

University of Wales Trinity Saint David

Wales Institute of Science & Art



Electronic Ignition & Fuel Control Systems

Electrical Control Systems ACHA4010

Callum Carter-Davies

Student ID: 2008376

Date: 04/22

Contents

1	Introduction	1
2	Methodology.....	2
2.1	Static Measurements	2
2.2	Warmup Testing.....	2
2.3	Injector On-time Testing	3
3	Results of Component Analysis.....	4
3.1	Static Measurements	4
3.2	Warmup Testing.....	4
3.3	NTC2 Comparison	5
4	Analysis of Oscilloscope Graphs.....	7
4.1	Primary and Secondary Coil	7
4.2	Spark Advance Signal	9
4.3	Crank Signal & Speed Reference.....	10
4.4	Amplifier Pattern.....	11
5	Injection On-time Adjustment	12
6	Improvements.....	15
7	Evaluation of Testing.....	16
8	References	17
9	Appendices.....	19
	Figure 1 - NTC2 resistance over temperature change for LE3 and Motronic systems.	6
	Figure 2 – Primary coil voltage against time.....	7
	Figure 3 – Secondary coil voltage against time.....	8
	Figure 4 – Spark advance signal plotted with the primary coil.....	9
	Figure 5 – Ignition ECU crank signal waveform.	10
	Figure 6 - Digital speed reference waveform for the Fuel ECU.	10
	Figure 7 - Amplifier pattern.	11
	Figure 8 – Fuel injector voltage at idle against time.....	13

Figure 9 – Fuel injector voltage under acceleration against time.	13
Figure 10 – Fuel injector voltage on deceleration against time, showing over-run.	14

1 Introduction

Controlling engine behaviour through engine management systems transmitting information from sensors to the electronic control unit (ECU) is essential to maintaining the emissions produced by the engine, sustaining the operation of the engine within the emission standards for the entire life of the engine, and to meet future emissions standards.

Tests were conducted on two engines with different Engine Management Systems to observe differences between the Engine Management Systems, determining the advantages and disadvantages of both systems in comparison to one another. The engines examined during the testing were a 2.0 Litre Vauxhall engine equipped with a Motronic 1.5 Engine Management System and another engine utilizing a LE3 Engine Management System.

The Motronic 1.5 system uses a single ECU to control both fuel injection and ignition whereas the LE3 system has two separate ECUs; an ignition ECU and a fuel ECU.

Both of the systems used a lambda sensor as a form of closed-loop control to allow the ECU to constantly adjust injection on-time in an attempt to maintain the air-fuel mixture close to the stoichiometric ratio.

The idle air control valve on the Motronic system assists in controlling idle speed as engine load varies, particularly important on cold start and warmup but also when experiencing extra load from air conditioning and electrical systems. It is used to bypass air around the throttle to maintain air intake when the throttle is closed in order to maintain idle.

The manifold air pressure sensor is used to measure the volume of air taken into the engine allowing the ECU to calculate how much fuel must be injected to make the desired air-fuel ratio.

A negative temperature coefficient (NTC) thermistor is used as a temperature sensor labelled NTC1 if it is used to determine the temperature of the air being supplied to the engine through the intake manifold, and NTC2 when used to measure the temperature of the coolant (Tutunea *et al.*, 2022). The resistance of the thermistor decreases as temperature increases and by measuring the voltage the ECU can compare this against a lookup table to determine the temperature of the air or coolant.

2 Methodology

It was vital to follow health & safety practices to ensure the tests were run with minimal risk of injury. A ventilation pipe was connected to the exhaust of the engine to remove exhaust gases from the area (Martyr and Plint, 2007). All individuals in the testing area were wearing appropriate PPE, removed accessories and loose clothing, and were aware of the dangers of being around an engine. Brightly coloured guards were fitted around the moving parts of the engine and a verbal warning was issued every time prior to the engine being run. Additional care was taken when taking readings after the engine was running at higher temperatures, avoiding burns which could occur from touching the hot metal.

2.1 Static Measurements

Both engines had readings taken from ECU pins and sensors under varying operating conditions. Using a digital multimeter, a set of readings taken were voltages from all the ECU pins with the ignition off followed by another set of readings taken with the ignition on. The LE3 system had readings taken from the Ignition ECU and the Fuel ECU. These readings were taken at the ambient temperature of the workshop, with the engine off. Schematics of the engine management systems were used to determine the uses for each of the pins to confirm that the voltages measured were reasonable.

To determine whether the components met the factory specifications, their resistance was measured using a digital multimeter and the values gathered were compared to the values specified by Autodata.

Values of resistance of the throttle potentiometer, when open and closed, were measured across the pins of the component. The injector resistance was measured across the pins of each injector to give a resistance value per injector. The resistance of the airflow sensor was measured in a similar fashion, being measured from pin 4 to pin 1, 2 and 3. The HT leads, used to make a connection between the coil pack and the spark plug, had their resistance measured across the length of the lead.

2.2 Warmup Testing

The next step of the testing was evaluating how the engine temperature affected the readings from various sensors, and when certain sensors switched. The components and their aspects being evaluated were as follows:

- NTC1 – Voltage
- NTC2 – Voltage & Resistance
- Injector – On Time
- Rotary Idle Valve – Percentage Open
- Lambda Sensor – On/Off

- Fuel Tank Vent Valve – On/Off

A digital multimeter was used to measure the values for the NTC1, NTC2, and the Fuel Tank Vent Valve. An oscilloscope was used to determine the Injector on-time, the state of the Rotary Idle Valve, and the state of the Lambda Sensor. The temperature gauge of the oscilloscope replaced the oil dipstick to continually measure the temperature of the oil, giving a value for the engine temperature.

The digital multimeter was used to measure static or slowly changing values, such as the resistance of the NTC1 sensor, as they quickly gave an accurate value. An oscilloscope was used for components with rapidly changing values, such as the voltage change of the primary coil of the Kettering coil, as the frequency at which measurements are taken is much higher, allowing the graphing of these values and the observation of the patterns they produce ("Oscilloscopes," 2010).

The injector on-time was recorded as the engine was cold cranked from the ambient temperature. Following this, the engine was run until it reached 20 °C and all the readings from the components listed above were recorded. This was repeated in intervals of 10 °C from 20 °C up to 80 °C for the Motronic and 60 °C for the LE3. The cooling fan on the LE3 was switched on at 60 °C. The engine was stopped before reaching the target temperature to give time for the preparation of measurements so that the measurements were always taken as close as possible to the target temperature.

2.3 Injector On-time Testing

Once at operating temperature, the next stage of testing was to observe how the injector on-time differed under acceleration, deceleration and idle. This was done with the LE3 system, using an oscilloscope connected to the injectors and operating the throttle in a way to simulate the specified operation.

3 Results of Component Analysis

3.1 Static Measurements

The full tables of static measurements taken from the Motronic and LE3 systems can be found in Appendix A and Appendix B respectively.

The battery voltage for the Motronic system was 12.4 V and this dropped to 12.1 V upon switching the ignition on. This voltage drop is expected as there will be extra load on the system from components being powered.

The throttle potentiometer on the Motronic system had been replaced with an aftermarket alternative however this had an incorrect resistance compared to the factory specifications (Table 1). The ECU would be treating the system as if the throttle plate was open when it was nearly closed, this restricted the air intake to much less than the ECU expected and caused inconsistent engine behaviour such as a rough idle.

Table 1 – Motronic throttle potentiometer resistance values.

	Factory Specification (Ω)	Measured Value (Ω)
Open	1900-2000	2107
Closed	1000-2000	2702

The resistance of the throttle switch on the LE3 system met the factory specifications with no resistance between terminals 2 and 18 and infinite resistance between terminals 3 and 18. The resistance of each injector on the Motronic system was between 16.5-16.6 Ω , and on the LE3 system they were each 16 Ω . These values are both within the specified resistance of 15-17 Ω given by Autodata. A higher resistance was found in the LE3 auxiliary air valve's measured resistance of 46.5 Ω to the data provided by Autodata which specified a resistance of 40 Ω .

3.2 Warmup Testing

The results of the warmup testing on the Motronic system (Table 2) show how the the variables changes as temperature increases. The injector on-time should gradually reduce with NTC2 resistance to a steady state as long as the engine remains idling, however there is an anomaly in injector on-time at an engine temperature of 40°C and between 70 and 80°C. This could be a result of the inconsistent idle caused by the throttle potentiometer affecting the engine speed causing the ECU to think there is increased load hence more fuel required.

The injector on-time for the LE3 system (Table 3) is more consistent in how it decreases as NTC2 resistance decreases and both systems end up with a similar injector on-time of 2.7ms and 2.8ms at idle.

Table 2 - Motronic Warmup Testing

Engine Temperature (°C)	NTC2 Resistance (Ω)	NTC2 Voltage (V)	Injector On-time (ms)	Rotary Idle Valve On-time (%)	Lambda (actuation)	Fuel Vent Valve (actuation)
20	1900	3.3	3.1	44	OFF	OFF
30	1020	2.5	2.8	42	OFF	OFF
40	660	2.2	3.2	41	OFF	ON
50	450	1.6	2.9	42	ON	ON
60	340	1.4	2.9	41	ON	ON
70	240	0.9	2.6	40	ON	ON
80	250	1.0	2.8	43	ON	ON

Table 3 - LE3 Warmup testing

Engine Temperature (°C)	NTC2 Resistance (Ω)	NTC2 Voltage (V)	Injector On-time (ms)
20	1940	1.7	3.8
30	1070	1.1	2.9
40	770	0.9	2.9
50	538	0.7	2.9
60	392	0.5	2.7

On the Motronic system the fuel vent valve opened between an engine temperature of 30 and 40 °C. Fuel vapour is temporarily stored in a charcoal canister and once the engine is warm enough, the vapours are vented into the engine through the intake manifold, mixing them with air. This is done to prevent excessive pressure build-up in the fuel tank (Chang *et al.*, 2021).

The lambda sensor switched on between 40 and 50 °C as the exhaust gases heated it up enough for it to be operational.

3.3 NTC2 Comparison

The NTC2 sensor is used to inform the ECU of the coolant temperature. It is a negative coefficient thermistor, meaning that as the sensor heats up, the resistance of the conductive material reduces. This alters the voltage supplied to the sensor, sending a voltage signal to the ECU. The ECU determines the temperature of the coolant from comparing this value to values stored in a lookup table.

In the warmup testing (Figure 1), the resistance of the NTC2 sensor in both systems reduces similarly as temperature increases, with a greater change in resistance at lower temperatures. The minor increase in resistance on the Motronics NTC2 between 70 and 80 °C could be a result of the thermostat opening and slightly cooling the engine.

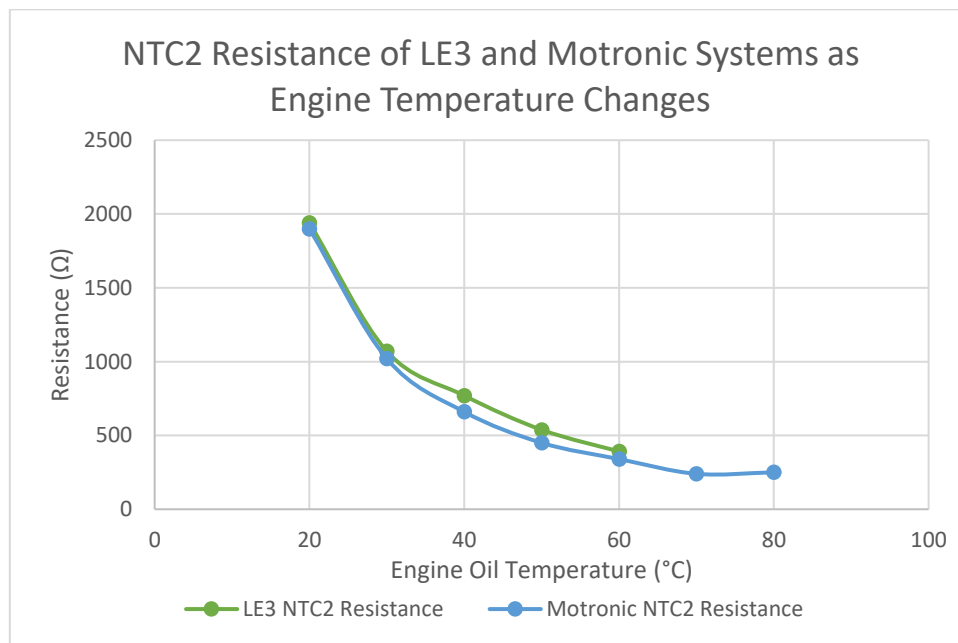


Figure 1 - NTC2 resistance over temperature change for LE3 and Motronic systems.

4 Analysis of Oscilloscope Graphs

4.1 Primary and Secondary Coil

The primary coil is constantly at the battery voltage until the dwell period (Figure 2). The dwell period lasted 6ms, with the abrupt spike in back EMF marking the end of the dwell period.

The dwell time is the period in which a signal from the ECU triggers a switch closes, allowing current to flow through the primary coil at battery voltage, creating an electromagnetic field surrounding the primary coil and intersecting the secondary coil. The dwell period finishes when the switch closes causing the electromagnetic field to collapse and induce a current through the secondary coil. As the secondary coil has many more windings, it acts as a step-up transformer and generates a much higher voltage (Ribbens, 2017, pp. 269-270).

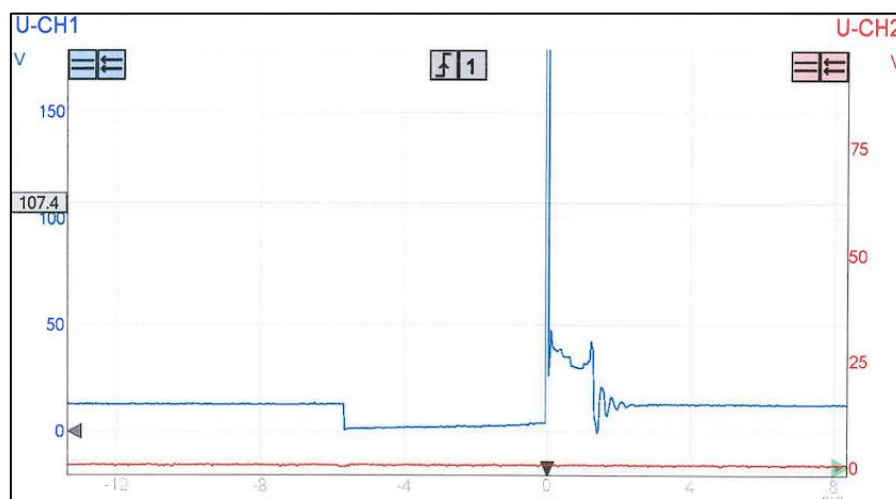


Figure 2 – Primary coil voltage against time.

The back EMF is the electro-motive force generated as the potential difference across the spark plug increases from the electromagnetic field in the Kettering coil. The back EMF in the system is dissipated over time using a Zener diode. A Zener diode is used to restrict the movement of electrons over a certain voltage to prevent the overloading of the components making up the circuitry. This is vital in an automotive electrical control system as the back EMF from the secondary coil is regularly reaching 11 kV every time the spark plug fires (Heisler, 1994, pp. 438-439). The distributor is mechanically connected to the engine and directs this high-voltage current to the spark plug where the spark is needed based on the firing order.

Following the back EMF, the spark line shows the period of the spark crossing the gap and igniting the air-fuel mixture. An increase in the temperature, pressure, or stoichiometric ratio of the air-fuel mixture increases the resistance across the spark plug gap. The period in which the spark is crossing

the gap can be seen to be approximately 1.5ms. The presence of several coil oscillations following the spark shows there is left-over energy after the spark spanning the gap in the sparkplug.

Looking at the secondary coil wave pattern (Figure 3), it is seen that it mimics the wave pattern of the primary coil. There is a major difference in the voltage measured however, with a back EMF spike of 11KV after the dwell period and spark duration of 0.7ms.

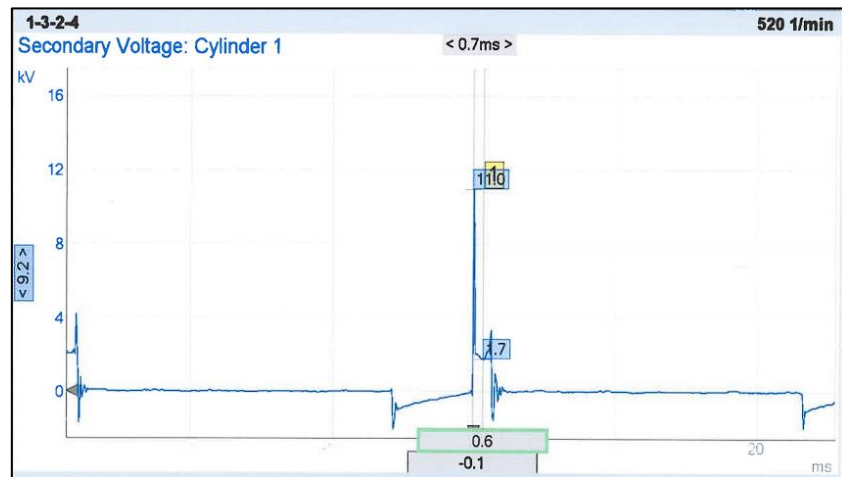


Figure 3 – Secondary coil voltage against time.

4.2 Spark Advance Signal

At higher engine speeds the triggering of the spark occurs earlier as the duration of time needed for the spark to ignite the air-fuel mixture and spread the flame front remains constant, but the piston moves through the cylinder faster. This is done to ensure complete combustion, maintaining power and efficiency at higher engine speeds. At lower engine, advancing the spark is done to increase the temperature of exhaust gases, heating the catalytic converter up to operating temperature to improve its efficiency (Lee *et al.*, 2002). The ECU refers to a lookup table to determine how far to advance the spark.

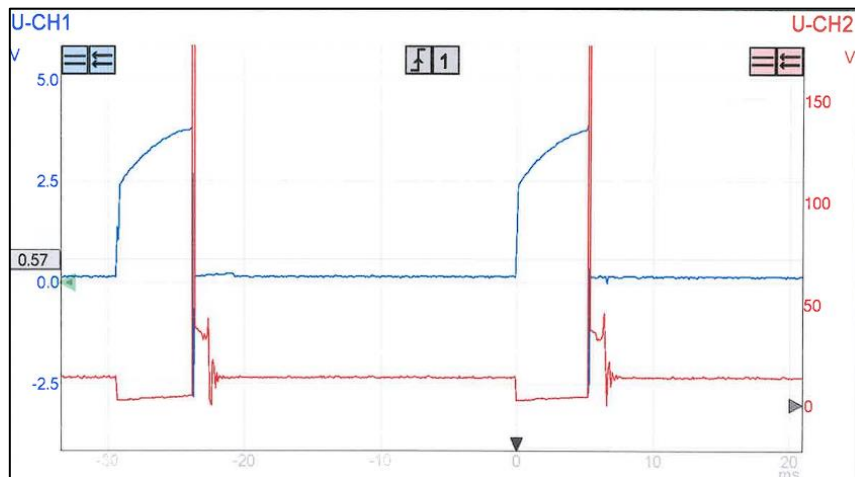


Figure 4 – Spark advance signal plotted with the primary coil.

4.3 Crank Signal & Speed Reference

The crank signal (Figure 5) is sent from the crankshaft sensor to the ECU and informs the ECU when it is at a specific crank angle, from this the ECU can decipher the speed and position of the crankshaft.

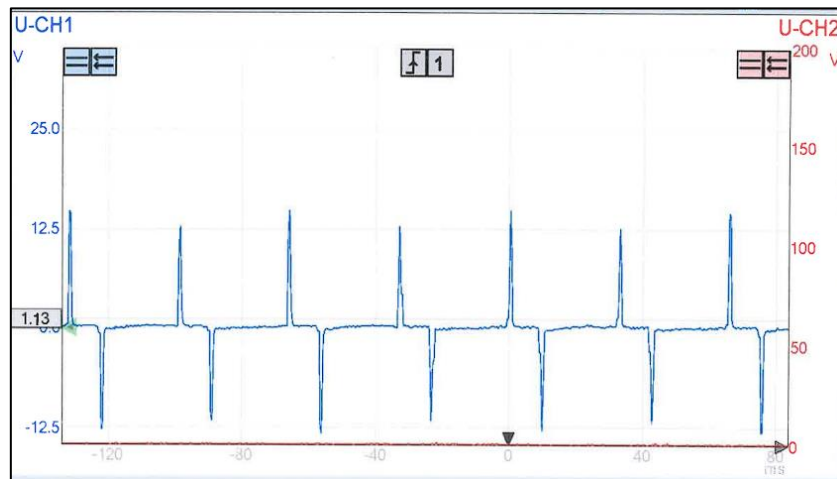


Figure 5 – Ignition ECU crank signal waveform.

The speed reference (Figure 6) is the analogue crank signal converted to a digital signal sent from the Ignition ECU to the Fuel ECU on the LE3 system to signal when to open the fuel injectors and how long to open them for. The duration between the peaks and troughs in the analogue signal corresponds with the troughs in the digital signal. The digital signal runs at 12 V for 20 ms before grounding for approximately 10 ms. The analogue signal's pattern of 20 ms between trough and peak followed by 10ms between the peak and trough matches the digital signal.

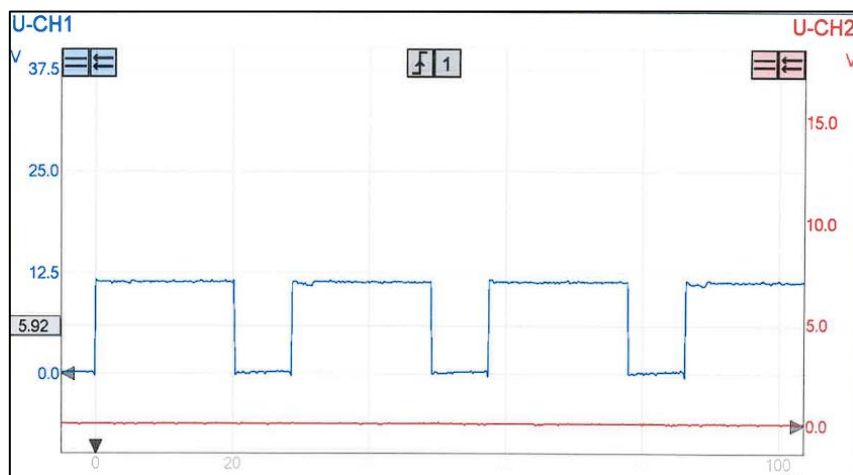


Figure 6 - Digital speed reference waveform for the Fuel ECU.

4.4 Amplifier Pattern

The amplifier pattern (Figure 7) shows the amplifier, after being pulsed by the pulse generator, switching to ground the primary coil, causing a drop in voltage of around 3 V on the supply line when this occurs, simultaneously increasing the voltage of the earth by the same magnitude. The amplifier then receives a signal from the ECU and switches, removing the primary coil from the earth and returning it to battery voltage. The peak following the dip is due to back EMF from ignition. The width of the dip is the dwell time, shown to be approximately 6ms.

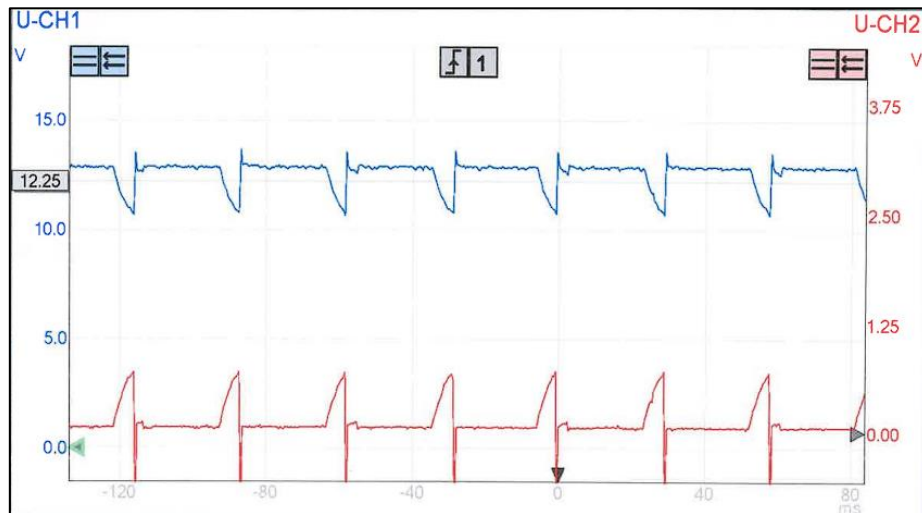


Figure 7 - Amplifier pattern.

5 Injection On-time Adjustment

When the ignition was on and the engine was not running, the injectors did not function as this would flood the cylinder with fuel. Upon cold cranking, the injector duration for the Motronic system was 20ms, dropping to 3.1 ms at 20 °C. The longer injector on-time on a cold-crank is due to the enrichment required on starting, which reduces once the engine runs at over 400 RPM. The purpose of this enrichment is to account for the engine being cold, as it is harder to atomise cold fuel and some of the atomised fuel injected into the cylinder can coat the surfaces of the intake valve and cylinder instead of mixing properly in the air-fuel mixture (Bosch, 2018, p. 658).

In comparison, the initial injector on-time for the LE3 system was 106ms, dropping to 3.8ms at 20 °C. The injector on-time is longer for both systems during the warmup phase when compared to the on-time at operating temperature. This is likely due to the ECU trying to warm up the engine to operating temperature. Both systems end up at operating temperature with similar injector on-times (Table 4).

Table 4 – Injector On-time values for the Motronic and LE3 systems from ambient to operating temperature.

Oil Temperature °C	Motronic Injector On-Time (ms)	LE3 Injector On-Time (ms)
17.8 – Cold Crank	20.0	106.0
20	3.1	3.8
30	2.8	2.9
40	3.2	2.9
50	2.9	2.9
60	2.9	2.7
70	2.6	-
80	2.8	-

When the engine was idling the fuel injectors were operating with a consistent injector on-time. In Figure 8 there are sections labelled A, B and C. Section A is the period between the injector pulse, where the system was running at the battery voltage of around 14 V with the injectors closed.

In section B, the injector was grounded, this opened the injector and released an atomised spray of fuel into the cylinder. Figure 8 shows the pulse width was around 2.6ms under idle at operating temperature, which correlates well with the values found in section 3. The injector was then powered again to close it which caused a large spike in back EMF of over 60 V, shown at point C, which is dissipated by a Zener diode as the voltage returns to battery voltage.

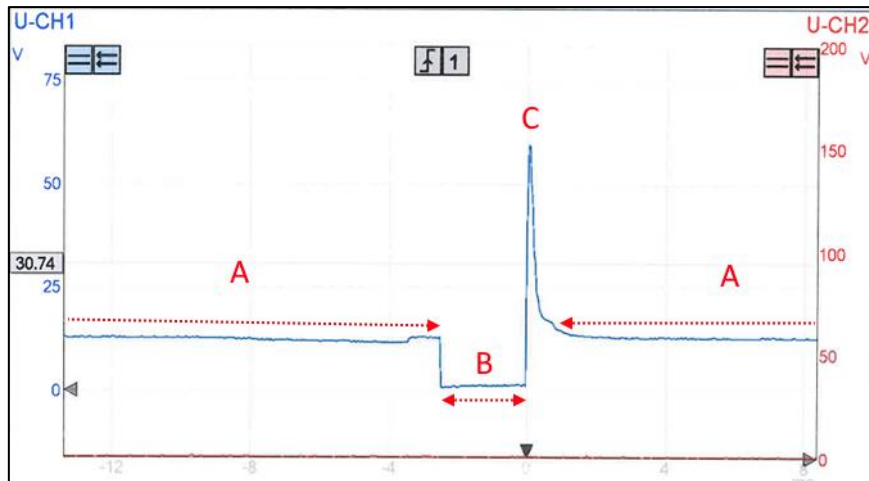


Figure 8 – Fuel injector voltage at idle against time.

The frequency of fuel injection pulses increased with the engine speed. Under wide-open throttle, the ECU opened the injectors for longer anticipating load but reduced the injector on-time following this to save fuel as the load was less than expected (Figure 9).

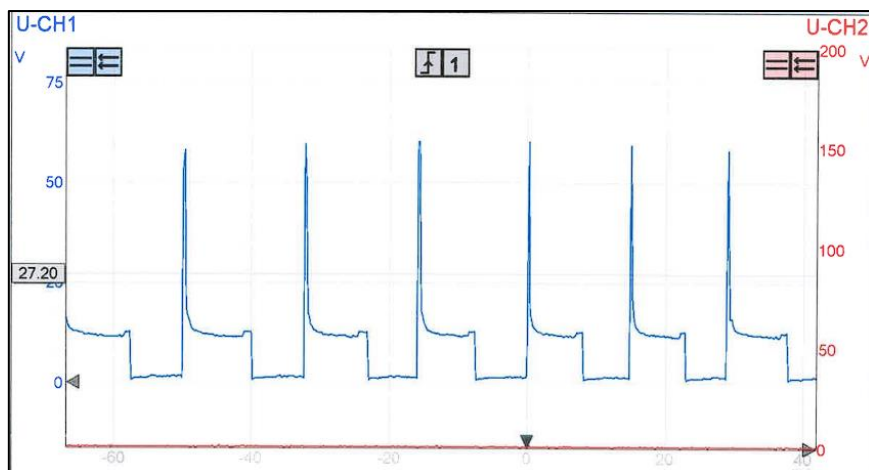


Figure 9 – Fuel injector voltage under acceleration against time.

When the ECU detected the engine was running at high speed with very little to no throttle input it reduced the amount of fuel injected by reducing the injector on-time until eventually the engine entered over-run and completely stopped injecting fuel (Figure 10). This would reduce fuel usage, leading to a reduction in unnecessary emissions (Leonard, Leckey and McCullough, 2012). This fuel cut-out would continue until the throttle was opened again or the engine speed dropped below a certain threshold.

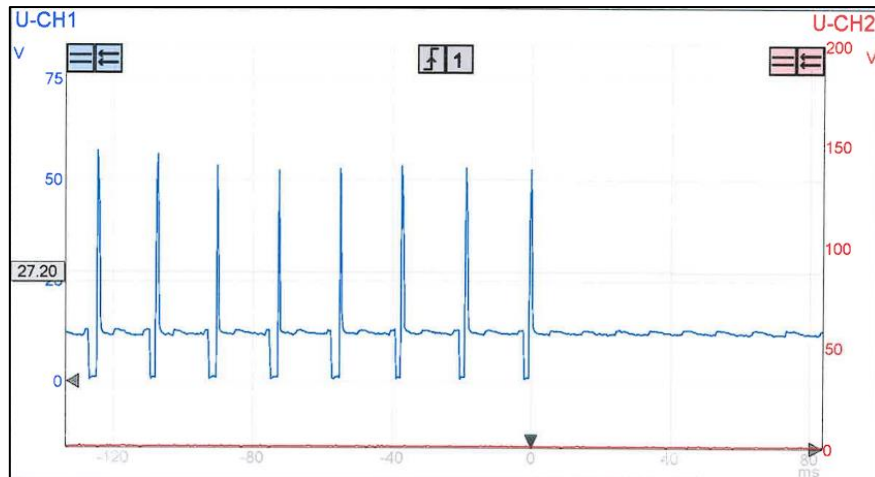


Figure 10 – Fuel injector voltage on deceleration against time, showing over-run.

6 Improvements

There are several changes that could be made to the Motronic 1.5 engine management system to improve its performance and allow the ECU to better adapt to the condition in order to reduce the emissions produced by the engine, ensuring the engine operates within emissions standards for as long as possible.

Using an improved wideband lambda sensor with a heating element would become operational quicker, provide feedback at an increased rate, and provide more information to the ECU about the ratio of the air-fuel mixture based on the exhaust gases, allowing it to adapt quicker resulting in a reduction of emissions (Martin, 2012).

The manifold air pressure sensor could be replaced with a hot-wire air mass sensor to improve the measurement of the amount of air being pulled into the engine, giving more accurate and more responsive results without compensation for air temperature or pressure (Igarashi *et al.*, 2014).

The distributor-to-spark plug setup could be replaced with a coil-on-plug ignition to reduce voltage losses from travelling along the HT leads and crossing the air gap at the distributor thus increasing the chance of a having a successful spark (Konrad Reif, 2015, p. 171). Along with this, a camshaft sensor could be added to synchronise the firing of the sparks and could also be used as a failsafe if the crankshaft sensor fails, allowing the vehicle to drive in a limp mode (Konrad Reif, 2015).

A knock sensor could be added to the engine management system to send a signal to the ECU when engine knock is occurring, allowing the ECU to alter the spark advance to prevent or mitigate knocking (Peyton Jones, Spelina and Frey, 2013).

7 Evaluation of Testing

To validate the results of the testing, each test should have been repeated multiple times. The room could have also been climate controlled to ensure the air temperature stayed constant as this would affect air pressure and the density of the air, changing the air-fuel ratio by a small margin. The tools used for taking measurements were suitable for their use cases. The tests were conducted safely with all individuals aware of the risks and taking precautions to mitigate them through verbal warnings, the use of an exhaust vent, and the use of PPE.

8 References

- Bosch (2018) *Bosch Automotive Handbook*. 10th edn. Karlsruhe: Robert Bosch.
- Chang, J. *et al.* (2021) "Analysis and optimization of idle noise caused by canister purge solenoid valve," in. Les Ulis: EDP Sciences. doi:10.1051/e3sconf/202126801018.
- Heisler, H (1995) *Advanced Engine Technology, Advanced Engine Technology*. Edited by Heinz Heisler. Oxford, UK: Butterworth-Heinemann.
- Igarashi, S. *et al.* (2014) "Various Types of Sensors," in *Encyclopedia of Automotive Engineering*. John Wiley & Sons, Ltd, pp. 1–18. doi:<https://doi.org/10.1002/9781118354179.auto196>.
- Konrad Reif (2015) *Gasoline Engine Management: Systems and Components*. Wiesbaden, Germany: Springer.
- Lee, S. *et al.* (2002) "Effects of Engine Operating Conditions on Catalytic Converter Temperature in an SI Engine," *SAE Transactions*, 111, pp. 637–646. Available at: <http://www.jstor.org.ezproxy.uwtsd.ac.uk/stable/44734551>.
- Leonard, T., Leckey, J. and McCullough, G. (2012) "Improving the fuel economy of a tuned 600cc FSAE engine," *SAE Technical Papers*, 4. doi:10.4271/2012-32-0027.
- Martin, T. (2012) "SENSOR SENSIBILITY," *Motor Age*, 131(7). Available at: <https://www.proquest.com/trade-journals/sensor-sensibility/docview/1221996038/se-2?accountid=130472>.
- Martyr, A.J. and Plint, M.A. (2007) *Engine Testing*. 3rd edn. Oxford, UK: Butterworth-Heinemann.
- "Oscilloscopes" (2010) *Nature Photonics*, 4(6), pp. 400–401. doi:10.1038/NPHOTON.2010.135.
- Peyton Jones, J.C., Spelina, J.M. and Frey, J. (2013) "Optimizing knock thresholds for improved knock control," *International Journal of Engine Research*, 15(1), pp. 123–132. doi:10.1177/1468087413482321.
- Ribbens, W.B. (2017) *Understanding Automotive Electronics: An Engineering Perspective*. 8th edn, *Understanding Automotive Electronics: An Engineering Perspective*. 8th edn. Oxford, UK: Butterworth-Heinemann.
- Tutunea, D. *et al.* (2022) "Evaluation of temperature sensors used in automotive applications type NTC and PTC," *IOP conference series. Materials Science and Engineering*, 1220(1), p. 012035. doi:10.1088/1757-899X/1220/1/012035.

Vauxhall_Motronic.pdf (no date).

9 Appendices

Appendix A - Motronic 1.5: Static Voltage Measurements (Vauxhall_Motronic.pdf, no date)

Pin no.	Ignition OFF (V)	Ignition ON (V)	Purpose
1	0	12.15	Negative side of coil
2	0	0.04	Earth
3	0	12.04	Control circuit for fuel pump (from relay pin 85B)
4	0	9.74	Pulsed side of Rotary Idle Valve
5	0	12.01	Pulsed side of Tank Vent Valve
6	0	11.31	4WD ECU – A/T ECU – Fuel Tell-Tale lamp
7	0	0.33	Load signal output from air-flow meter
8	-	-	Reserve, no use
9	-	-	Speedo, mileage frequency sensor
10	0	0	Earth
11	-	-	Reserve, no use
12	0	5.08	5v supply to air-flow meter & throttle potentiometer
13	0	10.1	Diagnostic socket supply
14	0	0	Earth
15	-	-	Reserve, no use
16	0	12.1	Pulsed side of injectors (bank of two)
17	0	12.1	Pulsed side of injectors (bank of other two)
18	12.4	12.1	Permanent live
19	0	0	Earth
20	0	0	Earth (for catalyser)
21	0	0	Earth (for A/T)
22	0	0.93	Engine tell-tale warning light
23	-	-	Reserve, no use
24	0	0	Earth
25	-	-	Reserve, no use
26	0	0	Earth via ECU
27	0	12.09	Ignition feed
28	0	0.45	Output from Lambda sensor
29	-	-	Reserve, no use
30	-	-	Reserve, no use

31	-	-	Reserve, no use
32	0	11.3	Output to on-board computer
33	-	-	Reserve, no use
34	-	-	A/T ECU
35	-	-	Reserve, no use
36	12.07	0.31	Control circuit for auxiliaries & ECU (from relay pin 85)
37	0	12.03	Supply to ECU & to on-board computer
38	-	-	Reserve, no use
39	-	-	Reserve, no use
40	0	0	A/C
41	0	0	A/C
42	0	0	Earth (manual transmission only)
43	-	-	CO potentiometer output (not fitted w/ catalyser)
44	0	3.69	Output from NTC 1
45	0	3.69	Output from NTC 2
46	0	0.25	Octane plug input
47	-	-	Earth (for 4WD vehicles)
48	0	0.07	Output from crankshaft sensor
49	0	0.11	Output from crankshaft sensor
50	-	-	Reserve, no use
51	-	-	A/T ECU
52	-	-	Reserve, no use
53	0	0.66	Output from throttle potentiometer
54	-	-	Reserve, no use
55	0	10.99	Earth for diagnostic socket

Appendix B - LE3: Static Voltage Measurements

Cells marked with - have no wire	Ignition ECU	
ECU Pin Number	Ignition Off (V)	Ignition On (V)
1	0	0.03
2	0	0.03
3	0	11.57
4	-	-
5	0	0.06
6	0	0.02
7	0	2.42
8	0	0.95
9	-	-
10	0	0.03
11	0	0.03
12	0	0.06
13	0	0.13
14	0	4.98
15	0	0.06
	Fuel ECU	
ECU Pin Number	Ignition Off (V)	Ignition On (V)
1	0	0.6
2	0	11.67
3	0	0
4	0	0.02
5	0	0.03
6	-	-
7	-	-
8	0	1.94
9	-	-
10	0	0.16
11	0	1.00
12	0	1.94
13	-	-
14	0	4.98
15	0	0.02