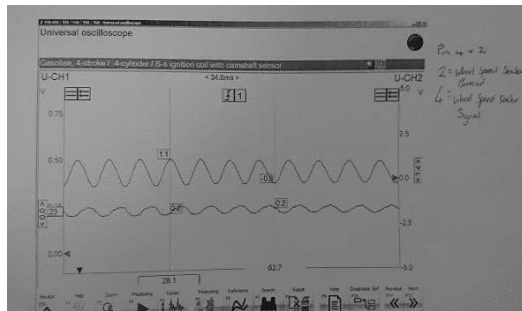
Pin 13 is the DLC (data wire) for the ECU to an OBD II reader. There is a voltage for the data and to supply power to the reader to read the fault codes.

Pin 16 is the warning lamp provided voltage from the ECU this shows voltage which gets grounded when the ABS intervenes and displays the Warning light on the dashboard. This can also be illuminated by a fault and with memory this can be illuminated from ignition on.

Lastly Pin 25 this is a permanent live to the ABS ECU on and would be used to power the System and the solenoids as these are integrated/enclosed in to the ECU.

See figure 2 in analysis for wiring diagram of the Teves Mk IV system.

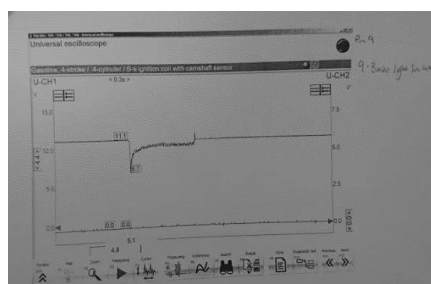
8.3.1 Bosch 2EH Oscilloscope Graphs.



(Graph 1, Bosch 2EH Pins 2 & 4, 2018)

The graph (Graph 1) above shows the wave output from pins 2 and 4 on the 15 pin side of the Bosch ABS ECU. This graph was taken during a constant speed during dynamic testing. Pin 4 as explained previously is the signal and is seen as the higher voltage value waveform on the graph. The ground voltage at pin 2 is the lower voltage waveform. On the graphs there is some points to notice such as the amplitude/height of pin 4 is greater than pin 2. As Speed of the “wheel” (Sensor ring on rig) increases the amplitude and frequency at pin 4 also increased. Pin 2 mimics this to maintain a constant reference.

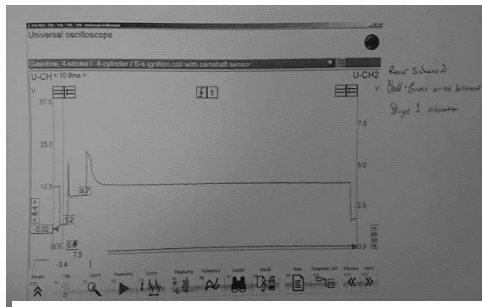
8.3.2



(Graph 2, Bosch 2EH Pin 9, 2018)

Graph 2 above shows ABS intervention effect on pin 9 voltage. At the moment of ABS Intervention the voltage drops as explained in section 8.1.1 (Brake lights dim as power supply for ABS). Small oscillations can be seen on the graph showing the solenoids engaging and disengaging multiple times during the brief period. Once ABS has seized to continue the voltage returns to normal.

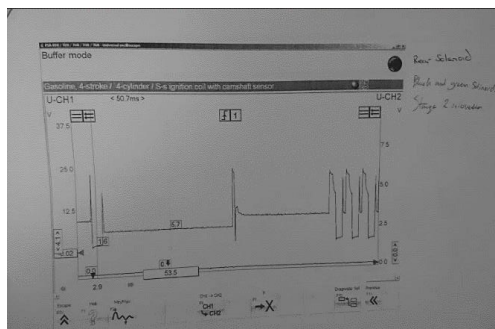
8.3.3



(Graph 3, Bosch 2EH Rear Solenoid, 2018)

Graph 3 (above) shows stage 1 ABS intervention on a solenoid. Described as “Starting voltage of 12.5v drops to 1.2v this voltage then spikes and then maintains at 9.7v, once again the voltage peaks and returns to 12.5v”. At the moment before ABS intervention the voltage is 12.5v, this drops to 1.2v as ABS initiates. This voltage moves the solenoid to the position at stage 1 (as it is dual action). Then the voltage goes to 9.7v this is the required voltage for the solenoid to maintain at this position in stage 1. Once ABS reverts back to normal breaking the solenoid returns to the normal position and so does the voltage.

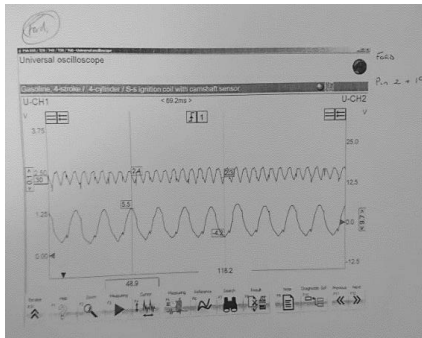
8.3.4



(Graph 4, Bosch 2EH Rear Solenoid, 2018)

In the graph above (Graph 4) stage 2 ABS intervention can be seen as well as stage 1 on a solenoid. This graph is described as “Voltage starts at 9.7v drops to 1.6v this voltage then spikes and then maintains at 5.7v, the voltage spikes again and then maintains 9.7v”. Similar to that of Graph 3 this graph starts in stage 1 of intervention (in this scenario the wheels are still locking up) at the 9.7v. The voltage drops to 1.6 as the system is engaging the solenoid to move to its second position for stage 2 of intervention. The voltage increases slightly to 5.7v and this shows the voltage required to maintain the solenoid in the position. Then the solenoid returns to stage 1 causing the spike and the 9.7v to return. The peaks and lows seen at the end of the graph show pump engagement.

8.4 Teves Mk IV Oscilloscope Graph.



(Graph 5, Teves Mk IV Pins 2 & 19, 2018)

Graph 5 shown above has some similarities to that of Graph 1. This graph shows the Teves Mk IV Wheel speed signal and ground in the form of pins 19 and 2 respectively at a constant speed. Unlike Graph 1 the frequency between the two pins in this graph are different. The amplitude of the signal is still significantly higher hence the relevance of the ground maintains as a reference of the data the ECU takes. The graph also as small irregularities possible down to the sensor ring being slightly damaged but not enough to be out of tolerance as the ECU doesn't show a fault during running of the test.

9. Analysis

9.1 The two ABS Systems have been tested and the results have been discussed. In this section an analysis of these two systems will be conducted for differences and what are the various Assets and Liabilities are.

9.2 Mechanically the two systems are similar as they both have the basics as outlined in 5.3. The main difference would be that the Bosch system has dual action solenoids and the Teves systems has single action solenoids. The Bosch 3 solenoids would be lighter than the 10 the Teves system has. Also the Bosch system has the solenoids not integrated to the ECU hence they can be replaced, unlike the Teves where the solenoids are integrated and replacing them would require a new ECU. However the dual action solenoids are more expensive to produce than the single action solenoids. In addition the dual action solenoid may be more likely to brake than the alternative. Hence both systems here have strengths and weaknesses.

9.3 Another mechanical aspect that benefits the Teves system is ASR (Anti Slip Regulation). ASR is technically traction control however this is on the system, mentioned in 5.4. The Teves system has 10 solenoids 8 are for the wheel and the 2 remaining are for ASR (See figure 3 in Appendix). What ASR does is limit wheel spinning under acceleration. This doesn't benefit ABS directly but it does benefit emissions (9.xxxxxx) and performance. As this is something the Bosch system doesn't have it's considered an asset. ^[12]

9.4 The Bosch system has the disadvantage of having the three solenoids mechanically in addition this limits it in operation. As the system has the rear wheels activated at the same time during ABS intervention this could cause unpredictable yaw during breaking and breaking in a corner. The Teves system has 4 wheel braking (See figure 3 in Appendix) however yaw can still occur on this system however it would be more likely on the Bosch system. ^[13]

9.5 The Teves system has OBD II and the Bosch system has OBD. In section 5.5 the argument for OBD II shows the benefits over the OBD counterpart. Hence why the Teves having OBD II makes this system better than the Bosch as the limitation with OBD.

9.5.1 On the same topic as mentioned in 9.5 the Teves system has a memory. This benefits the system by recording previous faults for technicians to see on OBD II readers. This saves time for the owner (less time for car in repair) and technician (less time looking for fault). With memory the fault is always present on startup reminding the owner of the issue.

9.6 Emissions

ABS prevents emissions by reducing wheel lock and skidding less tyre material is removed by friction with the road surface. The material leftover from skidding and wheel locking is the tyre compound. This compound makes its ways to soil and the ocean via natural (suspension in water from rain and wind) and unnatural ways (road sweepers). The compound of tyres according to Michelin is made up of; natural rubber, synthetic rubber, carbon, silica, steel, Polyester, nylon, rayon, aramid, sulfur, resins and oils amongst other things. ^[14]

In a document published by the European Commission tyre wear was considered a rising problem in the form of micro plastics. Consisting of cosmetics, tyres and other things the document states “75,000 and 300,000 tons of micro plastics are released into the environment each year in the EU”. Amongst the information in the document there is a statement that reads “Microplastics also need to

be monitored in drinking water, where their impact on human health is still unknown.”

(European Commission, A European Strategy for Plastics in a Circular Economy, 2018) ^[15]

The synthetic rubber of which tyres are made 60% is made up of “*petroleum-derived hydrocarbons*” (Michelin). Although there is evidence this ends up in the soil ^[15] there are multiple contributors to this such as roads building materials such as tarmac with PMB (Polymer Modified Bitumen). ^[16]

9.7 From the Analysis prior to 9.6 the Possible improvements to the Teves Mk IV system include placement of the solenoids on the outside for the ECU, and fitting and ESC (Electronic Stability Control). By fitting the solenoids on the outside of the ECU replacement would be easier, testing can be conducted however from a manufacturing point this would increase weight and cost. The major benefit would be to the customer of the vehicle as changing a solenoid costs much less than a ECU

The second improvement I would make would be to include ESC to the system, “With ESC, wheel sensors can detect the beginning of a slide and small amounts of braking can be applied automatically to individual wheels to regain stability.” (AA, 2017) ^[17]. The improvement would require very few components such as a yaw sensor, steering angle sensor and ESP (Electronic Steering Program). The rest of the components are part of the ABS system. Using the Steering angle the ESP can see the desired steering angle and using the yaw sensor see the actual steering angle. Then using the data from both the sensors the ESP would cause the ABS system to make small brakes to regain control. ^[18]

10. Conclusion

To conclude this report from the aims outlined in the beginning the ABS has been defined as a safety system used during braking to assist in steering. Various diagnostics have been mentioned from using fault flowcharts and a multi-meter to an OBD system. All diagnostics have been covered from OBD right up to OBD3 and the benefits and limitations have been shown. Tests carried out show all the data for me to draw conclusion to the Teves having more assets than liabilities overall. The assets to the Bosch system have been shown thought-out and the limitations to this system and the Teves. I have made suggestion to improve the system further by using ESC and changing the solenoid location.

11. Evaluation

In this report the content includes necessary information to have an understanding from the beginning. While maintaining a higher level of knowledge throughout with papers, articles and other referenced material from credible resources such as governments, European commission and recognized engineering bodies to back up points and statements. The construction of the report is to help flow as the reader goes from one section to the next picking up the relevant information to have a better understanding up until the conclusion. Laying the information out required a set procedure to stick to. Hence why references are referenced (EXP, Title, Author, Date) and have a reference number [0]. This allowed the references to be easily manageable therefore possibly the reason there are so many. The data collected was just as required and to my knowledge didn't contain any mistakes or anomalies. The group work was great in the workshop as this helped with understanding the topic in the beginning amongst peers. The time spent on the report I think will strongly reflect in the mark as much of the time was around research. The research has helped me improve my knowledge and understanding of ABS systems, OBD generations and electronics. Which in turn has helped me with this report.

Looking back over the report I would have liked to have spent some more time understanding wiring diagrams and emissions. The link between ABS and emissions still seems small to me, however the emissions around tyres has been shown as very important in the future and for human health.

12. References

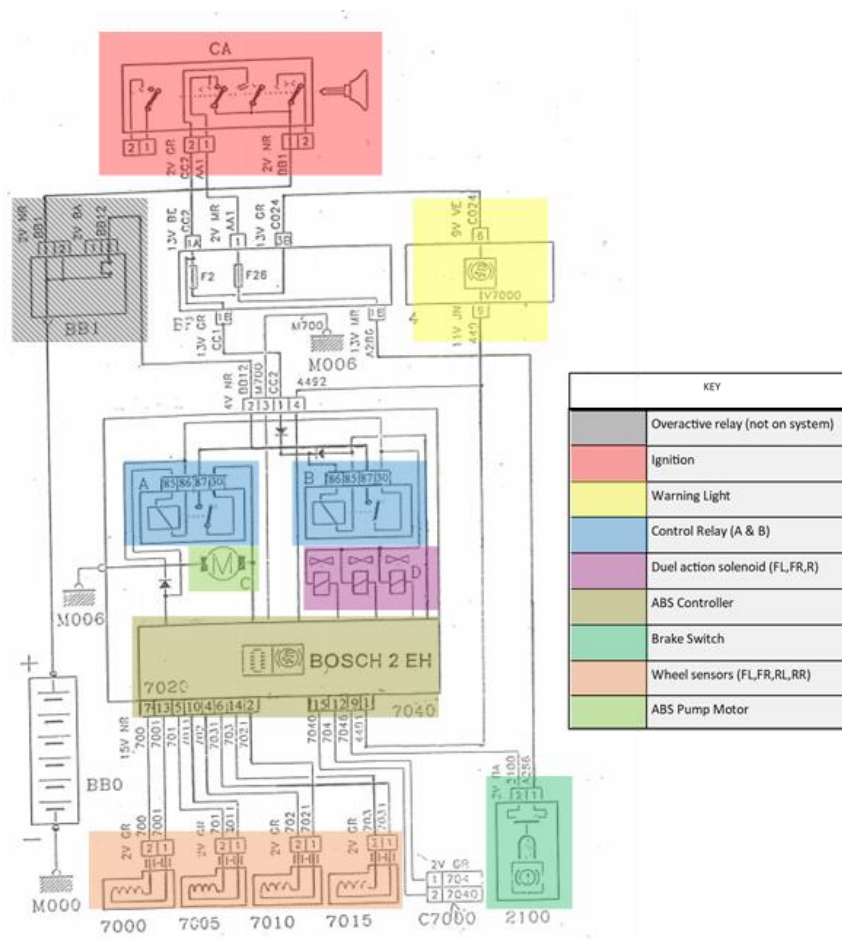
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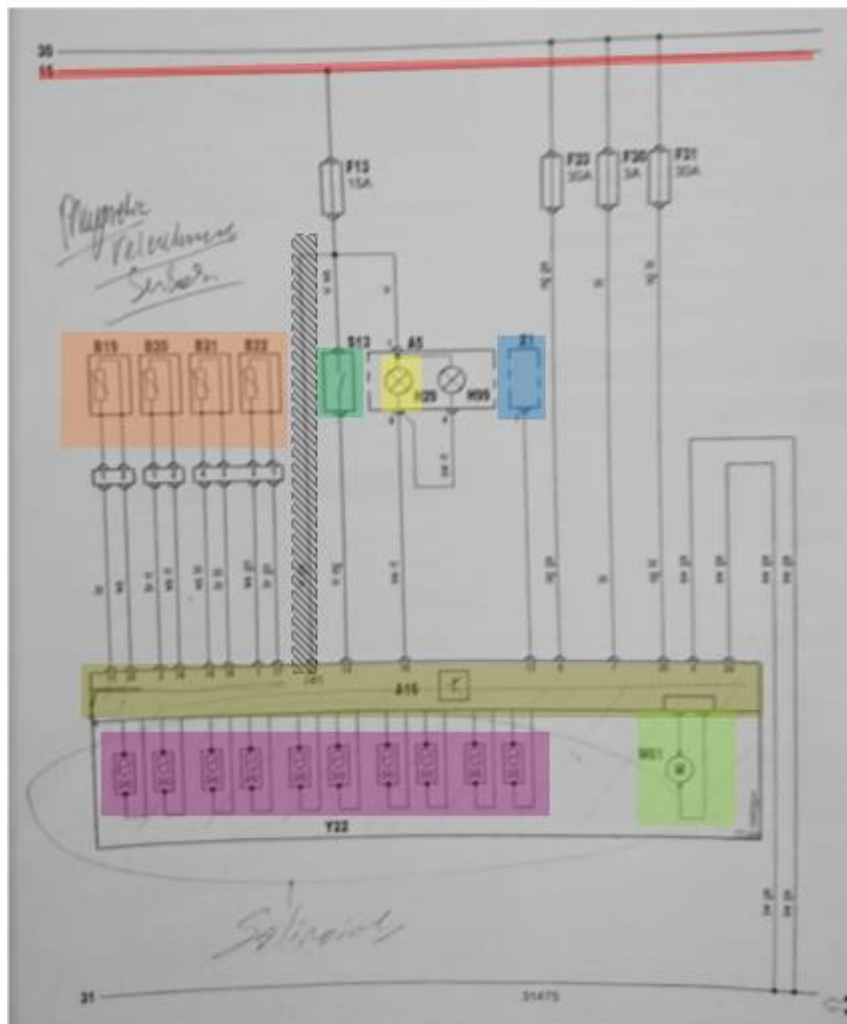
13. Appendix

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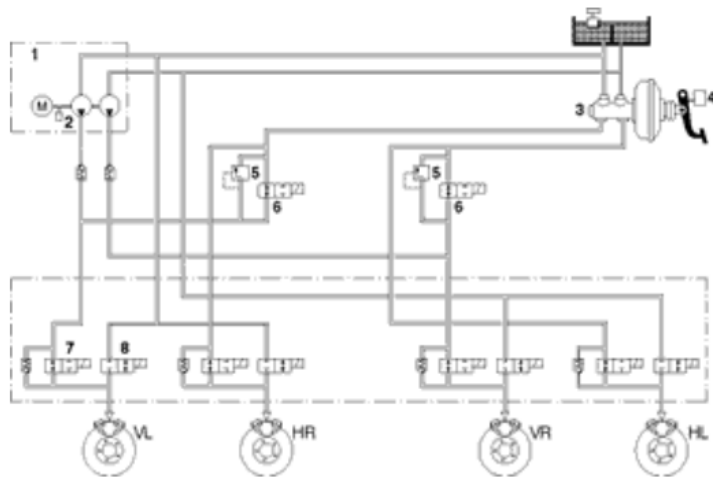


(Figure 1, Bosch Wiring Diagram.)

	(not on system)
	Ignition live (ignition switch)
	Warning Light
	Data link
	Single action solenoids
	ABS Controller (ECU)
	Brake Pedal Position (BPP)
	Wheel sensors (FL,FR,RL,RR)
	ABS Pump Motor



(Figure 2, Teves Mk IV wiring diagram)



ABS/TCS MK 4 (Teves)

1 Energy supply, 2 Wheel-speed sensor, 3 Master-cylinder piston, 4 Position sensor, 5 Pressure-relief valve, 6 ASR solenoid valves, 7 Inlet valve, 8 Outlet valve. V front, H rear, R right, L left.

(Figure 3, Bosch Automotive handbook)