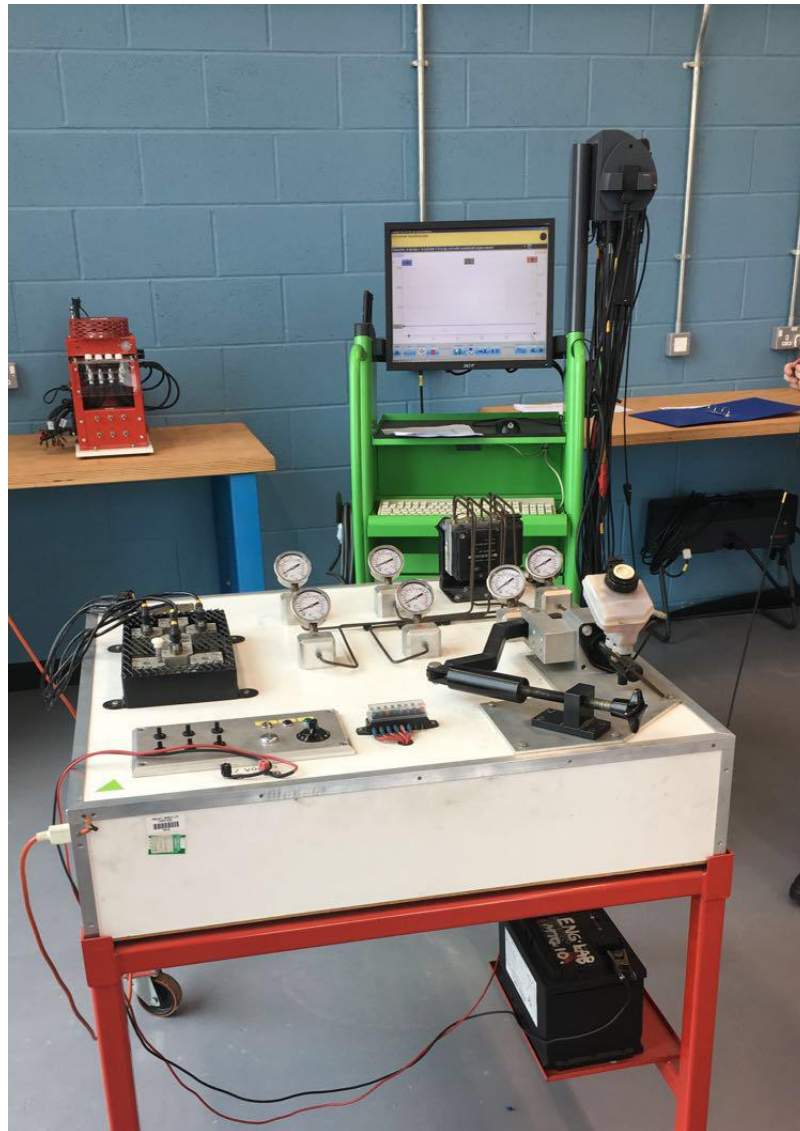


Emission Control and Diagnosis

Anti-lock Brake Systems



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Introduction

ABS systems were first fitted onto aircrafts during the 1920's, this was to prevent the aircraft from skidding on runways during harsh deceleration or on slippery surfaces. After a fairly long period of time they were developed to be fitted onto motorcycles in the 1950's and in the 60's, truck and car developers started implementing them on their luxury cars as added extras (Meineke, 2018). Since then the systems have significantly improved and are fitted onto most vehicles that travel the roads today.

There are many different types and evolutions of systems fitted onto cars these days, but the two that will be tested, analysed and compared are the Teves MkIV and the Bosch 2EH system. These systems will be separately tested in an engineering workshop, adhering to workshop rules and ensuring everything is done to minimise risk while following guidance from the HSE website the systems are statically and dynamically tested. Dynamically testing both systems will give a clear outcome of what all pins represent and what impact they have on the functionality of the systems, after the tests are completed the waveforms can then be analysed and the two systems can then be compared. Diagnosing problems can be difficult without the appropriate tooling and equipment. To aid the investigation and problem diagnosis a fault chart is created, the chart will be aimed at a fault within the ABS system and will be taken into depth of how the pump motor was found as the faulty part.

Because they are two different systems, the functionalities of both are compared and discussed along with what could be done to improve them and why those improvements would need to be done. Along with this discussion the systems pros and cons will be stated with some discussion as to the market they are intended for and to which customers they would be of value to, taking into consideration their release dates.

Anti-lock braking system

The purpose of the ABS system is to reduce vehicle speed without the wheels locking up into a skid. This is done by providing a 'closed loop control of wheel-slip rates at one or several wheels during braking manoeuvres' (E.Siegert, 1995). In normal braking conditions the driver of the vehicle will apply the brakes as usual but in slippery conditions or under harsher braking, as the wheels approach the lockup phase the anti-lock braking system will take over and modulate line pressures causing the car to slow down gradually without any skid. The ABS system will not only help with braking, but it will also allow the car to brake and steer without having excessive understeer or oversteer, this is because the brakes will not allow the wheels to lock up therefore the car will steer more freely (Limpert, 1992).

Service report

Working in groups of five, diagnosis tests were carried out on two different ABS systems known as the Teves MkIV system and the Bosch 2EH system. The testing was carried out in the workshop where all appropriate PPE was to be worn, this includes safety boots and dust coats. Regarding the Workplace Regulations 1992 and Approved Code of Practice (HSG129), the guidelines included in this publication aren't compulsory but if an engineering workshop follows them, they are usually complying with the law. Examples of the points made in HSG129 that apply to the testing procedures are as follows –

- Buildings to be in good repair
- Space for safe movement and access

The next examples are the law, therefore complying to these are compulsory –

- Workshop must be at reasonable temperature (16 Degrees Celsius minimum, depending on the type of work) and a thermometer supplied within the workshop

- Suitable and sufficient sanitary conveniences and washing facilities (relating to the ABS testing, for between 6 and 25 people there should be at least 2 wash stations)

(HSE, 2004)

Before any testing commences, everyone is briefed on how both systems work and what needs to be done, the systems are also checked for any defects that could mislead the analysis. Both systems are to be tested in the same manner, the first part of the testing is conducting a static test on both systems which will determine the amount of voltage running through each pin of the ECU plug. Doing this will allow the group to figure out what each pin represents and how they change when the ignition is turned on. Each student had one role in the testing procedure, student 1 would be responsible for turning the ignition on and off, student 2 would be responsible for taking down the readings on paper, student 3 would have the responsibility of using the voltmeter and the two other students would be responsible for looking out any unusual activity such as the ABS light and earth connection.

After the static tests are completed, the dynamic testing can be started on both systems. These types of tests are usually conducted using an oscilloscope, this type of testing equipment can determine the amount of voltage each pin receives while identifying how voltage figures change while the system is under braking. The roles and responsibilities of the dynamic testing procedure is similar but student 4 and 5 would be responsible of operating the oscilloscope computer. The testing is done by connecting the earth lead to the battery earth and then probing the positive lead into the ECU pins and looking at the readings on the oscilloscope computer. The difference between the static and dynamic tests are that the wheel speeds are raised to 6 on the dial and then the voltage readings are compared rather than only turning the ignition on and off. Doing this determines how the voltage values change while the car is in motion and under harsh braking. By analysing these factors on each pin of both ECU plugs the data can be compared between different pins which will determine how the pins send signals to the ECU.

Static tests results

Teves system

Pin No	IGN ON	IGN OFF	Pin No	IGN ON	IGN OFF
1	2.34 v	2.34 v	13	10.38 v	10.38 v
2	2.34 v	2.34 v	16	0.00 v	12.07
7	12.13 v	12.13 v	17	2.35 v	2.35 v
8	0.00 v	0.00 v	18	2.35 v	2.35 v
9	0.00 v	12.15 v	19	2.35 v	2.35 v
10	2.34 v	2.34 v	20	2.35 v	2.35 v
11	2.34 v	2.34 v	24	0.00 v	0.00 v
12	0.00 v	12.05 v	25	12.18 v	12.48 v

In the above table, pins 1,2,10 and 11 give the exact same values as each other, this is because they are all earth returns back to the wheel sensors. Opposite to the ground are the signal outputs from the sensors which are pins 17, 18, 19 and 20. These are the pins that send signals to the ecu therefore a change in the voltage value will occur when wheel speeds increase. As stated in the Automobile Handbook by Bosch, these wheel speed sensors will generate an electrical signal to the ECU where those signals will then be conditioned and processed (Schneider, 2014).

Bosch 2EH – Right plug

Pin No	IGN OFF	IGN ON	Pin No	IGN OFF	IGN ON
1	0.00 v	11.83 v	9	0.00 v	11.88 v
2	0.00 v	0.20 v	10	0.00 v	0.34 v
4	0.00 v	0.34 v	12	0.00 v	10.68 v
5	0.00 v	0.20 v	13	0.00 v	0.34 v
6	0.00 v	0.34 v	14	0.00 v	0.20 v
7	0.00 v	0.20 v	15	0.00 v	0.00 v

As the tables above show, the voltage at pins 2, 5, 7 and 14 all show a voltage value of 0.20 volts, this occurs because they are all ground pins for the wheel speed sensors. Along with these ground pins there are signal pins, these are to be seen on the table showing a value of 0.34 volts each. Pin 15 in the table doesn't provide any voltage value at the static test phase because of it representing the diagnostic excitation lead, this will be discussed with the dynamic test readings further on.

Bosch 2EH – Left plug

Pin No	Ign on	Ign off
1	11.79 v	0.00 v
2	12.08 v	0.00 v
3	0.00 v	0.00 v
4	11.79 v	0.00 v

The left plug on the Bosch system is showing zero voltage when the ignition is off and battery voltage when ignition is on, meaning that all pins are ignition related lines. Pin 3 on this plug doesn't show a voltage change when the ignition is turned on, this is due to it being the ground pin for the plug.

Dynamic test results

Teves MkIV

Pin No	Volts	Pin No	Volts
1	2.60 v	13	9.38 v
2	2.60 v	16	11.99 v
7	12.07 v	17	5.80 v
8	0.00 v	18	5.80 v
9	12.11 v	19	5.80 v
10	2.60 v	20	5.80 v
11	2.60 v	24	0.00 v
12	11.90 v	25	12.03

Referring back to the static test results, it indicated that pins 17 to 20 have an increased voltage of 3.45 volts, this is due to the wheel speed sensors are detecting movement in the wheels and sending signals to the ecu.

Looking at pin 13, when dynamically tested it indicated that the voltage has dropped in value by 1 volt, this is due to the voltage being drawn to other places that require it. As mentioned in appendix 1.B, an alternator is required to reduce the draw from the battery to keep it fully charged.

Bosch 2EH – Right plug

Pin No	Volts	Pin No	Volts
1	11.75 v	9	11.80 v
2	0.20 v	10	1.7 v
4	1.7 v	12	10.56 v
5	0.20 v	13	1.7 v
6	1.7 v	14	0.20 v
7	0.20 v	15	0.1 v

As mentioned in the static test results, pin 15 has increased to 0.1 volts which means that the ecu is receiving data from the excitation lead. This indicates that the ecu is receiving and processing data from the speed sensors while commanding the modulator to increase, decrease or maintain braking pressure (Smith, 2014).

Bosch 2EH – Left plug

Pin No	Volts
1	11.79 v
2	11.96 v
3	0.04 v
4	11.79 v

The only difference between the dynamic test results and static test results on the left plug is the value of pin 2. This value decreases while the ABS is working due to a voltage draw.

Waveforms Analysis and Evaluation

Appendix 1.A

Appendix 1.A shows the dynamic tests of pin 4 and 2 of the Bosch 2EH system, these pins represent the wheel speed sensor signal which is pin 4 and the wheel speed sensor ground which is pin 2. As stated, while discussing the static tests, pin 5, 6, 7, 10, 13 and 14 all represent the speed sensors. The waveform of pin 4 indicated that the voltage increases and decreases from a maximum voltage of 1.1 down to a minimum of -0.3 volts, this occurs due to the teeth on the sensor being in contact with the magnetic field and then leaving the magnetic field which creates the drop in volts, the drops in voltage are equal to the positive pulses (Ditex, 2016). The frequency seen in appendix 1.A is stable meaning that the wheel speed was constant while being tested, as Konrad Reif states that the frequency of the waveform is manipulated by the wheels speed meaning that if the wheel is not in motion then the induced voltage is zero (Reif, 2014).

Pin 2 waveform follow the pulses of pin 4 but have much smaller voltage pulses due to it being the ground of the sensor.

Appendix 1.B

Appendix 1.B represents pin 9 which is the brake light switch feed, the voltage before the drop is 11.1 volts and, as indicated in the photo, it drops to 6.7 volts before returning to its normal voltage. The drop in voltage, also known as draw, is caused by the engagement of the ABS pump which requires voltage elsewhere before returning it to the brake light switch feed. This draw occurs because the only power supply is the battery, whereas vehicles would have an alternator equipped with a 'voltage regulator so that it can supply the battery and the electrical equipment with a constant voltage' (Meyer, 2014).

Appendix 1.C

This example waveform shows the rear solenoid function, this is at the first phase which is pressure sustained meaning that no more pressure will be applied. The first phase will occur, according to Werner Schneider, when the speed sensor detects an abrupt deceleration the system will prevent further increase in pressure therefore the pressure will remain constant (Schneider, 2014). It shows a current battery voltage of 12.5 volts and before returning to normal it is sustained at 9.7 volts when the solenoid is generated, this happens because it is a two-amp draw.

Appendix 1.D

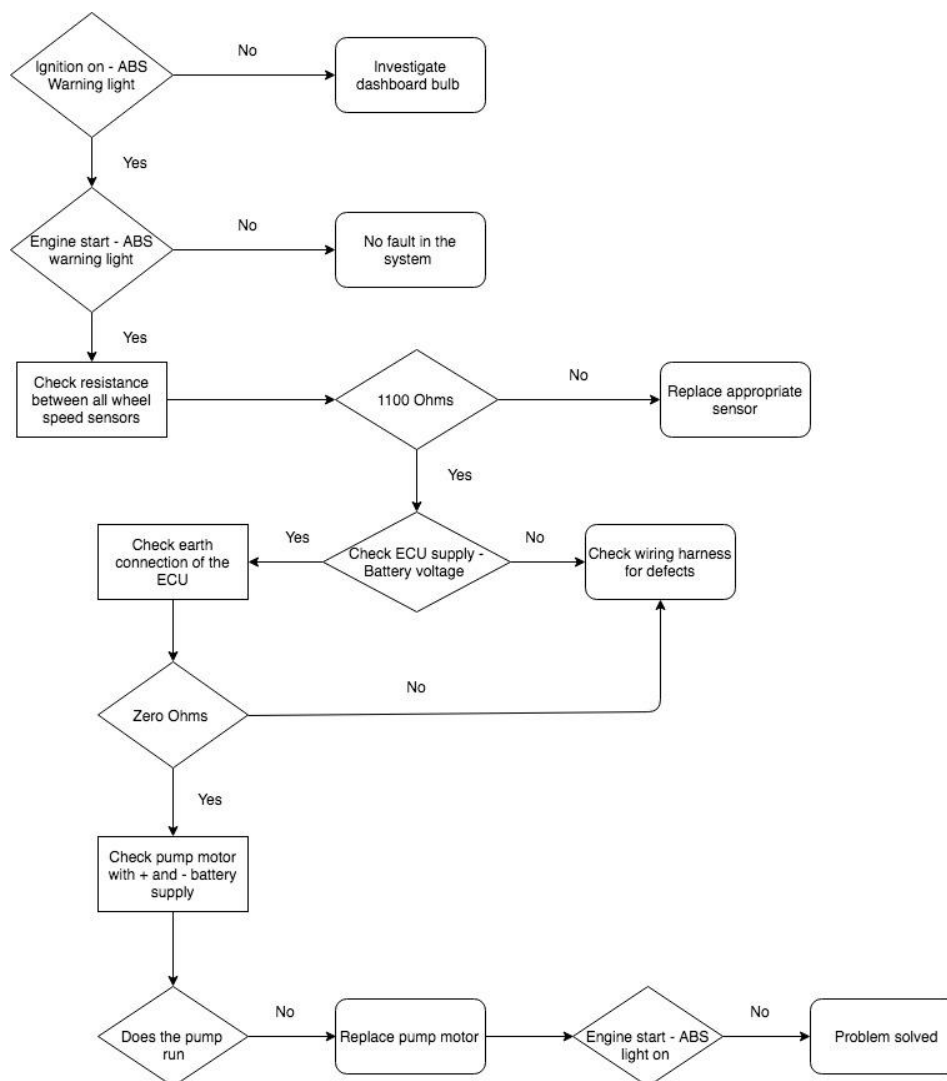
Following on from appendix 1.C, this is where the second phase occurs in the cycle. This procedure happens if the deceleration rate continues to increase from the first phase, the pressure in the cylinder will then drop causing the wheel to be braked less heavily, causing the excess fluid to be pumped back into the master cylinder (Schneider, 2014). As it indicates the voltage drops from 9.7 volts to 5.7 volts, affecting these figures is the fact that the pump is now on during the second phase.

Appendix 2.A

Pin 2 and 19 in appendix 2.A represent the wheel speed sensors on the Teves MkIV, whereas mentioned before, pin 2 is earth return and pin 19 is the signal output. Similar to appendix 1.A, the speed sensor earth return is seen to have a smaller voltage value than the signal output. The signal output has a peak voltage of 5.5 volts and a minimum voltage of -4.2 volts, the frequency of the waveform is constant meaning that the wheel speed is the same throughout the test. If the wheel speeds were to change the frequency and voltage peak of the waveform would increase, as stated by Josh Smith in Hilliers fundamentals of automotive electronics (Smith, 2014).

ABS Flow chart

The fault chart below resembles a fault causing the ABS warning light to be in the 'on condition'. The investigation into the problem can be aided by this fault chart which clearly shows the steps taken to diagnose the faulty pump motor. The system was not operating correctly, therefore, as shown in the chart the first steps taken to diagnose the problem were the easiest to access which were the wheel speed sensors. These steps are taken to minimise cost and save time during the process of diagnostics because if the pump was to be checked first it would consist of removing many obstructing objects whereas checking the wheel speed sensors require taking the wheels off only. This allows the engineer to identify the fault easier and quicker.



Comparing the functionalities of both systems

The Bosch 2EH is the oldest of the two systems, this system is equipped with the first generation OBD (On Board Diagnostic) whereas the Teves MkIV system has OBD 2. The OBD system allows external electronics to interface with the car's computer system which is vital in latest technology vehicles because they are becoming more computerized by the year (Edelstein, 2017). OBD 1 and 2 are pretty similar with minimal differences, main differences consist of the OBD 2 being more user friendly by adapting to universal scanning tools, this will majorly reduce tooling costs for diagnostic companies and also repair costs for customers. Another main difference is that OBD 1 was replaced with the second generation due to it not being able to meet the diverse need for the user to access relevant information useful for the healthy use of the car (Scantoolcenter, 2018).

Another difference between the two systems is that the Bosch 2EH system has three solenoids controlling the valves in the brake lines. The three solenoids in the system operate the two front wheels separately and the rear wheels together. Unlike the Bosch system, the Teves system has four solenoid valves operating the brake line pressure, this means that all four wheels can be independently adjusted during wheel lockup (Gibson, 2018).

The valves usually work in three operational phases, the first phase being pressure build up when the solenoid is at its base position therefore the pressure from the master cylinder to the calliper is un-obstructed. The second phase is pressure holding phase, this is when the valve reacts to wheel lock by interrupting the pressure in the brake line making sure that there is no increase in that specific corner of the car. The third phase of the valve is pressure reduction phase, in this phase the excess pressure is released by opening a passage between the affected cylinder and the accumulator. Once the pressure has been released the valve will either return to pressure holding phase or to its base where it would be non-energized (Stegmaier, 1995).

Pros and Cons

Both have different OBD generations but a downfall of the Bosch system is that it has OBD 1, this limits the amount of diagnostics that can be carried out therefore making it harder to solve problems within the system. Whereas the Teves system, equipped with OBD II, can be analysed in a more detailed way unlike OBD 1. As stated by Keith McCord, OBD II can store diagnostic trouble codes in non-volatile memory to be recalled later and allow real time controls to test a variety of management systems via a scan tool, along with many other advantages (McCord, 2011).

Another positive about the Teves system is its compatibility with two different traction control systems. The first of the two systems work with brake intervention only whereas the other type of system works with brake and engine intervention. Having this system on top of the abs system would have a big impact on many aspects of driving, but mostly it would provide additional assistance while cornering and overtaking at higher speeds (Seiermann, 1990).

Both systems have their own unique positives, the Bosch system's pros are that the system is very simple to understand and doesn't cost much to produce and fit to a car due to it having only three solenoids controlling the valves whereas the Teves would be more complicated and expensive. In argument with this, as stated by Max Seiermann, the Teves system fulfils its requirements of being a high performance and at the same time, a low cost system for manufactures (Seiermann, 1990).

Conclusion

One of the most important aspects to consider whilst working in an engineering environment is the health and safety of yourself and others around you. By adhering to the laws of health and safety it makes the environment safer for everyone by also making it easier to work which will give a better end result. The tests of both systems in the workshop were conducted in the correct manner using the appropriate tooling and equipment, making the tests very successful.

Looking at both systems by comparing them, considering the evolution of abs systems and that the two compared have been around for a while, the two systems have many positives to them making them very adaptable to modern cars in this day and age. The system most adaptable to a modern vehicle would be the Teves system as it has the advantage of being compatible with two traction control systems without much extras.

By looking at the tables included above, an explanation of what each pin represents and what changes when ignition is on or the vehicle is in motion. This gives a good understanding of what happens in the system and is a very good diagnostic tool when used to find a fault. By creating tables like these a thorough explanation is given making it easier to diagnose and understand, but to help the diagnostic process a flow chart is created. The flow chart will save time and money for the engineer and the customer by making fault finding quicker and effective. By implying these points into the testing stage, the group successfully tested and diagnosed an issue with the abs systems.

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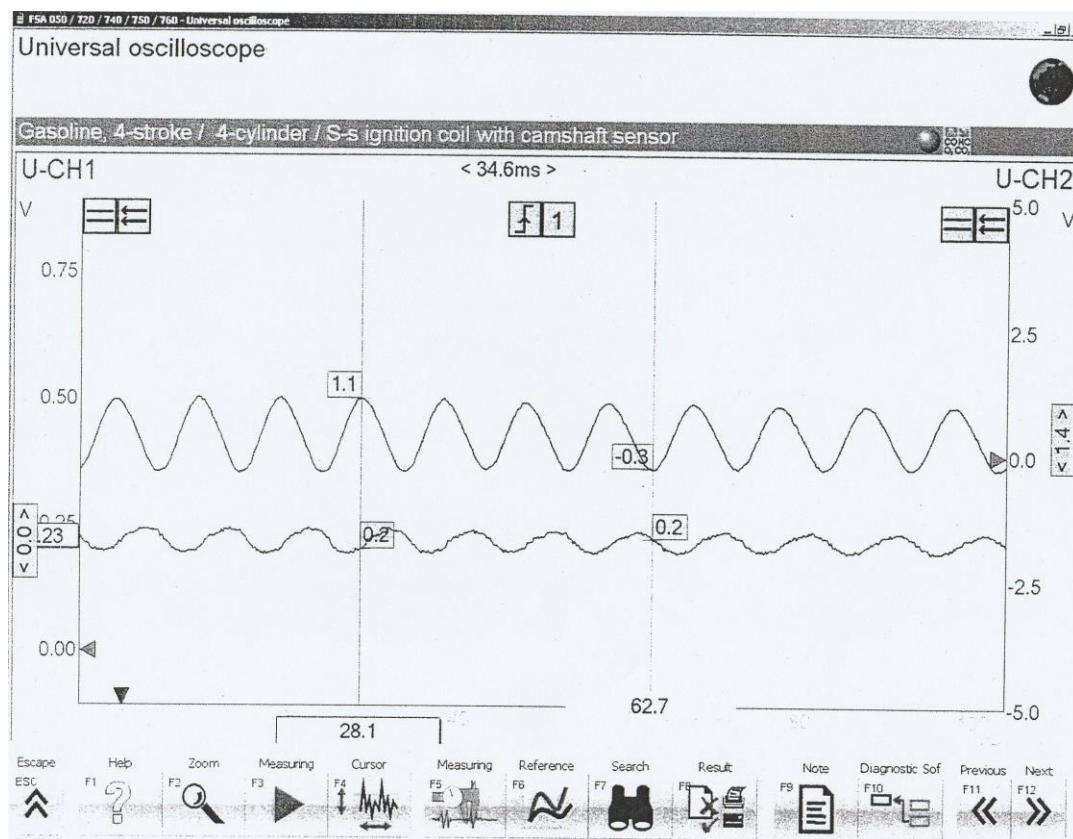
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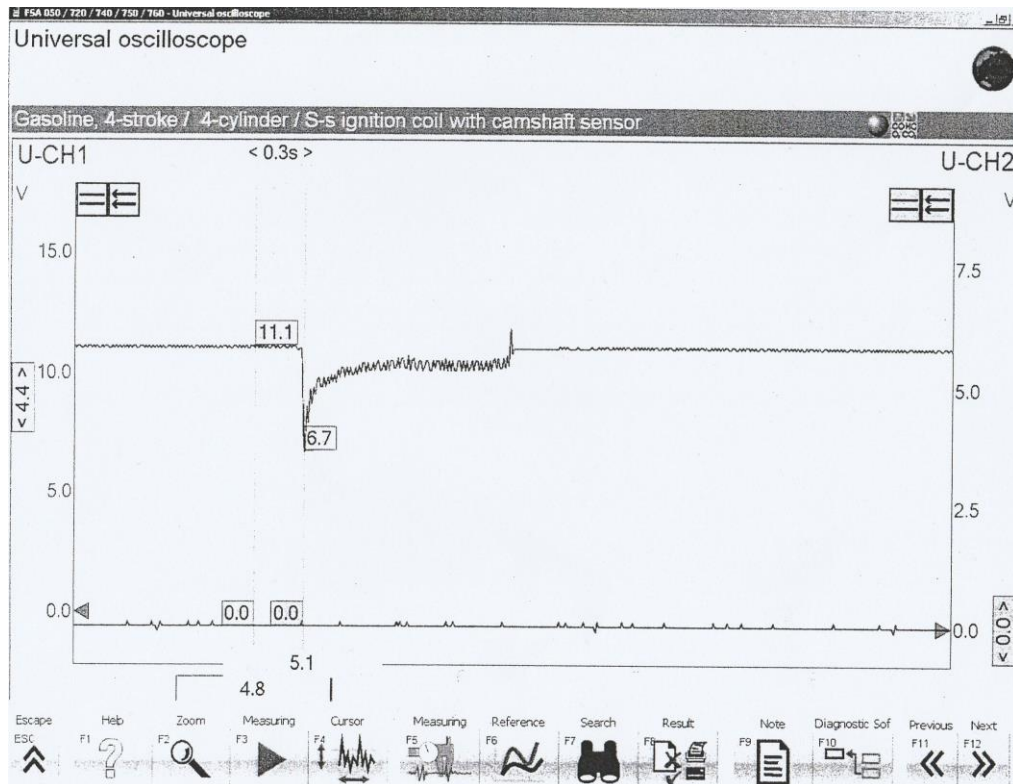
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Appendices

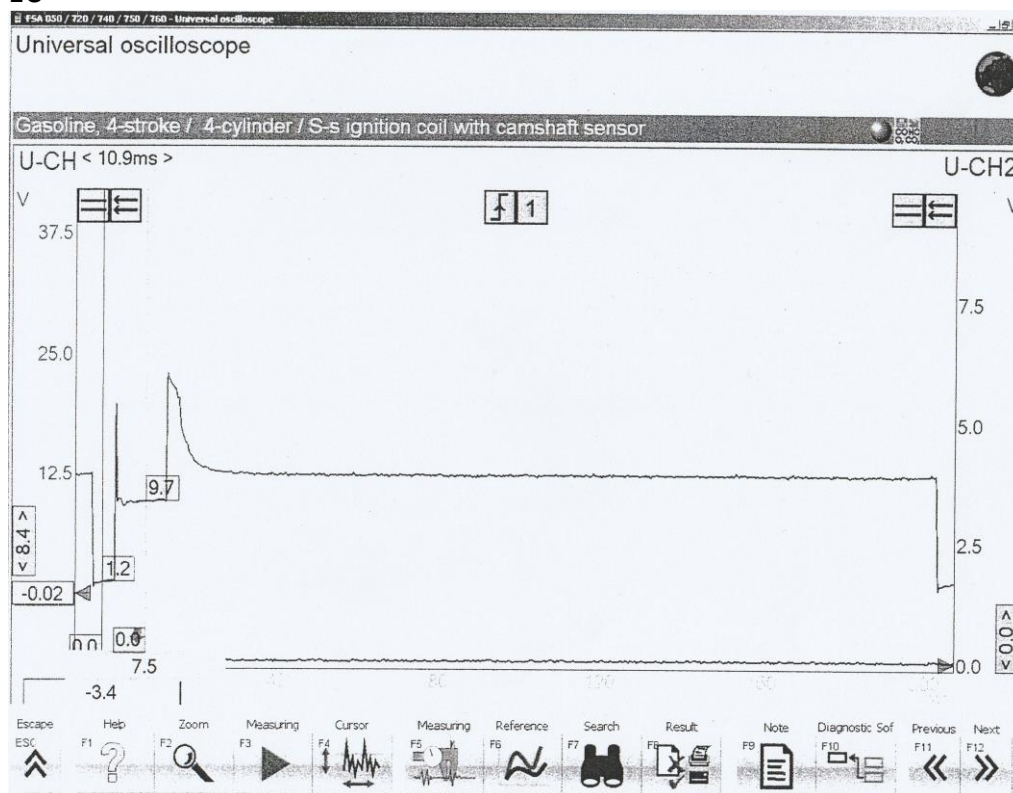
1A



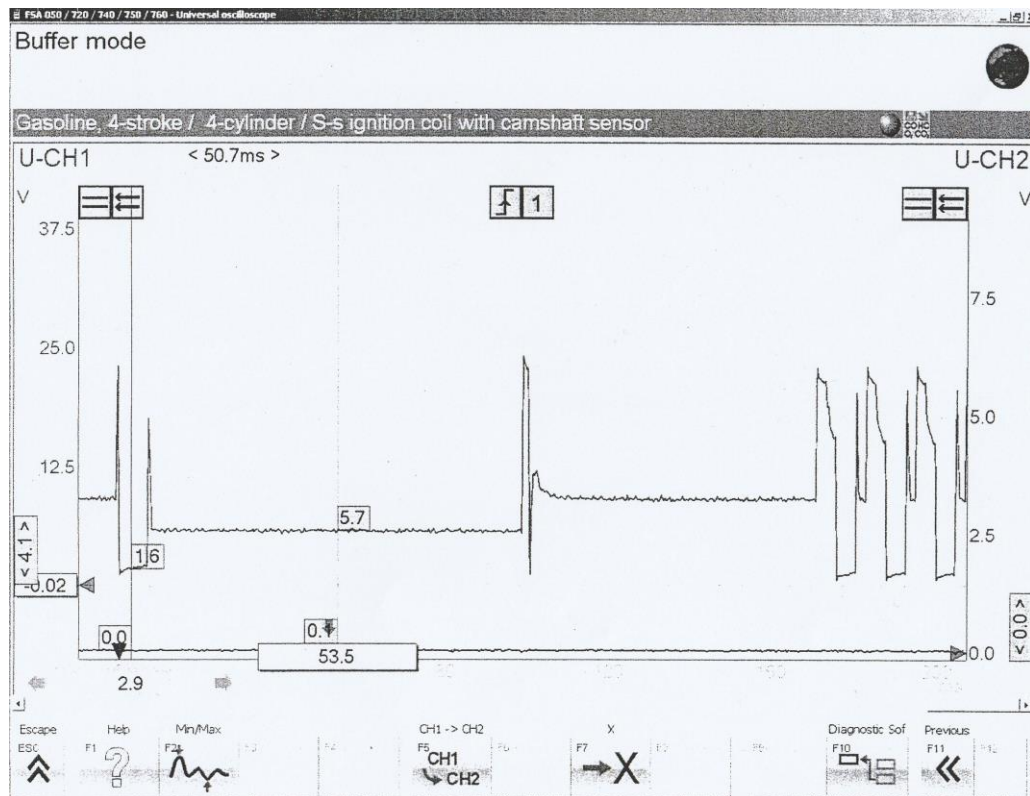
1B



1C



1D



2A

