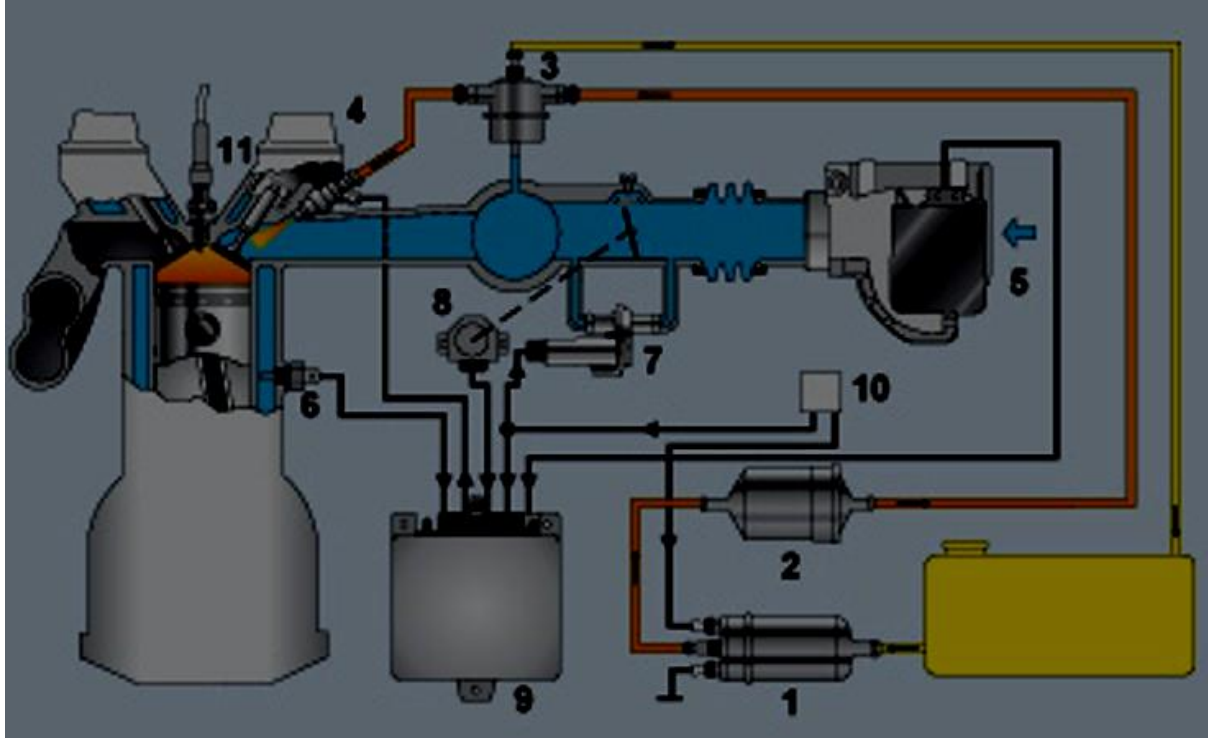




Engine control systems M4X02197 Sean Perks

1.0 introduction.

2.0 brief history of both systems.

2.1 Motronic.

2.2 LE3 Bosch.

Figure 1 picture of the LE3-jetronic ecu.

3.0 Test.

3.1 How the testing was carried out.

3.2 The equipment used during the testing.

3.3 Test results.

Figure 2 Motronic 1.5 test results.

Figure 3 LE3 jetronic test results.

4.0 comparing the data.

Figure 4 Throttle potentiometer table for Motronic 1.5.

Figure 5 injector test table for Motronic 1.5.

Figure 6 injector test table for LE3 jetronic.

Figure 7 table of data showing the warm up stages of the engine and the various data from the components tested.

5.0 Scope patterns from the testing.

Figure 8 scope pattern for the speed sensor from the Motronic 1.5 ecu.

Figure 9 scope pattern for pin 7 and pin 53 on the Motronic 1.5 ecu.

Figure 10 Scope pattern for the LAMBDA sensor on the Motronic 1.5 ecu.

Figure 11 Scope pattern showing the wave pattern of the rotary idle valve on the Motronic 1.5 ecu.

Figure 12 Scope pattern showing the primary wave form on the Motronic 1.5 ecu.

Figure 13 Scope pattern showing both the spark advance signal and primary wave form on the LE3 jetronic ecu.

Figure 14 Scope pattern showing the injector signal under acceleration and deceleration. LE3 fuel ecu .

Figure 15 Scope pattern showing the crank signal to the fuel ecu on the LE3 jetronic ecu

6.0 modifications

7.0 evaluation and conclusion

8.0 references

1.0

In this report, I will be discussing the differences between the Motronic ECU and the LE3 BOSCH ECU. I will be including two sets of data which will include scope patterns, voltage and resistance readings of various components from two separate practical sessions, along with facts. Following this I shall be comparing the differences against one another and the advantages and disadvantages of both systems.

2.0

Motronic

Motronic is the trade name given to a range of digital engine control units developed by Robert Bosch GmbH (commonly known as Bosch) which combined control of fuel injection and ignition in a single unit. By controlling both major systems in a single unit, many aspects of the engine's characteristics (such as power, fuel economy, drive-ability, and emissions) can be improved.

Motronic 1.5 (system we tested)

This system was used on some of General Motors engines (C20NE, 20NE, C20SE, 20SE, 20SEH, 20SER, C20NEF, C20NEJ, C24NE, C26NE, C30LE, C30NE, C30SE, C30SEJ, C30XEI...).
Motronic 1.5 operation.

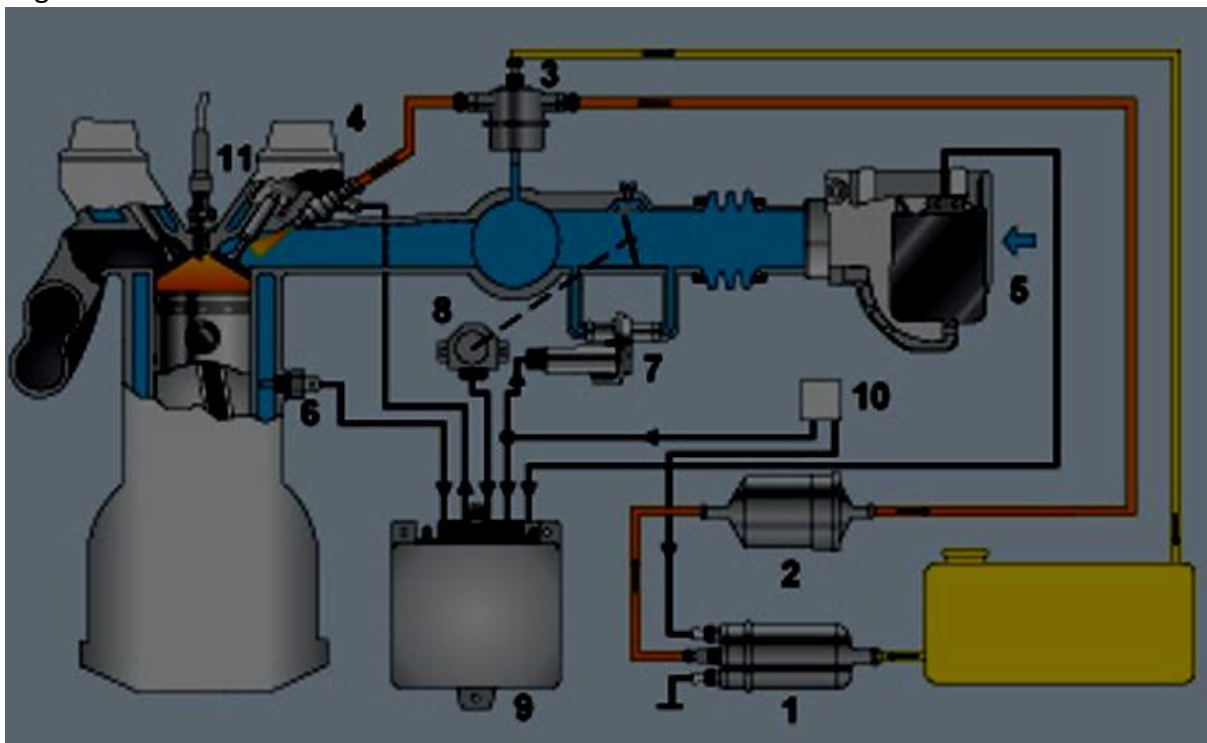
The Motronic 1.5 is an enhancement of the Motronic 4.1 EMS fitted to earlier Vauxhall and Opel vehicles. It was first fitted in the 1990 model year (late 1989) and is a fully integrated system that controls primary ignition, fuelling and idle control from within the same ECU. Both 4 and 6 cylinder engines use M1.5, with little difference between applications - other than that the six cylinder fuel pump is contained within the fuel tank. Also, the six cylinder 24 valve engine utilises a knock control facility. The Motronic ignition point and injection duration are jointly processed by the ECU so that the best moment for ignition and fuelling are determined for every operating condition. The injection function of the Motronic system is based on the well-tried 'L' jetronic system, although a number of refinements have improved operation. A 55 pin connector and multi-plug connects the ECU to the battery, sensors and actuators. This system description and tests are based upon the Cavalier and

Carlton vehicles equipped with Motronic 1.5. Most other vehicles are very similar with differences being mainly concerned with equipment levels (ie AT and A/C etc and their associated connections to the ECU) and the various ECU connections to earth. Not all vehicles use coding earth connections.

LE3 Bosch ECU

The LE3-jetronic ecu is the third ecu in the LE line of jetronic ecu's by Bosch. The LE3 was used from (1989–1991), it featured miniaturised ECU with hybrid technology, integrated into the junction box of the AFM. The LE3-jetronic system is analogue, and therefore it does not keep in memory possible damage that may occur. It has no fault lamp for the injection system. Unlike the Motronic, the LE3-jetronic does not have the ignition control incorporated into the same ecu.

Figure 1



3.0

We tested both systems, during the test we tested various variables which included measurements of different components before during and after the warm up phase. The

variables included ignition on times and coil dwell times at different stages during the warm up phase as well as when the engines were up to temperature. We also tested the the open loop function of Lambda.

3.1

Motronic

At the start of the testing, we tested the voltage each relevant pin of the ecu with the ignition off and recorded the results. Once each pin had been tested, we then turned the ignition on and proceeded to test the voltage. During the warm up stage which comprised of 10°C increments until the temperature reached 80°C, we tested the resistance of pin 45 (output from NTC 2) as well as the voltage. We tested pin 16 (pulsed side of injectors. (bank of two)) at each stage during the warm up period. We tested the injection on time during this. We also tested pin 4 (pulsed side of rotary idle valve) we measured the percentage that the valve itself was open at each stage of the warm up period. We also measured pin 5 (pulsed side of the tank vent valve). We were measuring to see when the valve itself turned on. At each stage of the warm up period we also measured the resistance of the water temperature sensor. Once the warm up had been completed and the engine was up to temperature, we turned it off and began measuring the resistance and voltage of various components on the engine to make sure they were within the manufacturers specifications. These components were as follows; throttle potentiometer, air flow sensor, air temperature sensor, idle speed control valve, the injectors, the primary and secondary coils and the HT leads.

LE3 jetronic

The testing for the LE3 jetronic was very similar to the Motronic in terms of following the same process, however there were some slight differences. Instead of just one main ecu, there were two one which control ignition and the other which controls fuel. There are 15 pins in each ecu, as well as 4 pins in the amplifier. There were also less sensors to test once the warm up stage had been completed. We tested all the pins on both ecu's and the amplifier with both ignition on and off. During the warm up stage we only tested pin 8 on both ecu's (pin 8 on the fuel ecu is ntc2 water and pin 8 on ignition is the octane plug) and we also tested pin 3 on the fuel ecu which is the injector bank.

For both tests, there was a safety procedure that was strictly followed. We all wore steel toe capped shoes to protect our feet. The door in the workshop was opened to allow fresh air to enter the workshop during the testing even though we were using a good ventilation system. When ever the engine was going to be cranked, the person operating the ignition

3.2

3.3

Motronic 1.5 results

Figure 2

[illegible]

Above is a screenshot of the various table of results that we gathered from the testing of the Motronic 1.5 ecu. When we tested the various components we compared the results to the handbook for the specific engine and ecu. Most of the results were in spec but some varied.

Figure 3

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Spark Advance Unit				Fuel Injection ECU				Amplifier						Book		Engine		Pin Number			
2	Pin Number	Ignition Off	Ignition On		Pin Number	Ignition Off	Ignition On		Pin Number	Ignition Off	Ignition On		Throttle Switch	Terminals		Resistance (Ohms)			Temperature (°C)			
3	1	0V	00.03V		1	0V	00.06V		1	0V	11.99V			28.16 Throttle Closed	0		0		20	1974	1.6	3.9
4	2	0V	00.03V		2	0V	12.06V		2	0V	00.02V			38.16 Throttle Closed	Infinity		Infinity		30	1105	1.1	3.1
5	3	0V	11.98V		3	0V	00.00V		3	0V	11.95V								40	747	0.9	3
6	5	0V	00.06V		4	0V	00.02V		4	0V	00.13V		Plant Temperature Sensor	Temperature (°C)		Resistance (Ohms)			50	512	0.6	2.6
7	6	0V	00.02V		5	0V	00.03V							-10	7000-16000			60	548	0.6	2.5	
8	7	0V	02.54V		8	0V	02.03V							20	2100-2300							
9	8	0V	00.95V		10	0V	00.16V							80	270-390							
10	10	0V	00.03V		12	0V	12.11V						Auxiliary Air Valve		Distance Between Terminals		40 Ohms	45.7 Ohms				
11	11	0V	00.03V		14	0V	04.99V															
12	12	0V	00.06V		15	0V	00.02V															
13	13	0V	00.13V																			
14	14	0V	04.98V		Primary Resistance		0.7 Ohms															
15	15	0V	00.15V		Secondary Resistance		7740 Ohms															
16																						
17																						
18																						
19																						
20																						
21																						
22																						

Above is a screenshot of the data we collected from the testing of the LE3 jetronic ecu. We tested the jetronic in a very similar way to the Motronic just we tested less components as they are not present on the jetronic. As mentioned previously we tested each of the other components against the values in the handbook for the engine and ecu that we tested.

4.0

Motronic results

As can be seen from the table containing the voltage values from ignition off, there are only two pins that are constantly live and they are pin 18 and pin 36. Pin 18 is a permanent live, this keeps the memory live on the ecu. Pin 36 is a control circuit for supply to the auxiliaries and the ecu itself. Pin 36 was showing as 21.1v with the ignition off and 0.73v with the ignition on. I find it odd how there can be a higher than battery voltage with no ignition on. When we turned the ignition on and tested all of the pins again, the earths remained either 0v or no more than 0.1v. The various sensors are showing a lower than 12v or 11v, for example the output for NPTC 1 is only 3.75v and the output for NPTC 2 is 00.73v. During cold cranking, the injector on time is 24.3ms whereas when the engine does start it drops to 3.5ms. This shows the cold start function in the ecu. As the engine proceeded to increase in temperature, the injector on time had decreased to just 2.8ms at 80°C. The tank vent valve had turned on by 52°C. Also the lambda sensor had gone open loop by 36°C. As the temperature increased, the resistance of NPTC decreases by around 1300 ohms, this tells us that as the temperature increases the resistance decreases and this is how the ecu knows at what temperature the water is inside of the engine. Also the voltage decreased from 3.1v to 0.6v. Without the engine running, the voltage at NPTC 2 was 0.73v. The percentage open of

the rotary idle valve drops from 47 down to 42 then steadily increases back up to 46 by the time the engine had reached its operating temperature. The resistance of the four High Tension leads varies greatly, cylinder 1 had a resistance value of 19570 ohms, cylinder 2 had a resistance value of 22200 ohms, cylinder 3 had a resistance value of 14900 ohms and cylinder 4 had a resistance value of 23100 ohms. There is a difference of 8200 ohms between the highest resistance of cylinder 4 and the lowest resistance of cylinder 3's lead. This could be down to a few factors, length of the lead or the state of deterioration of the lead itself. What I find very interesting is that the king lead has absolutely no resistance what so ever, This was down to it being faulty, in fact it was corroded. Despite there being a faulty king lead, the engine still ran, all be it a bit lumpy. The fan came on at 70°C which meant the electrical load on the engine therefore increased.

Figure 4

	Book	Engine
	Resistance-Ohms	
Terminals		
1&2, Throttle Closed	1900-2000	2129
1&3 Throttle Open	1000-2000	2707
Throttle Potentiometer		
Terminals	Voltage	
2&Earth, Throttle Fully Closed	0.12-1.22	
2&Earth, Throttle Fully Open	3.90-4.95	

Above is the table of the data collected from testing the throttle potentiometer, as is visible the resistance of both are above specification. This tells me that there is some sort of issue with the throttle potentiometer and was most likely the cause of the rough idle. We did not test the voltage as it was not necessary.

Figure 5

	book	Injector Number
		1 16.3 Ohms
Injector Valves	Resistance Betwwen Valves 12-17 Ohmes	2 16.3 Ohms
		3 16.5 Ohms
		4 16.3 Ohms

Above is the table showing the values we gathered by testing of the four injectors. They are within the specification but only just, this tells me that in the not too distant future they will need replacing with some new injectors.

Figure 6

	Terminals	Resistance-Ohms	
<u>Air Flow Sensor</u>	4&2	2200-2800	344
	4&3	300-550	501
	4&1	270-520	0

Above is a table showing the data we collected when we tested the airflow sensor, the resistance values for this sensor are very strange, there is only one value that is in spec and that is the resistance between terminals four and three. The resistance between terminals four and two is very low I would think that would cause an issue with the engines operation and how it runs. The same can be said for the resistance value between terminals four and one, there is not even any resistance, this further suggests that the component is faulty.

LE3 jetronic results

As can be seen from figure 2, all the pins in both ecu's and the amplifier are showing 0v with ignition off. This is to be expected as there is no memory function on the LE3 jetronic. Unlike the Motronic where there was 2 pins that were live even with the ignition turned off.

On the spark advance unit, pins 1 and two are both earth so even when the ignition is turned on, there is vary little voltage at them pins. Pin 3 is the supply to the spark advance unit so 11.96v is correct. Pin 5 is showing 0.06v. Pin 5 is the signal reference for the fuel ecu so with the ignition on but the engine not running, the voltage will naturally be low. Pin 15 is also a signal reference for the fuel and its showing 00.15v. Pin 6 is the throttle. The throttle is closed and at its idle position so the voltage is very low. However pin 14 is also labelled as throttle and that is showing 4.98v. Both pins 6 and 14 on the spark advance unit intercept pins 14 and 15 on the fuel ecu and go to the throttle switch. Throttle switches determine the throttle position. They are mounted directly on the throttle valve shaft. The various switch positions are transmitted to the engine management control unit and assist in the calculation of the required fuel quantity and whether or not to retard or advance the ignition. The throttle switch houses two switches which are actuated using a switching mechanism. The two switches give the engine management control unit information on the engine operating states "idle" and "full load" to ensure the necessary fuel quantity is accurately calculated and to ensure the engine is at the optimum ignition point. All the signal voltage values are below 1v which means that a signal given to an ecu is very low voltage.

The octane plug tells the ecu which fuel is in the vehicle and therefore in turn tells the ecu how much to retard or advance the ignition based on the RON rating that has been selected for the car to run on. It is a pre determined map based on the RON value of fuel.

The primary resistance was read at 0.7 ohms and the secondary resistance was measured at 7740 ohms. The resistance of the four High Tension leads is much more consistent than was seen on the Motronic ecu. Cylinder one had a resistance value of 8790 ohms, cylinder two had a resistance value of 8200 ohms, cylinder three had a resistance value of 7780 ohms and cylinder four had a resistance value of 6160 ohms. This equates to a difference of just 2630 ohms. The shortest high tension lead is the one for cylinder four hence why it has the lowest resistance and as the leads get longer, the resistance increases.

Figure 6

13				Injector Number	
14	Injector Valves	Resistance Between Terminals	15-17 Ohms	1	15.7 Ohms
15				2	15.7 Ohms
16				3	15.7 Ohms
17				4	15.8 Ohms
18					

Above is the table which shows the data collected from testing the injectors. All four injectors are well within spec and appear to be working perfectly so there is no need to worry about them. The cold crank injector on time was 27 milliseconds, this shows the ecu's cold start function is operating as it should to en-richen the mixture to aid cold starting.

Figure 7

	Pin Number		
Temperature (°C)	8	8	3
20	1974	1.6	3.9
30	1105	1.1	3.1
40	747	0.9	3
50	512	0.6	2.6
60	548	0.6	2.5

Above is the table that contains the data collected from the two components tested and also for pin 8, the two different values we tested. Pin 8 is the NPTC 2 sensor (coolant temperature) we tested both the voltage and the resistance values. Pin 3 is the injector bank, we were testing for the injector on time throughout the warm up phase and when the engine was up to temperature. As can be seen, as the coolant temperature increased the resistance decreased. Also as the temperature increased the voltage coming from NPTC 2 also decreased. This tells us that the component is functioning correctly and is communicating with the ecu correctly. The values for pin 3 (injector on time) also decreased as the temperature of the engine increased, this is to be expected as the engine is slowly reducing the amount of fuel needed to keep the engine running as it gets warmer as the engine requires less fuel to stay running as it gets warmer.

5.0

From the testing, we collected several scope patterns of the various components we tested such as the injector on time at idle, under acceleration and under deceleration, the secondary voltage, the spark duration, the pulsed side of the rotary idle valve, the ignition feed and the the earth return, the load output from the mass air flow sensor, the output from the throttle potentiometer, the LAMBDA sensor wave pattern and also the speed sensor. However, not all of these components were on both systems. I will now include these scope patterns below.

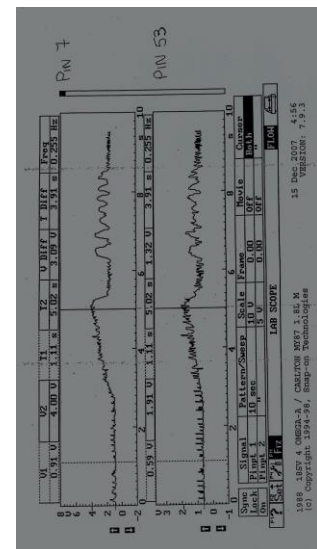
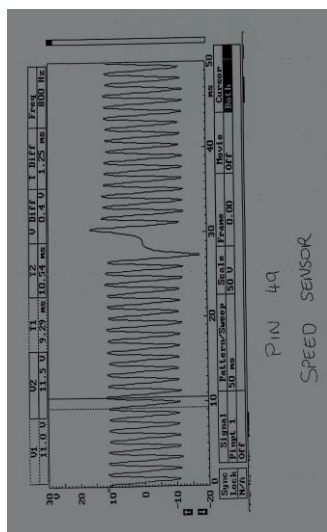


Figure 8 on the left

Figure 9 on the right
Figure 12

Pin 7 is the load signal output from the a
Figure 13
Pin 53 is the output from the throttle po

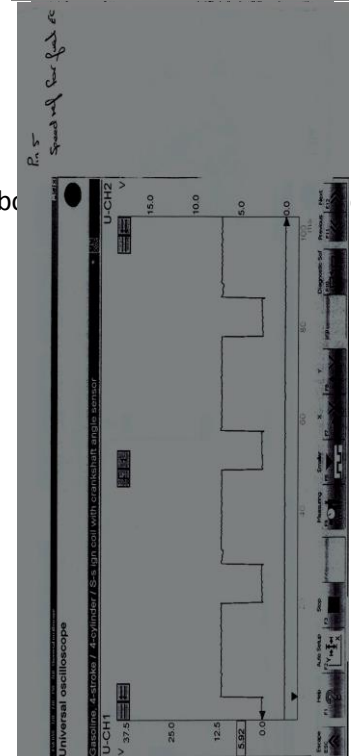
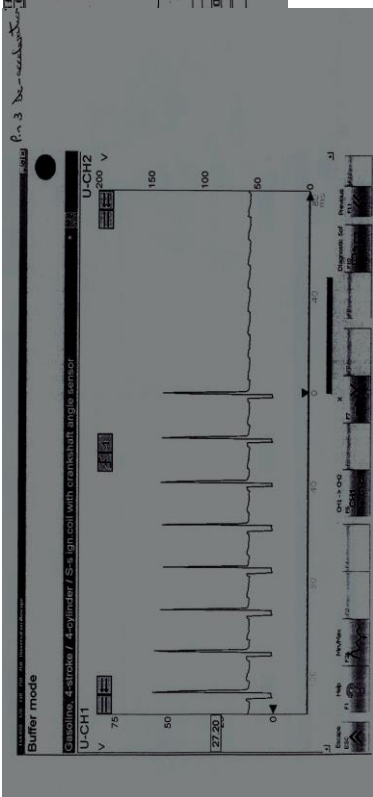
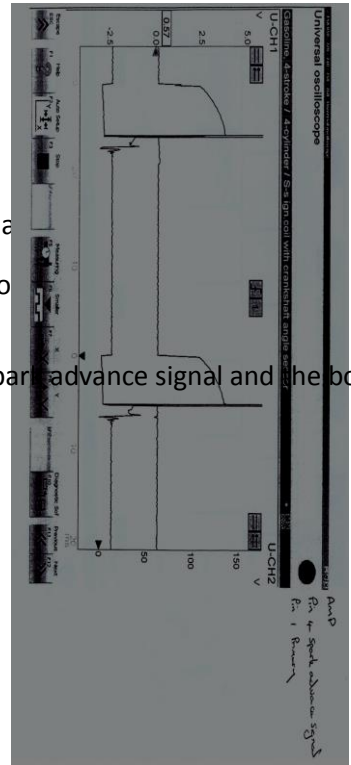
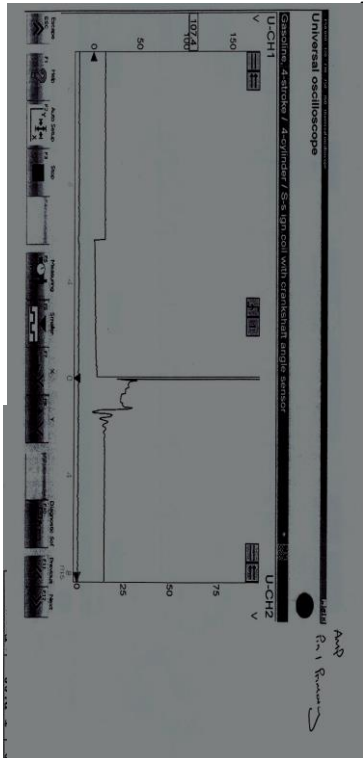
The top scope pattern shows the spark advance signal and the bottom shows the

Figure 10

Figure 11 **Figure 14**

This scope pattern shows bo acceleration of the

Figure 15



6.0

As is to be expected, neither of the ecu's were perfect as they were early on in the development of electronic fuel injection and electric ignition. I will now suggest a few modifications that would apply to both of the ecu's that would improve the function and improve emissions. One Modification that would apply to both ecu's would be an exhaust gas recirculation valve and the tank vent valve being directed into the intake of the engine to be burned. This would reduce overall carbon emissions from the exhaust of the engine.

While the Motronic 1.5 is a marked improvement over the LE3 jetronic, it still is not perfect. For example it still uses a HT leads, this could be improved by a direct coil on plug set up. More adaptive control of the engine could also be implemented to improve both the efficiency and overall running of the engine. The LE3-jetronic is nonbe adaptive meaning it does not adapt to any environmental or driving style changes, this is not an efficient way of running an engine therefore this could be added to improve the overall running and efficiency of the engine. Furthermore, the LE3 jetronic does not have a catalytic converter of LAMBDA both these help with the emission control of the engine and LAMBDA helps the ecu adjust the air fuel mixture based on exhaust gasses. In an ideal world, an engine would be running at stoichiometric.

7.0

The Motronic 1.5 is a much more developed and efficient ecu. This is because it has far more parameters to control the engine with in comparison to the LE£-jetronic. For example the LE3 jetronic only has 9 scope patterns in comparison to the Motronics 12. The Motronic 1.5 also has measures to improve efficiency, for example the tank vent valve which opens and puts any fuel vapours through a charcoal canister to reduce carbon emissions into the atmosphere whereas the LE3 jetronic does not have this feature. Another sensor that the Motronic has that allows the ecu to run the engine with greater efficiency is the air flow sensor, it tells the ecu exactly how much air is entering the engine at any one time, along with the other sensors it allows the engine to adapt to change which in turn gives more power, greater efficiency and improved driveability over the LE3-jetronic.

The testing provided very important information on how an ecu works and how an engine is controlled by the ecu. It also provided us with the skills and knowledge to diagnose faults with a system in the future. It also taught us even though the change to fuel injection was good, the early fuel injection systems were still in efficient and had a lot of room for improvement. I feel like the testing went well and highlighted all the necessary information.

8.0

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