

Anti-Lock Braking Systems

M5X02202

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Contents

Introduction-	3
Function of an abs system	3
Pressure Build up.	3
Pressure-holding.	4
Pressure Reduction.	4
Dynamic Testing-	4
Bosch 2HE	5
Ford Teves Mk IV	6
Signal Waveforms.....	7
Appendix 1.....	7
Appendix 2.....	8
Appendix 3.....	8
Appendix 4.....	8
Appendix 5.....	9
Fault Diagnostic Flow Chart-	9
Operational Differences-	10
Conclusion-	13
References	13
Signal waveforms Figures-	14
Figure 1-Waveform Bosch wheel speed sensor	14
Figure 2-Brake light switch.....	15
Figure 3-Brake rear solenoid	15
Figure 4-Brake rear solenoid	15
Figure 5-Teves wheel speed sensor	15

Introduction-

This report will be covering the functionality, testing, operations, and servicing of the Anti-lock Braking System (ABS). Two systems were specifically looked at; the Bosch 2EH and Ford Teves. The procedure for testing the two systems will be covered, the waveforms and results recorded will be evaluated, the report will also document the relevant safe working practises used whilst testing. The information gained from testing will aided in producing a fault diagnostic flow chart where the ABS warning light 'on condition' is present; this will enable an ABS fault to be investigated and determine cause the of malfunction. Comparison will be made between the two ABS systems with a main focus into their protocols, operation, and diagnostics in particular thier use of OBD-1 and OBD-2. The report will then evaluate the main advantages and disadvantages of the two systems.

Function of an abs system-

The main principle of anti-lock braking (ABS) system is to achieve the maximum coefficient of friction between the tyre and road surface with maximum effort achieved. ABS should be able to provide the maximum braking force, keeping the vehicle stable and allowing steering effort to remain functioning. The ABS system is designed to avoid yaw ('Yaw the rotational or oscillatory movement of a vehicle around a vertical axis passing through the centre of gravity' (Hillier, 2012)) of the vehicle when braking on surfaces of different traction across the car, it must be controlled to a point where the yaw is easily controlled by the operator of the vehicle. The system provides the same amount of braking efficiency across all speeds of the vehicle. Capable of recognising and responding to aquaplaning of the vehicle, whilst remaining the vehicles stability and its road position. (Bosch, 1995) To be able to provide all these functionalities, the ABS system achieves its maximum brake effort by using 3 operations; Pressure build-up, Pressure holding, Pressure reduction.

Pressure Build up.

During this point the solenoid is not energized and is in its base position. This means unrestricted brake-pressure can be built up, this will be during normal breaking or during the appropriate phase when the ABS is active. When the ABS is active the wheel sensor sends signals to the ECU to show free running of the wheel. At this point in the solenoid unit, there are two springs which exert opposed forces, the main spring is under more

tension allowing the input valve (regulated fluid line) to be opened. (Bosch, 1995) (what-when-how, 2018)

Pressure-holding.

The input valve must react to a developing wheel lock, to interrupt the pressure between the brake master cylinder and the wheel brake cylinder, to prevent additional brake pressure increase. The ABS system sends 50% current to the solenoid, the armature then closes the input valve. The springs then stop exerting forces against each other, this is because the windings aren't strong enough to overcome the forces of the main spring. The armature is now in its intermediate position, this is where the valves have a degree of 'stroke overlap' which allows the output valve to be opened (during pressure-reduction) only once the input valve is closed. (what-when-how, 2018) (Bosch, 1995)

Pressure Reduction.

During this phase excess pressure is released, the system achieves this by opening a passage between the brake wheel cylinder and the return valve. Maximum current is sent to the solenoid windings, the armature then opens the output valve by overcoming the full force which is exerted by the springs. Once adequate pressure has been released the solenoid closes the output valve. The system then moves the solenoid to holding pressure phase or build-up pressure phase depending on the information received from the wheel sensor. (Bosch, 1995) (what-when-how, 2018)

The ECU uses this cycle to manage the wheel speed within its slip limit to provide the maximum braking force, this is achieved whilst varying coefficient of friction between the tyre and road surface are present. The cycle is on average repeated 12 times a second, the speed of the operation prevents vibration of the wheel and suspension components. (what-when-how, 2018)

Dynamic Testing-

In the workshop full operation tests were carried using the Bosch 2EH and Teves Mk IV ABS test rigs. These were tested in groups of 5 where each member performed a role in gaining the data. All tasks completed in the workshop were completed within the guidelines of The Health and Safety at Work Act (1974), also good general working practise should also be observed these were controlled by good housekeeping of equipment, wires and

components. The correct PPE was worn at all time, requiring steel toed boots and dusk coats. Validation is a large factor to consider when performing the tests. Both test rigs were operated in the same operating conditions, to improve the validation of the results multiple tests could be completed to remove any anomalies in the results which would be shown up during comparison. During the tests a multimeter and a Bosch Oscilloscope were used to gain results, during the test the battery probe was connected to the battery negative and positive so the scope could monitor the battery voltage during the test. The scope display was set so channel one was reading voltage and milliseconds. Schematic's of the systems components and plug pin data was used to be able to record data from the system.

Bosch 2HE

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

The results in the table above show all the values to have no voltage when the ignition is off this is because the all pins are ignition feeds and don't have power unless the ignition is turned on. Pin 2, 5, 7, 14 are all ground for the wheel speed sensors which is why they show a small interference voltage, when the system is running the earths show the same small voltage as they are still grounding the wheel speed sensor. Pin 4, 6, 10, and 13, are the pulse signals from the wheel speed sensors, the frequency of the alternating voltage is proportion to the speed of the wheel. (Bosch, 1995) So the faster the wheel rotates the larger the

voltage relayed to the ECU. (Hillier V. , 2014) Pin 1 is the ABS warning light feed, this is at battery voltage which is why it goes down when the system is running as the test rig is not equipped with an alternator to recharge the battery. Pin 9 is the brake light switch feed which is battery voltage, the brake light switch has voltage because the system is active with brake pressure. Pin 15 is the diagnostic data signal lead, which pulses allowing communication in the unit.

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

Pin 1 is the power supplied to the unit which is 11.79V once the ignition has been turned on as it is an ignition live. Pin 2 allows the unit to monitor direct battery voltage. The reason it drops when the system is running is because as mentioned before the system is using more current and without an alternator fitted on the test rig it has drained some current from the battery. Pin 3 is an earth which is why it doesn't display any voltage during all testing parameters. Pin 4 this pin is the connection to the ABS unit and if there was fault on the system this would ground. This is why there is 11.79V present as there were no faults on the ABS rig when we performed the testing.

Ford Teves Mk IV

Pin Number	Ignition Off (v)	Ignition On (v)	System Running (v)
1	0	0	0.25
2	0	0	0.25
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	0	11.99	11.99

13	9.28	9.28	9.28
16	0	11.99	11.99
17	0	0	1.25
18	0	0	1.25
19	0	0	1.25
20	0	0	1.25
24	0	0	0
25	12.2	12.2	12.2

Pins 1, 2, 10, and 11, are the grounds for the wheel speed sensors they show 0v when the system isn't running, but when the system is running they show 0.25v which is interference current from the inductive sensor. (Bosch, 2000) Pins 17, 18, 19, and 20, are the pulse signals from the wheel speed sensors, the frequency of the alternating voltage is proportion to the speed of the wheel. (Bosch, 1995) So, the faster the wheel rotates the larger the voltage relayed to the ECU. (Hillier V. , 2014) Pin 7, 9, and 25, are all permeant lives which are the same as the battery voltage. Pin 8, and 24, are grounds for the ABS unit. Pin 12 is brake light switch feed which is 11.99V when the ignition is on and when the system is running this is because the brake pedal had pressure when testing, when the ignition was off 0v was present because the brake light switch has an ignition live feed. Pin 13 is the data link for the OBD plug, this has 9.28v because the data systems which read the fault codes through the OBD port requires power from the vehicle to power itself. Pin 16 is the power from the instrument cluster for the ABS warning lamp, this pin is earthed when there is a fault in the system which will illuminate the ABS warning lamp to inform the driver of the vehicle. This is why the pin showed it as 11.99v during testing when the ignition was on and the system was operating. The pin shows 0v when the ignition is off because the power for the instrument panel is an ignition live.

Signal Waveforms

Appendix 1

This waveform has been taken from PIN 2 & 4 of the system which is a wheel speed sensor, showing a wave form for each pin the positive voltage and ground for the sensor. Pin 4 the positive signal has an oscillating voltage between 1.1V and -0.3V, this oscillation is created

by the magnetic inductive sensor rotating passed a trigger wheel which is designed with teeth and air gaps in-between, when the sensor passes over the gap the voltage drops to - 0.3V. The maximum voltage of 1.1V is when the sensor is passing a tooth of the trigger wheel. As the speed of the trigger wheel increase with wheel speed this will increase the frequency and amplitude/voltage of the waveform (Pico Technology, 2018) Pin-2 is the ground pin for the sensor which is why it has the same frequency as pin 4 but small voltage change between 0.2V and 0.23V.

Appendix 2

This waveform is for Pin 9 the brake light switch, the switch has a power of 11.1v due to the brake being activated the drop in in voltage to 6.7V is the initial point in which the abs is operating, the voltage then raises until it reaches 11.1V again. This voltage drop is caused by engagement of the abs system which draws more current that is available this cause a voltage drop on other circuits in this case the brake light switch feed (Lathrop, 2016). Voltage drop seen in the waveform isn't good but on a normal car the alternator will be supplying current to the battery and circuits, but this was waveform was taken on a test rig with only a battery and no alternator recharging the battery.

Appendix 3

This waveform is for the rear solenoid of the ABS system. The wave form shows a voltage of 12.5V this is where the solenoid is in the pressure built up phase. The voltage then drops to 1.2V as this this is when the ABS is first engaged causing a voltage drop but then the voltage then settles at 9.7V before the voltage returns to 12.4V. The drop in voltage is caused by the activation of the abs system and the solenoid. The solenoid requires a large amount of current to alter its position to allow the system to change into its pressure hold phase.

Appendix 4

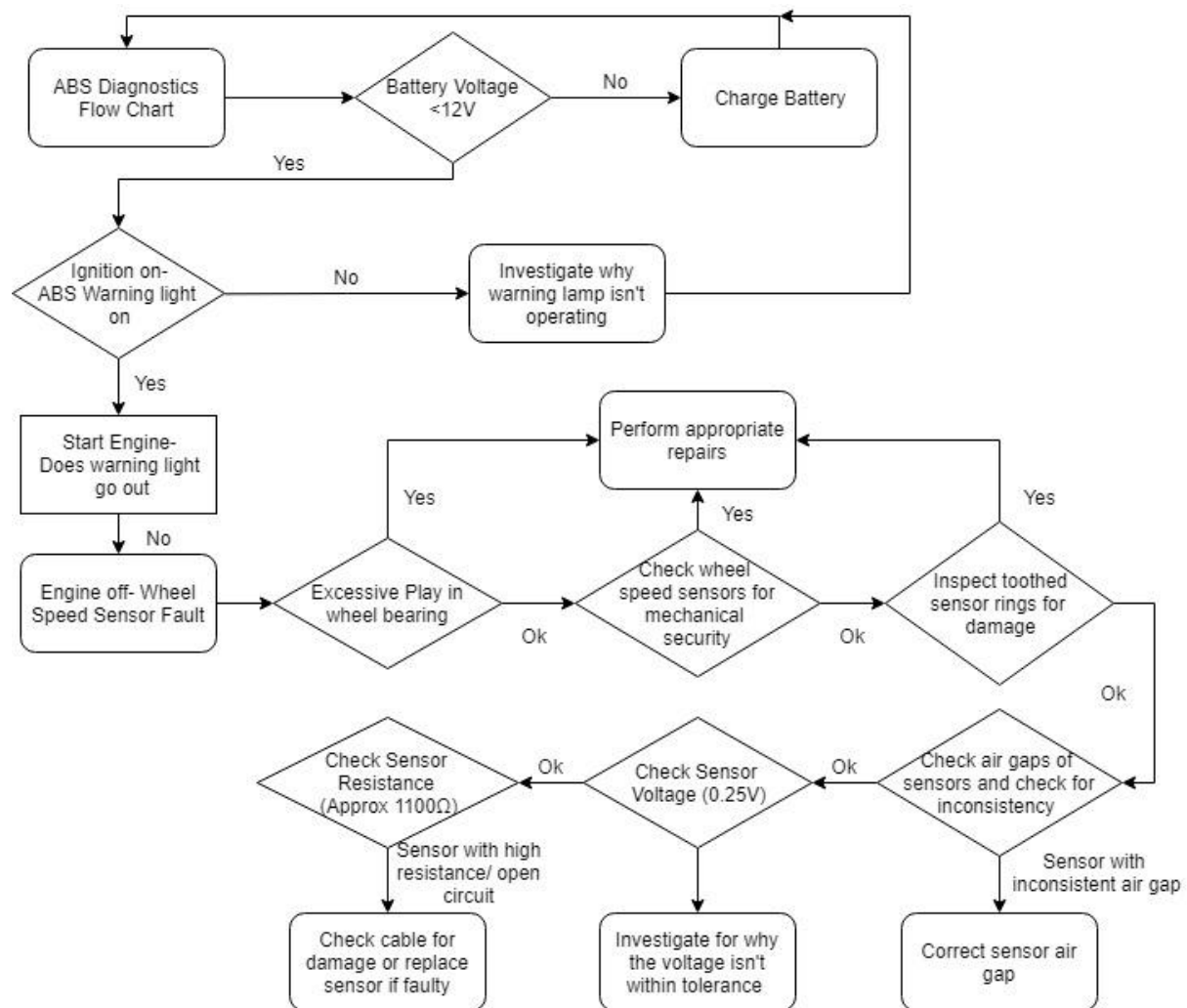
The waveform is for the rear solenoid but as it enters its next operating phase. The voltage drops to 1.6 V then raises to 5.7V. The drop-in voltage is caused due to the ABS system engaging and the solenoid moving its position causing a large draw in current and a drop-in voltage (Lathrop, 2016). The movement of the solenoid is due the ABS system changing its phase into pressure reduction due to a wheel lock up.

Appendix 5

This wave form is for pins 2 & 19 on the Teves ABS system, these pins are the ground and positive voltage pins for the wheel speed sensor. Pin 19 oscillates between 5.5V and -4.2V. Similar to the 2EH system the Teves uses a magnetic inductive sensor and a trigger wheel. The 5.5V is the reading when the sensor is facing a tooth of the trigger wheel and -4.2V is when the sensor face is opposite the air gap in the trigger wheel. The sensor changes as the speed of the trigger wheel increases with wheel speed this will increase the frequency and amplitude/voltage of the waveform (Pico Technology, 2018) Pin-2 is the ground pin for the sensor which is why it has the same frequency as pin 4 but small voltage change between 2.3V and 2.4V.

Fault Diagnostic Flow Chart-

The flow chart has been produced to aid in the investigation and diagnosis of an ABS system fault. The chart below was investigating the ABS warning light 'on condition' which displays to the user that the system has a fault causing the system not to operate correctly. The chart below was used to diagnose the fault which is an open circuit on one of the wheels sensors. The chart goes through each step when testing components to check they are operating correctly.



Operational Differences-

The Bosch 2EH system is the older of the two systems. This system is equipped with OBD which is now commonly known as OBDI as newer versions have been released. The OBD I system was mainly introduced to monitor emission related inputs to the ECU monitored by opened and closed circuits. Some early systems didn't have a keep alive memory which meant that intermittent faults are hard to find, due to the memory being wiped when the ignition is turned off (Baltusis, 2004). The Teves system was in production after the 2HE system, by this point OBDII was in operation and the system was fitted with nit because of its advanced diagnostic capabilities over OBD I. OBD II has many benefits when compared to

its predecessor, due to its advancement and standardisation. OBDII can be used with universal scanning tools due to the standardisation of the OBD port, rather than individual manufactures using different diagnostics ports which was common practise with OBDI. This brings the cost of diagnostics down as one diagnostic system can be used on many manufactures cars, this means multiple systems are not necessary. OBDII regulations required monitoring more systems, recording the malfunction, monitoring the system through the use of read less codes which allow for values of the system to be inspected to improve fault diagnosis (Baltusis, 2004).

The Bosch 2EH the system comprises of 3 solenoids and 4 wheel speed sensors. The system uses a solenoid to control each of the front wheels and a third solenoid along with the master cylinder to control the rear wheels. The rears wheels are controlled as a pair to minimise the difference in speed of the rear wheels to avoid unsettling the car under braking. The system uses 4 wheel speed sensors to monitor each wheel to avoid a lock up this is the same as the Teves MK4 system. The 2EH has a plunger/floating piston arrangement this allows for minimal loss of comfort of brake pedal feedback to the driver and advancement from the earlier Bosch 2S system (Bosch, 2000). The 2EH system has its components open and separate this allows for ease of access when diagnosing or repairing a fault, whereas the Teves system has all its components in a sealed unit meaning that diagnosing and repairs are more difficult and in some cases may result in the whole unit needing to be replaced resulting in an expensive repair. The Teves uses a vacuum booster which effectively creates a separate ABS system from the master cylinder. This systems design also allows for the advancement of a Traction control system to operate alongside the ABS. When the system is in pressure release phase it allows fluid to flow through back to the reservoir, but when the valve opens to increase pressure the pedal will give way slightly to avoid this the system uses an electronic pump. The pump extracts fluid from the reservoir to the supply valve and excess back into the master cylinder. A position sensor on the pedal, which will turn the pump off at a certain point to allow for adequate feel and travel of the pedal when the ABS is active (Alexander Kolbe, 1990) (Bosch, 2000). The Teves system uses 10 solenoids and 4 wheel speed sensors in its system; each wheel has its own inlet and Outlet solenoid for each wheel, then 2 ASR valves for each diagonal split of the brake circuits (Brake lines linked between the front left and right rear, and between the

front right and left rear) (Bosch, 2000). The diagonal split of the brake circuits with the two separate solenoids means that if a brake circuit would fail then the car would still be able to operate 2 of its brakes (one at the front and one at the rear to avoid a major unsettling of the car whilst braking).

Both systems have many advantages and disadvantages when it comes to their operation, control and diagnostics of the system. The Bosch 2EH is a good system due to its simple but efficient design, the system is a 3 channel design meaning that the front wheels are controlled individually and the rear wheels as a pair providing (Bosch, 2000) the maximum coefficient of braking force across all differing road conditions. (Bosch, 1995) The 3 channel system isn't as effective as the later 4 channel system which is used on the Teves MKIV which will provide a more accurate and responsive braking force. The 2EH system is made up of simple components which are easily accessibility for repairs and diagnostics of the system. The system has the availability so if a fault was to occur to the system then normal braking would remain just without the aid of abs. The system has areas which are a downfall of its design; the system uses OBDI for fault diagnostics as stated above. OBDI can be difficult for diagnostics due to the lack of standardisation of equipment to read fault systems. The do always provide the detail of information needed, meaning more time will be spent finding a fault, but the systems open design of components means that use of an oscilloscope is made easier. The Teves MKIV system uses a 4-channel system with independent brake control of each wheel which gives an accurate, responsive and efficient coefficient of brake pressure across differing road conditions (Alexander Kolbe, 1990). The system use of a brake booster with a pump system which allows for minimal change in pedal feel which gives the driver comfort in braking even when ABS is active (Bosch, 2000). The system uses OBDII for its diagnostics which brings benefits to the system; the standardisation of the diagnostic plug means diagnostic equipment is easier to access. The system also uses a fault safe concept where it monitors: programs flow with the electronic controller, electrical connectors, and hydraulic energy supply. The system uses two microprocessors one which is for plausibility criteria to check sensor signals and a processor for active test stimuli to check valves and switches. The system then uses a redundancy concept which will recognise failures in data processing which is checked against the plausibility criteria, such as; continuity of sensor signals, comparison of wheel speed

sensors, and switch response under defined physical conditions. If a fault is detected and affects the ABS function, it will switch the braking system back to its conventional braking function (Alexander Kolbe, 1990). The system uses a compact unit which makes fitment in the vehicle easier but makes diagnostics of individual components, the use of an oscilloscope on components, and the repairs or replacement of individual components difficult.

Conclusion-

The function of the Bosch 2EH and Teves MKIV ABS systems have been observed, tested and evaluated. A common goal was achieved by the team working together, testing the two systems demonstrating the use of safe working practises, and a successful method to obtain results from the systems which has helped understand their functionality. The results obtained allowed a service report to be produced which documented the test procedures and results. The test results were analysed to develop an understanding of the control, operation, and function of the two systems which gave a detailed understanding of their operational differences. The Teves system proved to be more complex system, this however meant that it had advances in accuracy and efficiency when in direct comparison to the 2EH system. The report elaborated on the two systems use of on-board diagnostics (OBD); the Bosch 2EH using OBDI and the Teves using OBDII. The report found that the Teves OBDII system was greater advanced than the Bosch 2EH and that it boasted more benefits and operational improvements. The report includes the production of a fault diagnosis flow-chart to investigate when the system displays a warning lamp 'on condition', the chart allows the user to follow a step by step process which eliminates plausible faults.

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Signal waveforms Figures-

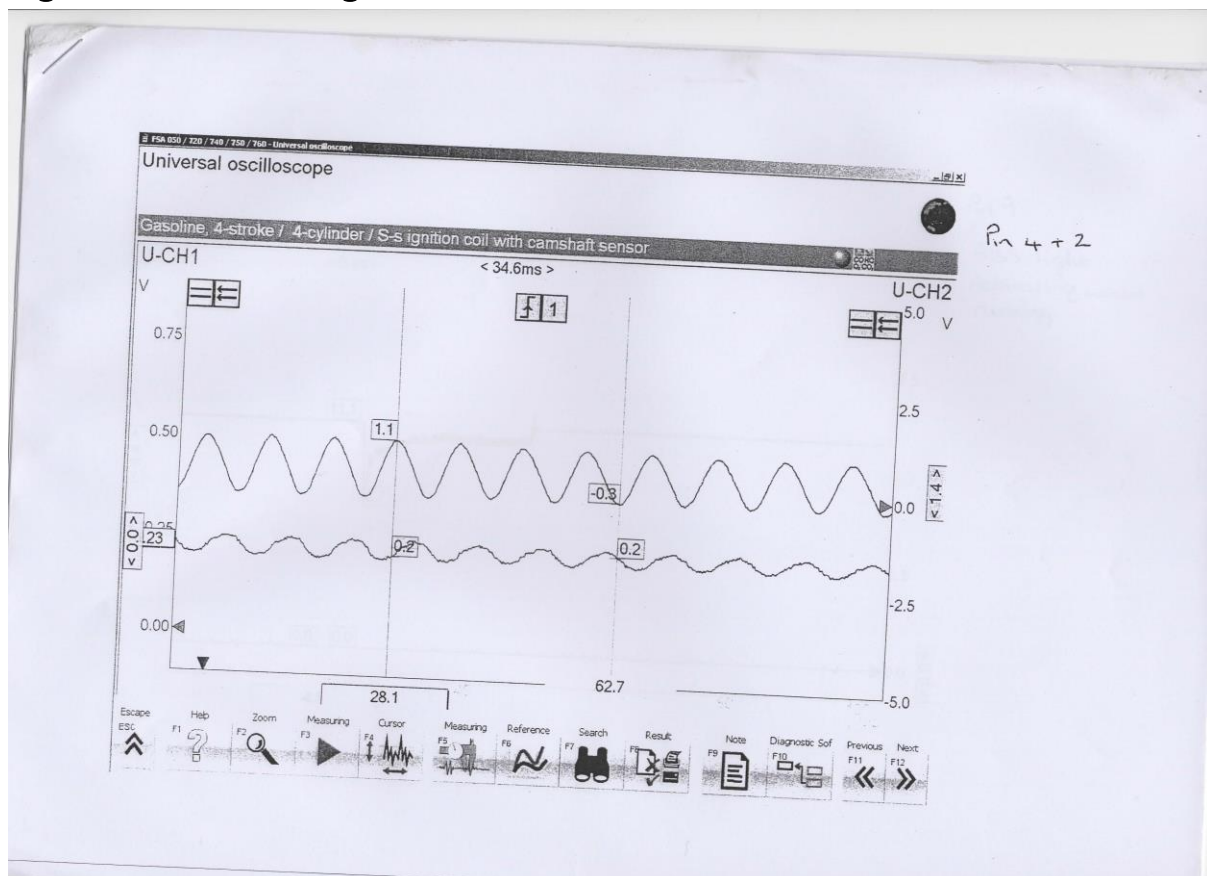


Figure 1-Waveform Bosch wheel speed sensor

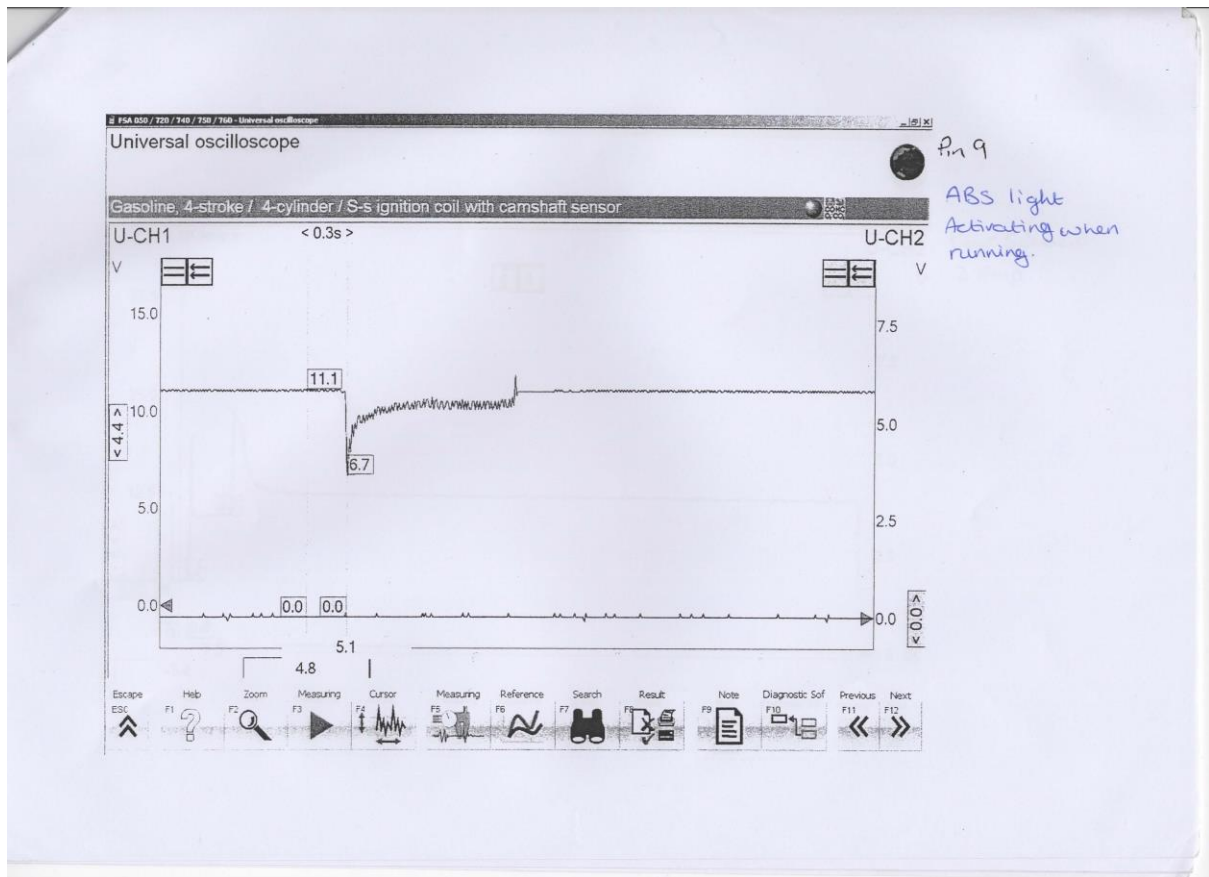


Figure 2-Brake light switch

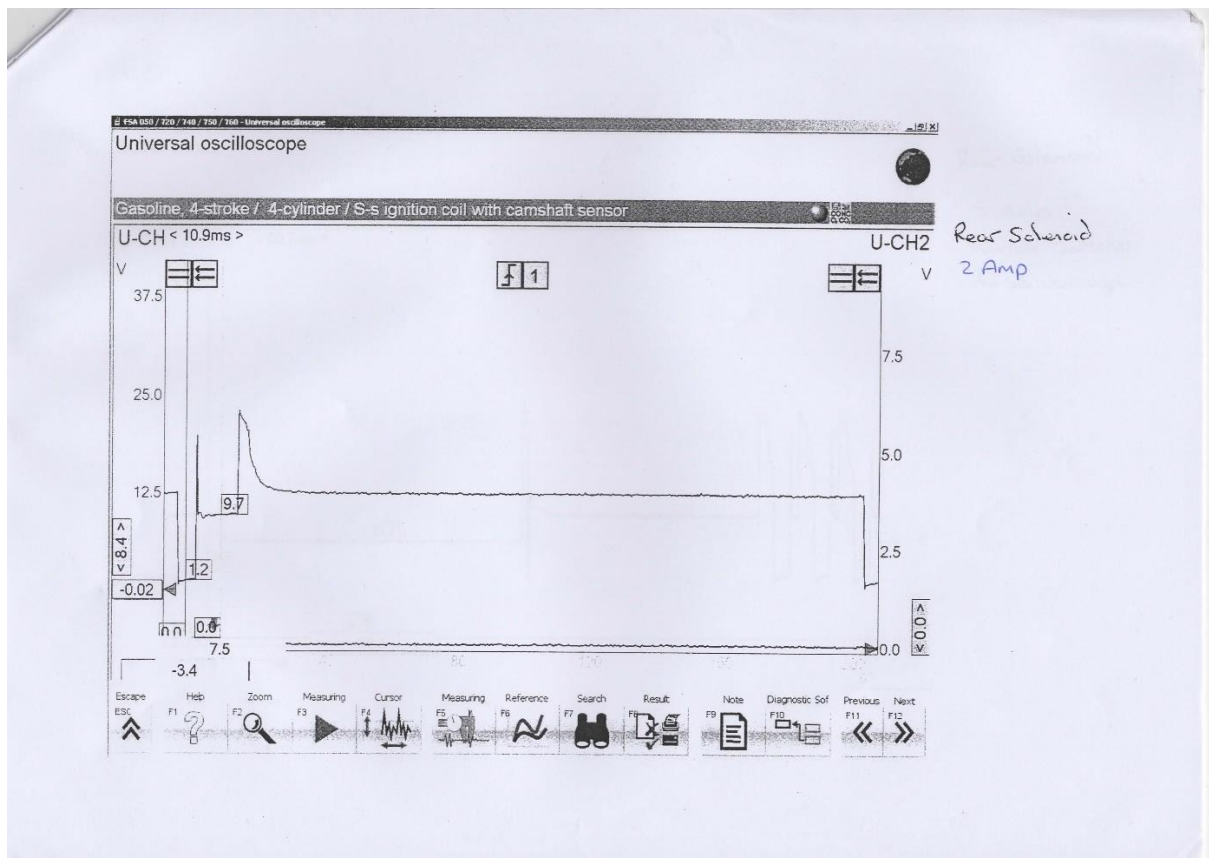


Figure 3-Brake rear solenoid

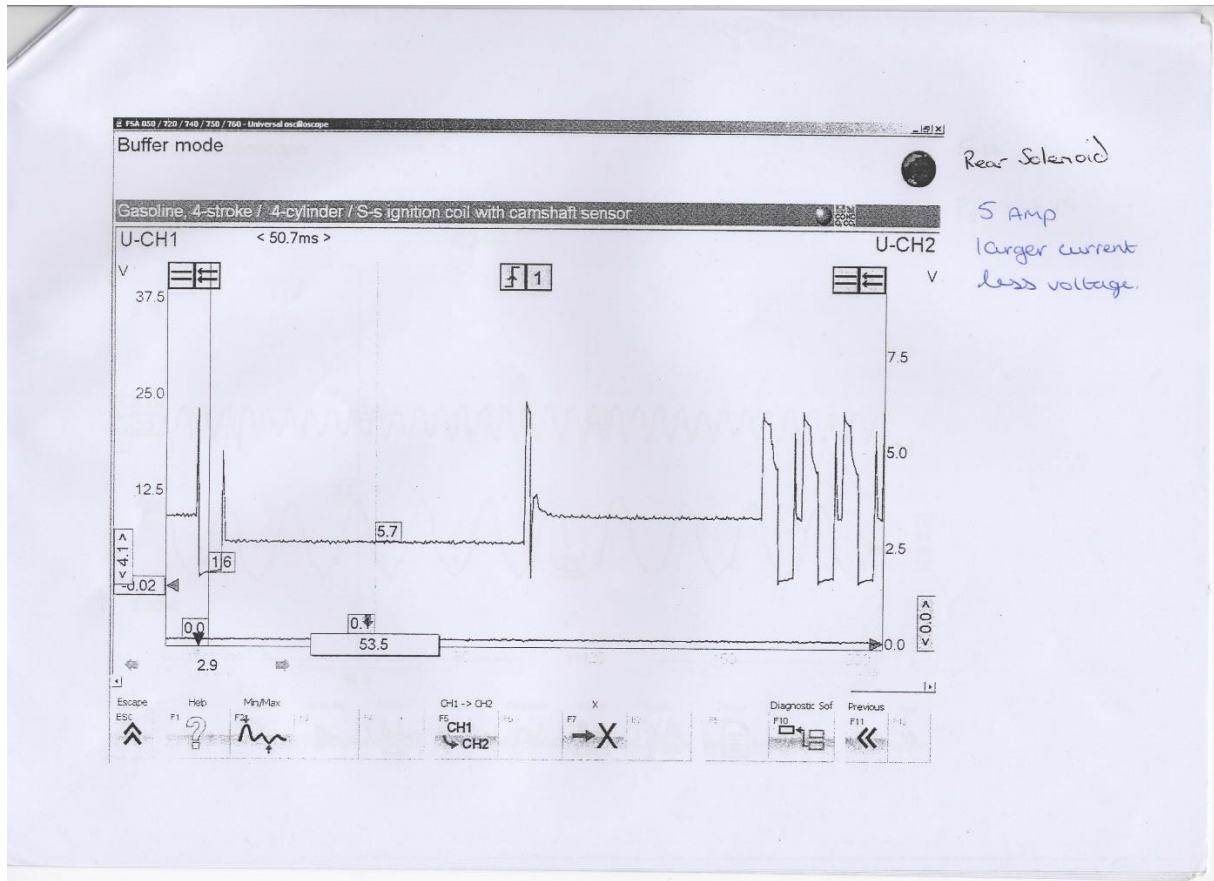


Figure 4-Brake rear solenoid

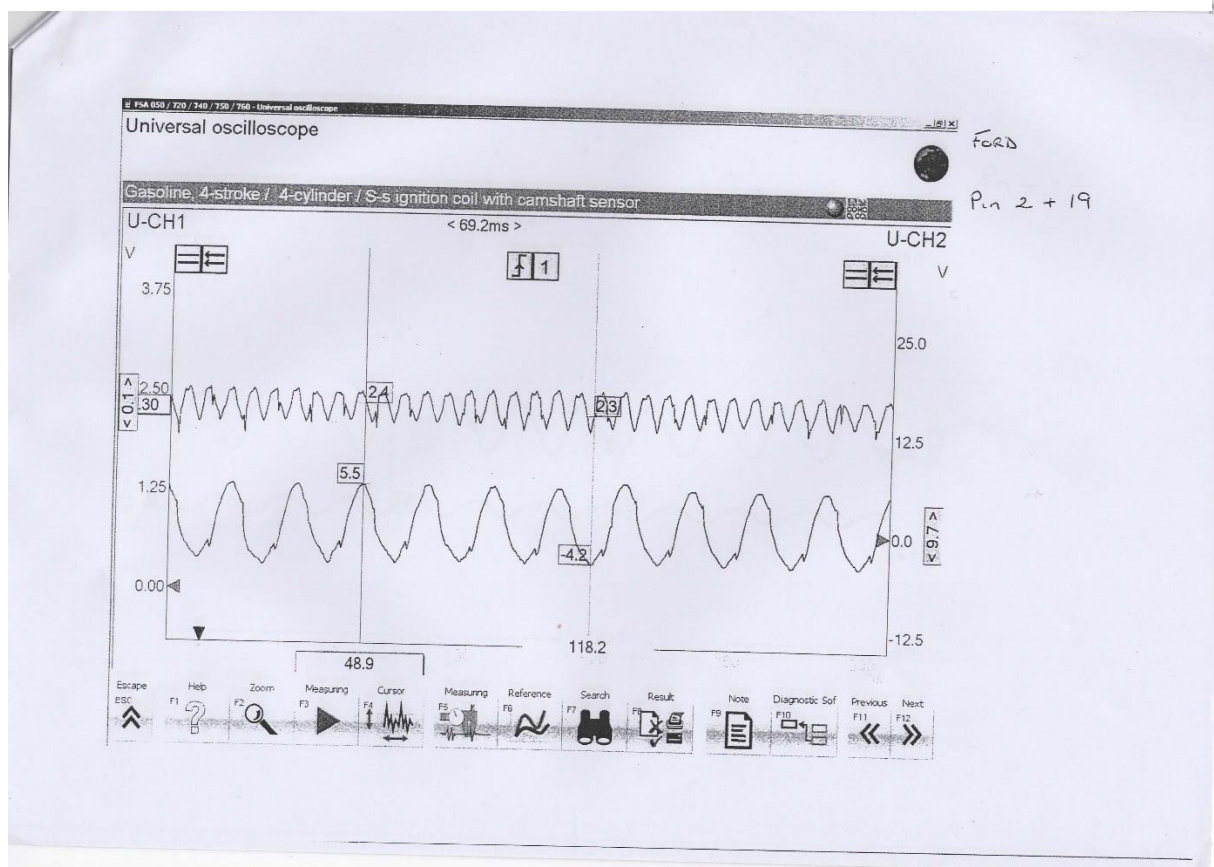


Figure 5-Teves wheel speed sensor