



Adaptronic ECU Installer's Manual  
for ECU model e420c version 1.0

FIRMWARE VERSION: 1.0I  
SOFTWARE VERSION: 1.07

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# Table of Contents

Table of Contents .....	2
List of Figures .....	4
0. Introduction .....	6
1. Wiring the Adaptronic .....	7
1.0. Introduction .....	7
1.1. Temperature Sensors (20-pin connector, yellow/black, blue and violet) .....	9
1.2. Throttle Position (20-pin connector, black, red and green).....	9
1.3. Manifold Absolute Pressure (20-pin connector, brown, orange and yellow)	10
1.4. Crank Angle Sensors (16-pin connector, black shielded cable).....	10
1.5. Vehicle Speed Sensors (16-pin cable, brown and orange).....	12
1.6. Auxiliary Digital Inputs (20-pin cable, various colours) .....	12
1.7. Power (8-pin and 6-pin connector, red and black) .....	12
1.8. Injectors (8-pin connector, purple, white, grey and pink).....	13
1.9. Auxiliary Outputs (6-pin various, 16-pin various) .....	14
1.10. Knock Sensor (20-pin, grey shielded cable or yellow/green) .....	14
1.11. EGO Sensor (20-pin, black shielded cable or yellow/red).....	15
1.12. Connecting a Wideband Oxygen Sensor.....	16
2. Initial configuration of the ECU.....	18
2.0. Basic Setup .....	18
2.0.0. Ignition Outputs .....	18
2.0.1. Crank/Cam Angle Sensor - General.....	19
2.0.2. Cam angle sensor - Nissan style .....	23
2.0.3. Cam angle sensor example - 24 + 1 + 1 .....	25
2.0.4. Crank angle sensor example - Honda CBR600 .....	26
2.0.5. Cam angle sensor example - Suzuki G13B .....	26
2.0.6. Injector Outputs .....	27
2.1. Configuring the Analogue Sensors .....	28
2.1.0. Manifold Absolute Pressure (MAP).....	28
2.1.1. Temperature Sensors .....	30
2.1.2. Load Sensing (Tuning mode) .....	30
2.1.3. Throttle Position Sensor (TPS) .....	32
2.1.4. EGO (Exhaust Gas Oxygen) Sensor .....	33
2.1.5. Knock Sensor .....	33
2.2. Corrections .....	33
2.3. Auxiliary Outputs .....	33
2.4. Special Functions.....	36
2.5. Road Speed.....	37
2.6. Auxiliary Inputs .....	37
2.7. Power Cut, Idle, Waste gate .....	37
2.8. Target AFR.....	37
2.9. Fuel and Ignition Maps (Tuning).....	38
3. Starting the Engine .....	40
3.0. Getting Started.....	40
3.1. Initial Tuning.....	41
3.2. Adaptive Fuel Tuning Explained.....	42
3.3. Further Tuning.....	44
3.4. Ignition Tuning.....	46
4. Software .....	48

4.0.	WARIVI.....	48
4.0.0.	General .....	48
4.0.1.	WARI Menus.....	48
4.0.2.	WARI Settings Management.....	50
4.0.3.	ECU Data Window .....	50
4.1.	FlashIt.....	54
4.2.	Specifications .....	54
	Physical.....	54
	Sensor Interfaces .....	55
	Actuator Interfaces .....	55
	Control Characteristics .....	56
5.	ECU Operation.....	57
5.0.	Introduction .....	57
5.1.	Reading Inputs.....	57
5.1.0.	Analogue Inputs .....	57
5.1.1.	Temperature Inputs .....	57
5.1.2.	0-5V Inputs (TPS, MAP and Ext).....	58
5.1.3.	Oxygen sensor input and Air-Fuel Ratio.....	59
5.1.4.	Knock Sensor Input.....	62
5.1.5.	Digital Inputs .....	62
5.1.6.	RPM and Triggering.....	64
5.1.7.	Vehicle Speed Sensing .....	65
5.1.8.	Supply voltage .....	65
5.2.	Calculations, Control Policies and Special Behaviour .....	65
5.2.0.	Introduction.....	65
5.2.1.	Fuel Calculation .....	65
5.2.2.	Ignition Calculation.....	66
5.2.3.	Tuning Modes .....	66
5.2.4.	Fuel Trim Calculation .....	69
5.2.5.	Ignition Trim Calculation .....	70
5.2.6.	Asynchronous Accelerator Pump.....	71
5.2.7.	Closed Loop Fuel Control .....	71
5.2.8.	Adaptive Fuel Control .....	72
5.2.9.	Closed Loop Ignition.....	73
5.2.10.	Adaptive Ignition .....	73
5.3.	Power Cut.....	74
5.4.	Special Functions.....	75
5.4.0.	Fuel Pump Control .....	75
5.4.1.	Air Conditioner .....	75
5.4.2.	Purge Valve .....	75
5.4.3.	PRCV Control.....	76
5.4.4.	Second Serial Port.....	76
5.4.5.	Blow-off Valve .....	76
5.4.6.	Turbo Timer Control .....	77
5.4.7.	Variable Valve Timing.....	78
5.5.	Generic Outputs.....	79
5.6.	Idle Control.....	79
5.7.	Wastegate Control.....	82
5.8.	Driving Outputs .....	83
5.8.0.	Ignition Outputs .....	83
5.8.1.	Injection Outputs.....	85
5.8.2.	Auxiliary Outputs.....	86

## List of Figures

Figure 1:	Wiring Diagram .....	8
Figure 2:	Connectors on the Adaptronic ECU.....	9
Figure 3:	Reluctor Waveform (correct).....	11
Figure 4:	Reluctor Waveform (inverted, incorrect) .....	12
Figure 5:	Stripped back sheath and cut braid .....	15
Figure 6:	Stripped back sheath and insulated braid .....	15
Figure 7:	Stripped back sheath and twisted braid.....	16
Figure 8:	Heatshrink over braid.....	16
Figure 9:	Heatshrink over join.....	16
Figure 10:	Ignition Configuration Dialogue Box .....	18
Figure 11:	Configuration for checking the timing during cranking.....	21
Figure 12:	Timing Lock on option box .....	23
Figure 13:	Stylised Nissan cam angle sensor waveform.....	24
Figure 14:	Trigger Example for Nissan SR20DET engine .....	24
Figure 15:	Trigger Example for Mazda B5 DOHC engine .....	26
Figure 16:	Trigger Example for Honda CBR600 Crank angle Sensor .....	26
Figure 17:	Trigger Example for Suzuki Swift GTi Sensor .....	27
Figure 18:	MAP sensor calibration value in kPa.....	29
Figure 19:	Load Sensing Options .....	31
Figure 20:	Location TPS calibration.....	32
Figure 21:	Water Injection Auxiliary Output Example.....	34
Figure 22:	Shift Light Auxiliary Output Example.....	35
Figure 23:	Stall Saver Auxiliary Output Example.....	36
Figure 24:	Sample Road Speed setup for a vehicle with a single speed sensor ...	37
Figure 25:	Rapid Learn Settings .....	42
Figure 26:	ECU Data Window .....	51
Figure 27:	Response of Knock Filter .....	62
Figure 28:	Series Mode turbo timer configuration .....	78
Figure 29:	Ignition Waveforms in Different Modes.....	85
Figure 30:	Injector Firing Pattern Example.....	85

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## **WARNING**

Modifying engines is dangerous. With incorrect tuning, it is possible to destroy engines. Incorrect triggering can also cause this. Care must be taken; tuning is not something that should be attempted by anyone not knowledgeable and experienced in the field.

Furthermore, if the product is to be put on a controlled vehicle (eg, a road going car), you should check with local authorities about the legal implications of this. For example you may need to get an emissions test done after tuning the engine, and/or an engineering certificate/report.

## 0. Introduction

This manual is for installers and people setting up an Adaptronic e420c ECU. This document pertains to hardware version 1.0 of the Adaptronic ECU.

This document assumes that the reader has a basic understanding of:

- General automotive systems;
- General automotive wiring; and
- General ECU and EFI operation.

The following describes the basic procedure of installing an Adaptronic ECU:

1. Source a wiring diagram of the vehicle, if the ECU is being fitted to an existing vehicle.
2. Plan how the ECU is to be wired and installed - for example how all the outputs, inputs and triggering will be handled.
3. Wire up the ECU.
4. Set the settings in the ECU in accordance with the input, output and triggering configuration.
5. Verify the operation of the sensors.
6. Verify the operation of the actuators.
7. Verify triggering.
8. Get the engine to run.
9. Tune the no-load conditions.
10. Set up idle control (if applicable).
11. Tune the loaded conditions.
12. Set up other ancillary devices.

# 1. Wiring the Adaptronic

## 1.0. Introduction

The Adaptronic ECU is wired similarly to other aftermarket ECUs, in terms of sensor and actuator connection. A sample wiring diagram is shown in Figure 1.

There are six plugs on the Adaptronic, the first four of which must be wired in to the vehicle harness. These are shown in Figure 2, and are as follows:

- An 8-way single-in-line connector, which connects to power, ground and injectors;
- A 6-way single-in-line connector, which connects to auxiliary outputs 1-4 and ground;
- A 20-way dual-in line OEM style connector, which connects to sensor inputs;
- A 16-way dual-in line OEM style connector, which connects to low current outputs and real-time inputs;
- A 9-way D connector (DE9), female, which connects through a DE9 extension cable to a PC or hand controller; and
- A 9-way D connector (DE9) male, used for ancillary devices (eg wideband oxygen sensor).

Each vehicle will be different, but what follows is a set of general guidelines that will help with most vehicles and installations.

- Work out which loom you need to order in advance. There are two versions of the loom available; a 0.5m long version and a 2m long version. The 0.5m version is intended for installers connecting to the existing vehicle harness; whereas the 2m version is intended for installers running a new harness. If in doubt, it would be advisable to order the 2m version. The difference in price is not four times because most of the cost is in the termination of the wires in the plugs rather than the cable itself.
- If you are wiring into an existing harness, do your best to obtain a wiring diagram of the existing wiring. This may include obtaining the wiring diagram of the vehicle if it's a factory loom, or in the worst case, disconnecting the wires and following them to find out which ones connect to which sensors and actuators.
- Whether you intend running a new loom or adding to the existing loom, it will help to draw a diagram of what you intend to do. For example, if you are connecting to an existing harness, it may be sufficient to take the example wiring diagram in Figure 1 and mark on it the factory loom colours. If you are running your own loom, you may want to write down functions for the auxiliary outputs.

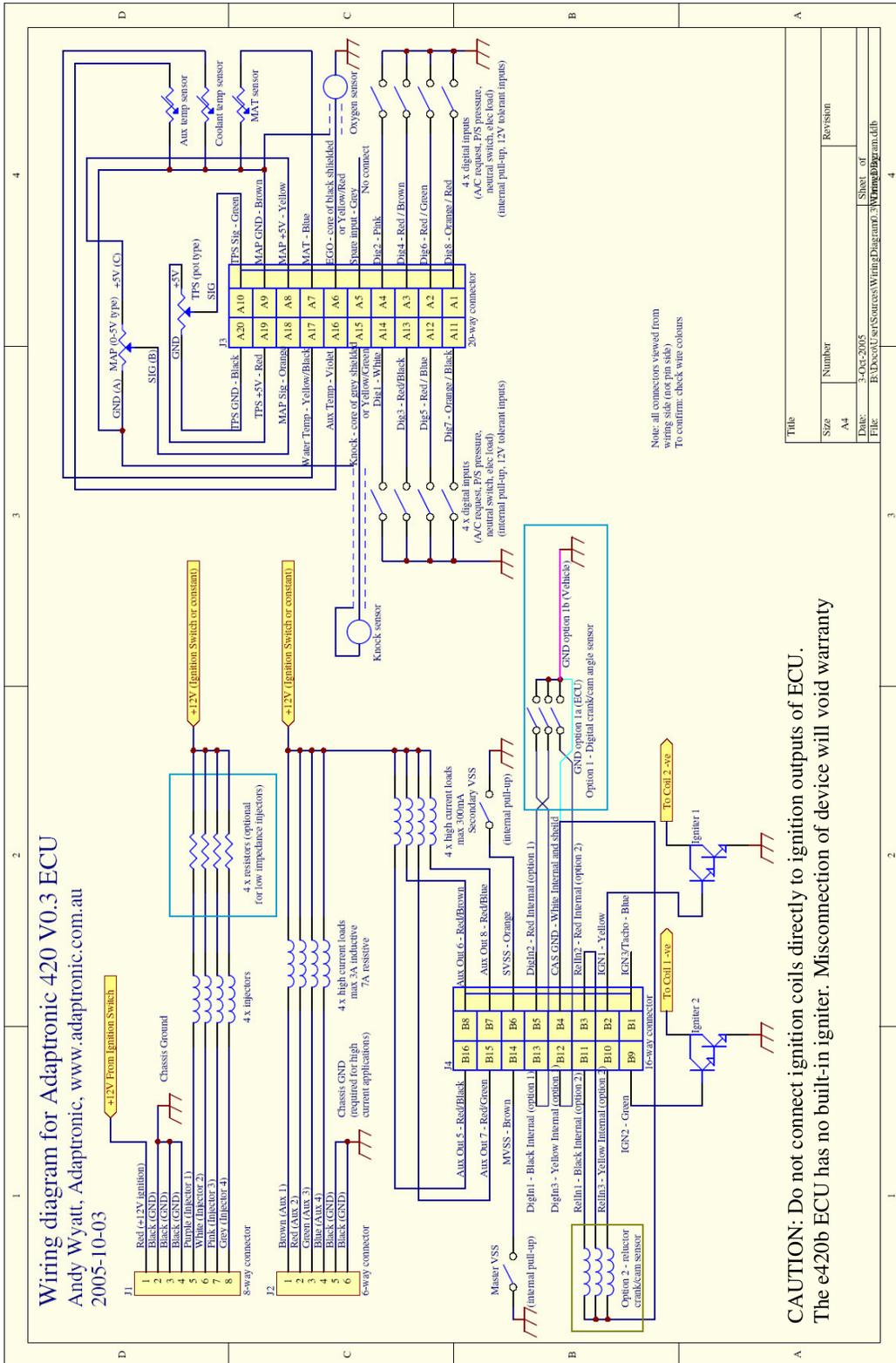
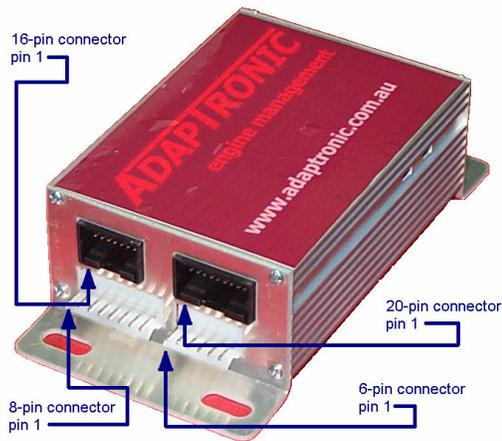


Figure 1: Wiring Diagram



**Figure 2: Connectors on the Adaptronic ECU**

What follows are some notes on individual sensor inputs.

### 1.1. Temperature Sensors (20-pin connector, yellow/black, blue and violet)

These are to be connected as a thermistor (a resistor whose resistance varies with temperature) between ground (brown wire) and the sensor input (yellow/black for water temp, blue for air temp, violet for aux temp).

- Do NOT connect one side of the thermistor to ground at the engine block - the only connection to ground must be through the ECU. If poor grounding conventions are followed, large amounts of noise will result, leading to fluctuating temperature readings.
- It is most important to connect the water temperature sensor. Without it, there will be no temperature-based enrichment, and the engine will be very difficult to start when cold, or run very rich when hot.
- The air temperature sensor can be left disconnected if there is no sensor available. It will however improve general drivability (idle quality, fuel mixture consistency etc) if installed.
- The aux temperature sensor is not used by the ECU, except to send data to the PC, and operate any auxiliary outputs configured to operate based on that input.

### 1.2. Throttle Position (20-pin connector, black, red and green)

The Throttle Position Sensor (TPS) should be configured as a variable resistor. There should be three wires connecting the TPS to the ECU; a ground, a supply and a signal wire. The ground, although a separate wire from the temperature sensor ground in the loom, is connected to the temperature sensor ground internally to the ECU, and if the original wiring harness had these two sensors running from the same ground wire, then this is acceptable.

The ECU supplies 5V to the TPS via the red wire. The TPS is traditionally wired so that full throttle gives the highest voltage on the signal wire, and closed throttle gives the lowest voltage.

### 1.3. Manifold Absolute Pressure (20-pin connector, brown, orange and yellow)

Some ECUs use an internal MAP sensor. The Adaptronic uses an external MAP sensor, allowing different maximum pressures (1-4 Bar) to be used. The MAP sensor is configured similarly to the TPS; that is, as a variable resistor, with a 5V supply, a ground and a signal wire. Again, a dedicated ground wire is run from the loom to the MAP sensor; however if the wiring harness already has a ground wire which is used for TPS or temperature sensing, this can be used instead. Please ensure that this ground wire is isolated from the engine block (when the ECU is disconnected), otherwise the sensor readings will be inaccurate.

When using a standard Delco MAP sensor, the two outside terminals are the ground and +5V connections and the centre is the signal output. Again, it is convention to wire the unit so that the maximum pressure (atmospheric on a naturally aspirated car) gives the highest voltage, and that vacuum delivers the lowest voltage.

If you have a MAP sensor of unknown pin configuration, remember that there are only 6 possible permutations of the pins. To simplify the task, it may help to measure the resistance between all the pairs of pins. The lowest reading (normally around 1.5k $\Omega$ ) will likely be the +5V and ground connections. If the resistance reads the same with either polarity of the multimeter, you can probably pick a polarity at random and wire it up using alligator leads, and verify the voltage at the remaining pin, under atmospheric and vacuum. On the Delco/GM sensors, the A pin is the ground, B is the signal and C is the supply (as shown on the wiring diagram).

### 1.4. Crank Angle Sensors (16-pin connector, black shielded cable)

There are two main types of CAS; those that give a digital output (usually Hall Effect or optical) and those that give an analogue output (reluctor, or "variable reluctance" sensors).

Hall Effect and optical sensors give a digital pulse to ground. The following tips may be useful:

- For optical and Hall Effect sensors, the sensor will usually require a supply voltage. This may be anywhere between 5V and 12V, depending on the particular sensor. There is no hard and fast rule for determining what it should be for any given sensor; except by consulting the documentation for the donor vehicle.
- The output will usually be an open collector (that is, an output that shorts to ground), which is suitable for the Adaptronic. The ECU has an internal pull-up resistor. Simply connect each output from the sensor to one of the three inputs (red, white, yellow) on the digital crank angle sensor input cable (the one with four cores, and a shield). If the sensor is isolated from the engine block, it may

help to ground the sensor through the white wire inside the shielded cable. If it is grounded at the engine block, do not ground this back at the ECU as well.

- For digital inputs, option 1 should be followed (ie, pins 13, 5 and 12 on the connector).
- Before committing to a wiring method; it may help to read section 3.1.4, regarding CAS setup of the ECU. For example, on the B3 SOHC engine, the ECU will be required to trigger from both sides of the single output, and therefore the output should be wired to two ECU inputs.

Reluctor sensors generate a voltage spike. The voltage across the reluctor coil normally sits a zero Volts. As the tooth approaches the pickup, the voltage increases. The peak voltage will be somewhere between 0.5V and 50V, depending on engine speed and the type of reluctor. When the tooth passes the middle of the pickup, the voltage suddenly swings negative. As the tooth recedes from the pickup, the voltage increases back to zero. See Figure 3.

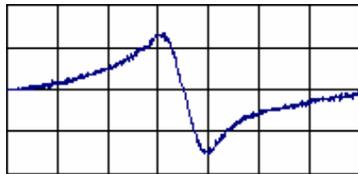


Figure 3: Reluctor Waveform (correct)

- For reluctor sensors, the same cable (black shielded) is used. The white wire in this cable must connect to the common ground of the reluctor, and the other three internal wires (red, black and yellow) should connect to the positive side of the reluctor coils.
- For reluctor type systems, option 2 should be used. That is, pins 11, 3 and 10 in the ECU connector.
- In many cases (eg B5 DOHC, 4AGE, 4EFTE), the reluctor will have three pickups, whose grounds are already connected together. Therefore, the sensor has a 4-wire connector. To determine which wire is which, one can use a multimeter set to the resistance range ( $2k\Omega$ ). The resistance between any two coil positive pins will be double that between a coil positive and the common ground. For example if the following measurements are made:
  - pin 1 to pin 2 is  $170\Omega$
  - pin 1 to pin 3 is  $170\Omega$
  - pin 1 to pin 4 is  $170\Omega$
  - pin 2 to pin 3 is  $340\Omega$
  - pin 2 to pin 4 is  $340\Omega$
  - pin 3 to pin 4 is  $340\Omega$

then it would appear that pin 1 is the common ground, and pins 2, 3 and 4 are the outputs.

- Make sure that the polarity is as shown in Figure 3. If the waveform is inverted, the ECU will not trigger reliably from the pulse. If the reluctor has all the wires coming out of it (eg 3 coils would require 6 wires), then it should be possible to reconnect the common to the other side of the coils. Most reluctors are not of this type, however Honda use inverted outputs (as shown in Figure 4).

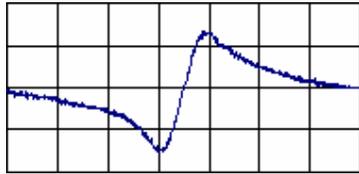


Figure 4: Retractor Waveform (inverted, incorrect)

## 1.5. Vehicle Speed Sensors (16-pin cable, brown and orange)

This is used for idle speed control on vehicles which have no neutral switch, however they can also be logged by the PC.

- These inputs have a passive pull-up, and therefore a sensor that shorts to ground (for example, Hall Effect, optical or reed switch) will be suitable.

## 1.6. Auxiliary Digital Inputs (20-pin cable, various colours)

These are intended to add "heuristic" behaviours to the ECU. Most factory ECUs have connections to other devices on the vehicle, such as headlights, neutral switch and so on, to allow certain behaviour in certain conditions (for example, allowing the purge valve to open only when in-gear).

- These inputs have an internal pull-up, so are "high" if left not connected. In the settings, you can select whether the inputs are "active low" (default - used when an input is shorted to ground) or "active high" (used for an input that is normally shorted to ground, and is raised when it is active).
- For example, to connect a clutch switch that shorts to ground, merely connect the switch contact to the digital input.
- To connect a headlight (to increase the idle speed), find the side of the switch that goes to +12V when the headlights are on, and wire this into the ECU input. **NOTE: you must also configure the settings for this input to be "active high".**

## 1.7. Power (8-pin and 6-pin connector, red and black)

There is one +12V input, and it is found on the 8-way plug. This should be connected so that it comes on only with the ignition. Only a small amount of current flows through this wire (< 0.5A), as it is only required to power up the electronics in the ECU.

There are five ground wires; three on the 8-way plug and two on the 6-way plug.

- Depending on your application, they may all need to be connected to a solid earth near the ECU.
- The reason for so many wires is the large amount of current that they may be required to carry.
- Each high current auxiliary output is rated at a maximum of 7A resistive (or 3A inductive) - so there is a maximum total current of 28A. Each low current auxiliary output is rated at a maximum of 200mA, and the ECU itself may require another 200mA, leading to a further 1A. Each injector output may

deliver up to 1.9A continuous, which is 7.6A. The total ground current may therefore be around 36A in the absolute worst case steady-state condition.

- Each ground wire is rated at 7.5A.
- You should calculate the maximum current draw and determine the number of ground wires required.

For example:

Aux outputs:	1 idle solenoid (1A max)	1
	3 relays (air con, thermofan, fuel pump) - 3×150mA	0.45
	3 LED shift lights (20mA each) - 3×20mA	0.06
	1 canister purge valve (0.5A)	0.5
	ECU circuitry	0.2
	4 injectors, running at 1A	4
	total	6.2A

- In this case, one ground wire would carry the current adequately. However, it is good practice to run a few, as this will reduce the voltage drop, and will allow for future expansion (eg, if one of the outputs changed to a 3A water injection pump).

## 1.8. Injectors (8-pin connector, purple, white, grey and pink)

These outputs are current-controlled open collector outputs from the ECU. They pull low when the ECU activates an injector. They can be used with or without external resistors (standard on many vehicles with low resistance injectors), or with high or low impedance injectors. The difference to the ECU is that increased heating will take place with lower impedance injectors, and therefore if you are using very low value injectors at very high duty cycles, it would be a good idea to monitor the heatsink temperature to make sure the ECU doesn't get too hot.

The outputs are current regulated, and the current is controlled by a setting. If you intend connecting two injectors to a single output, you have two options:

- Connecting them in series. This is only recommended for low impedance injectors. It guarantees the same current is applied to both injectors (by Kirchoff's current law). It will also lead to less heat dissipation in the ECU. It does however mean that if an injector becomes open-circuit or a plug falls off, then you will lose both injectors rather than just one. In this case, the current setting in the configuration should be sufficient to drive a single injector (0.9A is typical).
- Connecting them in parallel. This must be done with high impedance (>12Ω) injectors to enable enough current to flow. Because the current is now shared between the two injectors, the current setting in the configuration must be doubled (1.9A). Although this is commonly done with low impedance injectors, it does not guarantee that each injector will receive the same current.

The injector outputs have been designed so that they can be left "live" when the ignition is switched off. However, there will be a small amount of current drain. This is around 0.4mA in total. This current drain exists because of the voltage sensing circuitry, for detection of injector failure.

The four wires, labelled Inj 1, Inj 2, Inj 3 and Inj 4, refer to the firing sequence, not the cylinder numbers. Therefore, if your engine's firing order is 1-3-4-2, you will need to connect the injectors as follows:

Name	Colour	Cylinder
Inj 1	Purple	1
Inj 2	White	3
Inj 3	Pink	4
Inj 4	Grey	2

## 1.9. Auxiliary Outputs (6-pin various, 16-pin various)

There are two types of auxiliary output: high current (numbers 1-4) and low current (numbers 5-8).

- The high current outputs have a maximum load of 7A resistive (simple loads like globes) or 3A inductive (anything with coils in it, eg motors, solenoids).
- They may be connected to outputs that are switched with ignition or always powered up.
- The first 3 auxiliary outputs have a PWM capability, and so should be left for functions that may require variable control (eg idle solenoids, water injection pumps etc).
- These are open-drain outputs, so they pull to ground when they are enabled. The conventional method of connection would be to connect the negative side of the solenoid to the ECU, and the positive side of the solenoid to ignition positive (+12V when ignition is on).

The low current outputs have the following characteristics.

- The low current outputs have a maximum current of 200mA, and so are suitable for driving light loads such as relay coils and LED indicators. None has PWM capability.
- They may be connected to outputs that are switched with ignition or always powered up.
- These are open-collector outputs, so they also pull to ground when the output is enabled. They are back-EMF suppressed, so are suitable for driving inductive loads such as relays.
- The conventional method of wiring a relay output is to connect one side of the coil to the ignition positive line, and the other side to the auxiliary output of the ECU.

## 1.10. Knock Sensor (20-pin, grey shielded cable or yellow/green)

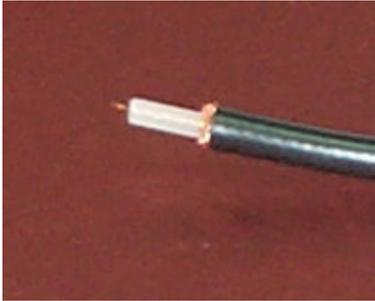
If you are using a knock sensor, the knock sensor should be connected via shielded cable because of the low signal levels. Usually, a knock sensor will have two wires coming from it. In this case, either wire can usually connect to the shield of the cable or to the signal conductor in the centre of the cable.

## 1.11. EGO Sensor (20-pin, black shielded cable or yellow/red)

There are three main types of passive exhaust gas oxygen sensor, characterised by the number of wires.

A single wire sensor should be installed in the following manner:

- Strip back the sheath on the EGO sensor cable from the ECU, and cut off the braid, leaving just the centre conductor (see Figure 5).
- Insulate any loose strands of the braid, by shrinking a piece of heat-shrink over the end of the sheath (see Figure 6)
- Connect the central conductor to the EGO sensor, either by crimping a spade connector on the end or whatever is suitable for your particular sensor.



**Figure 5: Stripped back sheath and cut braid**



**Figure 6: Stripped back sheath and insulated braid**

A three wire sensor should be installed in the following manner:

- Perform the same steps as above to prepare the end of the EGO sensor cable.
- Find out which wires are the heater wires on the sensor. This can be performed by measuring the resistance between the pins on the plug. Usually, the heater resistance will be around  $6\Omega$ , and the sensor will read open circuit when cold.
- Connect the EGO sensor wire from the ECU to the pin that measures open circuit on the sensor.
- Confirm that both the other two pins are isolated from the body of the sensor (using the resistance range of a multimeter). If so, connect a 12V ignition line and Ground to the other two pins. If not, find which of the two pins is connected to the sensor body ( $0\Omega$ ), and connect this pin to Ground and the other pin to ignition switched 12V.

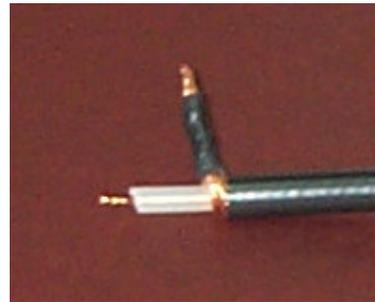
A four wire sensor should be installed in the following manner:

- This assumes the standard colour codes - two white wires, one grey wire and one black wire.
- First determine whether or not the sensor output is isolated from ground. Measure the resistance between the grey wire and the sensor body. If it is open circuit, you have a proper 4-wire sensor. If it is short circuit, your sensor is a 3-wire sensor with an extra wire. In this case, the black wire is the signal wire and the two white wires are the heater wires. Do not connect the grey wire. Connect the sensor as the 3-wire description above.

- Assuming you have a sensor with an isolated output, you should connect the two white wires to switched +12V and ground.
- Strip back the sheath of the EGO sensor cable from the ECU, but do not cut the braid. Instead, twist the braid so that it forms another conductor (see Figure 7).
- Shrink a length of heatshrink around the braid, to insulate it from other conductors (see Figure 8).
- Shrink a length of heatshrink over the join, to insulate any exposed braid (see Figure 9)
- Connect these to the sensor, either by using crimp terminals or whatever is used on your sensor. The signal wire (central conductor of the EGO cable from the ECU) should connect to the black wire on the sensor; the ground (braid) should connect to the grey wire on the sensor, and the two white wires connect to ignition positive and ground.



**Figure 7: Stripped back sheath and twisted braid**



**Figure 8: Heatshrink over braid**



**Figure 9: Heatshrink over join**

## 1.12. Connecting a Wideband Oxygen Sensor

There are three methods to connect a wideband oxygen sensor:

- Into the normal oxygen sensor input. The voltage at this input must not exceed 3V, so is unsuitable for most types of linearised oxygen sensors.
- Into the "spare" analogue input (grey wire). This input is 5V tolerant and is suitable for most linearised oxygen sensors.
- Into the secondary serial port of the ECU. This is the most preferable option.

The secondary serial port is the DE9 male connector, next to the serial port that connects to the PC. The following serial protocols are supported through this serial port:

- M&W LSU4
- Innovative Motorsports LC1 / LM1
- Techedge WBO2 serial frame format 2

Once the correct mode is selected, the ECU will use the serial input from the wideband sensor to override any value interpreted from the analogue input. This allows a tuner to install an ECU with a normal narrowband oxygen sensor, but connect a wideband sensor for tuning purposes.

The serial connection is preferable to an analogue connection because the ECU can determine if the sensor output is valid by other information in the serial packet (for example, sensor temperature), and default to the analogue input (or indicate an invalid reading) if no information is available. With an analogue input, there is not usually a way for the ECU to determine if the sensor is giving valid information or not.

## 2. Initial configuration of the ECU

Before setting up the ECU it would be advisable to have a walk through some of the helpful extras in the software. At any point where there is power to the ECU and a sensor connected you can see the current value of that sensor by selecting the menu option Windows -> Gauges, or by pressing F2, an invaluable tool in setting up your ECU. By pressing F11 or selecting the menu item Windows -> ECU Data, you can view all the current outputs and flags, another invaluable tool in diagnosing any problems with your current settings.

### 2.0. Basic Setup

Once the wiring is done, connect the white 8 pin plug to the ECU (and ONLY the white 8 pin plug). This should power up the ECU which should then be connected to a PC using a straight through RS232 DE9 extension (male-female) cable. WARI, the Windows Adaptronic Remote Interrogator, should be run on the PC, and the COM port should be selected.

- Verify that WARI can see the ECU (a message such as "ECU connected Adaptronic V1" should appear, rather than "No ECU connected")
- Make sure the settings are all ready from the ECU (when first connected, a message such as "Reading Settings 0%" should appear, and when this reaches 100% and the message changes to "ECU connected", the settings have all been read).

Once the ECU is online, you should then begin by configuring the basic setup.

#### 2.0.0. Ignition Outputs

Refer to the ignition control section on the basic setup tab. Click the "Configure" button under the Ignition Control pane to setup the ignition outputs. It will bring up the following window:

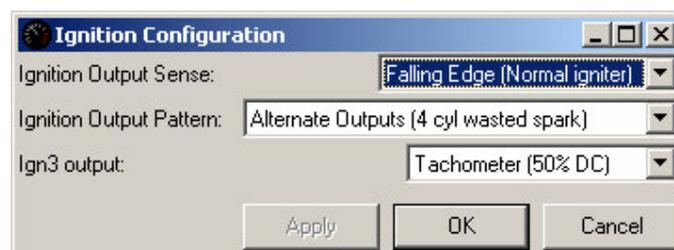


Figure 10: Ignition Configuration Dialogue Box

Set the ignition output sense one of two ways:

- Falling edge sensitive. Most igniters will be falling edge sensitive; that is, the ECU ignition output goes high to begin charging the coil, and low again (falling edge) to generate the spark.
- The rising edge option is only for certain igniters that were intended to work with Kettering ignition (points), and are triggered by the rising edge. Some Honda igniters seem to use this logical sense. If a rising edge ignition output sense is selected, a warning message will be brought up.

There are three ignition outputs on the e420c. These should be set to be fired in one of five different ways:

- Simultaneously, as on an engine with a distributor. The third ignition output can then be configured as a tachometer function.
- Alternately, as on a 4 cylinder, wasted spark engine or a dual-distributor engine (eg Toyota 1UZFE). The third ignition output can then be configured as a tachometer function.
- In a cycle of three, as in a direct fire ignition on a three cylinder engine, or wasted spark on a six cylinder engine. In this mode, the tachometer output, if required, must be sourced from an auxiliary output, and the ign 3 output function set to ign 3.
- Leading/Trailing, as in on a two rotor Wankel engine. Currently in this mode the ECU can fire the leading/trailing spark plug via addressing (ign 3 set to coil address) with the factory addressing igniters or with a distributor.
- In a cycle of four, as in direct fire ignition on a four cylinder, or wasted spark on an eight cylinder engine, (ign 3 set to ign 3) and aux 1 set to ign 4.

Ignition Output 1 will fire first after the reset pulse from the crank/cam trigger. Each output will turn on a fixed amount of time (the "dwell time", configurable in the Trigger/Output window) before the spark is to fire. The output will then turn off at the angle at which the output is supposed to fire, discharging the coil and generating the spark.

**CAUTION: Many igniters are not very intelligent. If you apply a constant "on" signal to them, the output transistor will often stay on, which can cause damage to the igniter or the ignition coil. A warning message will be brought up if the ECU's current state would cause the ECU to apply a constant "on".**

The dwell time is the time for which the coil is charged before firing. Typically values between 3000 $\mu$ s (3ms) and 3500 $\mu$ s (3.5ms) are used successfully. If the dwell time is set to be longer than the minimum period (eg 5ms is one period at 6000 RPM), the dwell will be shortened to the next available trigger pulse once the RPM becomes too high. Some igniters (including all capacitor discharge ignition (CDI) systems) generate their own dwell time, and so the dwell time asserted by the ECU is unimportant.

In the case of alternating ignition outputs, the dwell time allowable is up to double the period, as each output fires only once every two periods. This is one reason why a wasted spark system (or coil-on-plug) is used on high revving engines rather than a conventional single coil/distributor system. If you have not already set the dwell time you should do so now.

The Timing Lock feature allows the ignition timing to be fixed (or offset based on the  $^{\circ}$  BTDC) when the engine is running to verify the ignition timing.

The remaining plugs should now be connected to the ECU.

### 2.0.1. Crank/Cam Angle Sensor - General

This is traditionally the most difficult of sensors to configure because of the multitude of different sensors available. Because of the flexibility of the Adaptronic, it can be

configured to a myriad of different sensors. This flexibility also makes the configuration process longer than that on a simpler system. These settings are all controlled in the Basic Setup tabsheet, in the "Advanced" options.

There are three input channels on the ECU. Each of these can be configured as a reductor or a digital input. For digital inputs, each channel can be configured to fire on the rising or falling edge. The Adaptronic can be programmed to detect missing teeth, and can also be configured as a crankshaft or camshaft sensor (360° period or 720° period). Furthermore, the timing mark angles from the sensor can be selected.

In most cases, you will have the following:

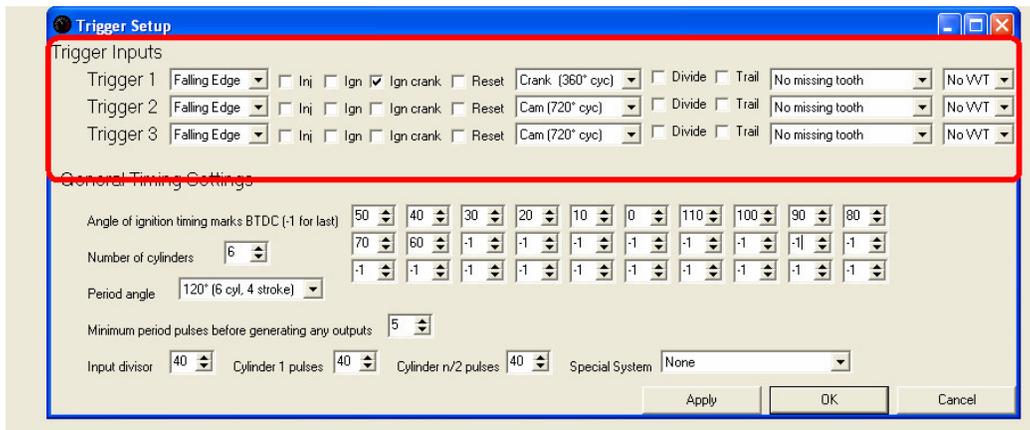
1. One sensor channel that gives a timing mark, for example, a multitooth wheel;
2. Another channel (or two) that give synchronisation information, for example, a single pulse every 720°;
3. If the timing mark is too inaccurate, sometimes you may have another pulse that occurs at the correct ignition timing during cranking.

In any case, the procedure is:

1. Verify that the ECU is detecting the pulses from the sensor;
2. Find out at what angles the pulses occur;
3. Configure the ECU to suit.

Because the ECU can accept a channel specifically to fire the ignition during cranking, one can connect a timing light to the ignition output from the coil, and select each input (which has been connected, see Figure 13) in turn, crank the engine and determine the angle at which the pulse occurs. For each connected channel in turn:

1. Deselect all the boxes in all other channels.
2. If this channel is a reductor input, select "Falling Edge". Otherwise, this must be performed twice; once using "Falling Edge" and once using "Rising Edge".
3. Deselect all the boxes in this channel, and select "Ign Crank" (see Figure 13).
4. Make sure that the ignition output is set to "Both at once", that the dwell time is appropriate (eg 3ms), and that the correct ignition sense for the igniter is selected (rising or falling edge, falling edge being the most common).
5. Crank the engine, and use the timing light to determine at what angles the pulses occur.
6. Record it before you forget it.



**Figure 11: Configuration for checking the timing during cranking**

Some hints:

- Usually the crank pulley is marked with timing marks only from 20° BTDC to TDC. However, often pulses occurring outside this range are subdivisions of one revolution. For example, if there are 12 pulses during cranking, they appear to be evenly spaced, and one of the pulses is at 10° BTDC, you can be pretty sure that the others are at 160°, 130°, 100°, 70° and 40° (and these plus 180°).
- When you crank an engine with the spark plugs installed, the ring-gear makes a sound like "nyeh-nyeh-nyeh-nyeh-nyeh". Each "nyeh" is a single cylinder, which corresponds to 180° on a 4-cylinder 4-stroke engine. The significance of this is that if you have a sensor that only triggers once every 4 "nyeh"s, this occurs every 2 revolutions, or 720°. This will likely be a cylinder reset marker.

**NOTE: this requires that the ignition output has been set up and tested already. Also recommended is that in a distributor system, the coil be connected directly to a spark plug to avoid the angles where the distributor does not make a connection. If you do not get regular pulses, you should check your wiring. If you are using a reluctor input, you can look at the conditioned signals on the digital CAS input wires using an oscilloscope; they should be high except for the duration of the negative slope in the reluctor waveform, at which time the appropriate channel should become low.**

Once you have documented what the sensor outputs do, you can configure the ECU to suit this sensor.

Each "nyeh" (the sound made during cranking) is called a "period". This period refers to 180° on a 4-cylinder 4-stroke engine, 120° on a 6-cylinder and 90° on an 8-cylinder. All the timing for the Adaptronic is calculated on a "per period" basis. This is a throwback to the days of distributors, where a new ignition pattern would occur every period. Each period, a new ignition pulse is generated, and a new injection pulse is generated. The RPM is also measured between periods.

- The most highly accurate sensor (that is, the one with the most pulses per revolution) should be used to measure the ignition timing and to fire the injector. (Tick Inj and Ign) e.g. a multi tooth wheel (If it has no missing

teeth, then "No missing tooth" should be selected, and whether Cam or Crank is selected makes no difference.)

- Using a multi-tooth wheel, the ECU can also reset its position within the period by detection of missing teeth or an additional reset pulse. In the case of a missing tooth system, a certain number of missing teeth should be selected for the ECU to detect. The "reset type" should also be selected. This will be "Cam" if there is a single missing tooth per camshaft revolution, "Crank" if there is a single tooth per crankshaft revolution, and "Period" if there is a missing tooth for each ignition event.
- Any other input triggers should be used to stabilise the timing by resetting the count. (tick reset)

This is required because the timing sensor may generate several pulses per period, and therefore the ECU needs a means of determining which pulse corresponds to which angle measurement.

Unless a Nissan style optical sensor is used, the Trail and Divide check-boxes should be deselected on all inputs. (refer to 2.0.2 if you have a Nissan sensor)

Any unused inputs should have all boxes deselected.

The minimum number of pulses before an output should be set such that ECU will know where the engine is before an output occurs.

Batch fire during cranking is recommended for easier starting. Some applications may require this to be disabled, for example if it's necessary for precise fuel metering e.g. when very large injectors are used.

The input divisor must be used if the trigger sensor generates more than 30 pulses per period. The "Input Divisor" field determines the division ratio. This is explained in greater detail in section 2.0.2, Nissan Sensor.

The cylinder 1 pulses and cylinder n/2 pulses allow the ECU to detect cylinder 1 and the opposing cylinder using the "Trail" option. The number of ignition trigger pulses between the period reset and the trail event are counted for the purposes of generating a "cam" or "crank" reset condition. Again, see 2.0.2 for more information.

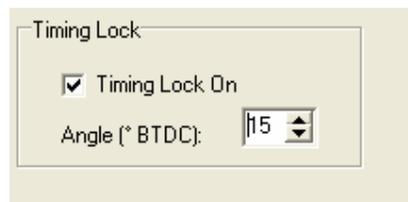
The next step is to work out the angles of the trigger pulses, in the order that they are received by the ECU, starting with the first one after the reset pulse (or the gap in the teeth). These should then be calculated in terms of the angle BTDC of that period. These should then be entered in the table, in order, with the value after the last pulse being -1.

If there are inputs that provide only synchronisation information, they should have all boxes deselected, except for "Reset". If the setting is "Cam (720°)", then the ECU will be reset to cylinder 1, and also reset to the start of the timing table, when the pulse occurs. If the setting is "Crank (360°)", then the ECU will be reset to cylinder 1 or the third cylinder in the cycle on a 4-cylinder (usually cylinder 4), or cylinder 1 or the fourth cylinder in the cycle on a 6-cylinder (usually cylinder 6), or cylinder 1 or the fifth cylinder in the cycle on an 8-cylinder. This is because a sensor on a crankshaft can only give 360° worth of information, but can still be of use. If the setting is the "Period" option, the current position will reset to the start of the angle table, however

the current cylinder number will be unaffected. This is useful on sensors which do not provide any cylinder phasing information, such as the Suzuki G13B engine, or a sensor on a throttle-body injected engine.

Once you have set up the triggering, you should make sure all outputs are disconnected, crank the engine, and verify that the RPM indicator in the gauge window reads a steady value (usually around 200 - 300 RPM during cranking). If you have set up the ignition outputs (see the appropriate section), you should set the "Ignition timing during crank" to a reasonable value (eg 10°), crank the engine and with a timing light, verify that the ignition pulses occur at the appropriate angle.

A diagnosis mode allows the ECU to fix the ignition timing at times other than cranking. By selecting the "Timing lock on" box, and setting an angle (such as 15 degrees), the ECU will assert that ignition timing to the engine (except during cranking). This will allow you to verify triggering at idle, or over a small engine speed range. It has been suggested that engine damage can occur if you rev an engine with no advance.



**Figure 12: Timing Lock on option box**

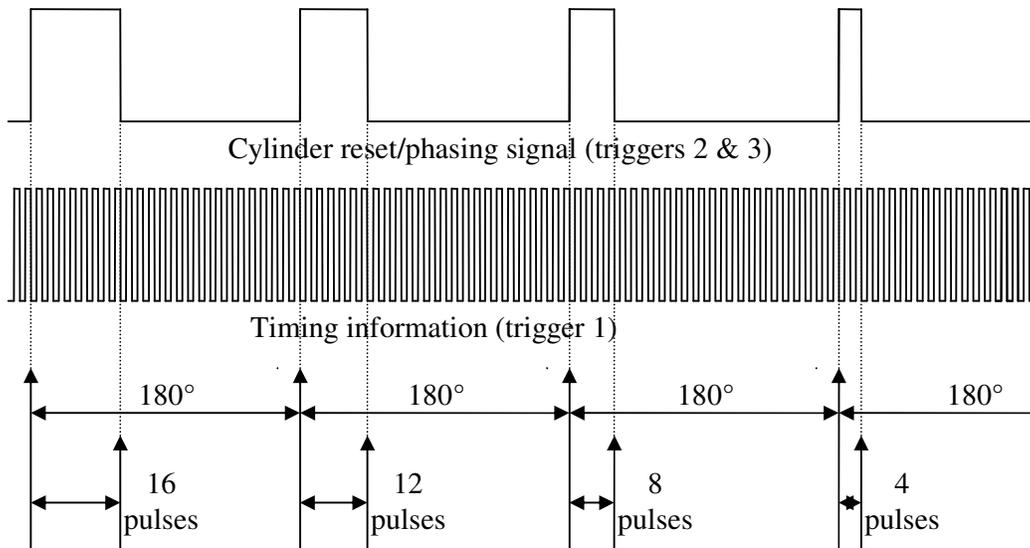
The VVT trigger option is currently in the BETA stage, however if you wish to use it, set the cam trigger/s as VVT1 and VVT2. For further information, see the VVT section in the ECU Reference section.

### 2.0.2. Cam angle sensor - Nissan style

The "Divide" check-box causes the ECU to ignore pulses from the sensor. This is intended for Nissan style optical inputs which deliver a pulse every two crankshaft degrees. The "Input Divisor" field tells the ECU how many input pulses should correspond to a single pulse in the timing table. For example, if the "Input Divisor" field is set to 15, then only one in 15 of the pulses from the cam angle sensor will generate a trigger in the ECU. This corresponds to 30 degrees of crankshaft revolution, which is tractable to enter into the angle table. The first pulse is always counted.

In addition to the very high pulse rate from the Nissan sensor output, a separate output gives cylinder phasing and reset information. The rising edge of the reset pulse occurs at a constant angle before top dead centre (for example 70 degrees BTDC). The falling edge occurs a certain number of 2 degree pulses later, depending on which cylinder is about to fire.

The following is a stylised view of the waveforms from the 4-cylinder Nissan sensor, as found on E15ET and SR20DET engines:



**Figure 13: Stylised Nissan cam angle sensor waveform**

The way to connect this to an Adaptronic ECU is as follows:

Connect the 2 degree output from the sensor into a digital trigger input (eg Trigger 1)  
 Connect the (cylinder reset pulse) into the two remaining digital inputs (eg, Triggers 2 and 3)

On Trigger 1, select "Divide", "Ign", "Inj" and "Rising Edge" only. This allows the ECU to use the main timer output from the sensor (ie, every 2 degrees) to do the ignition timing and injection.

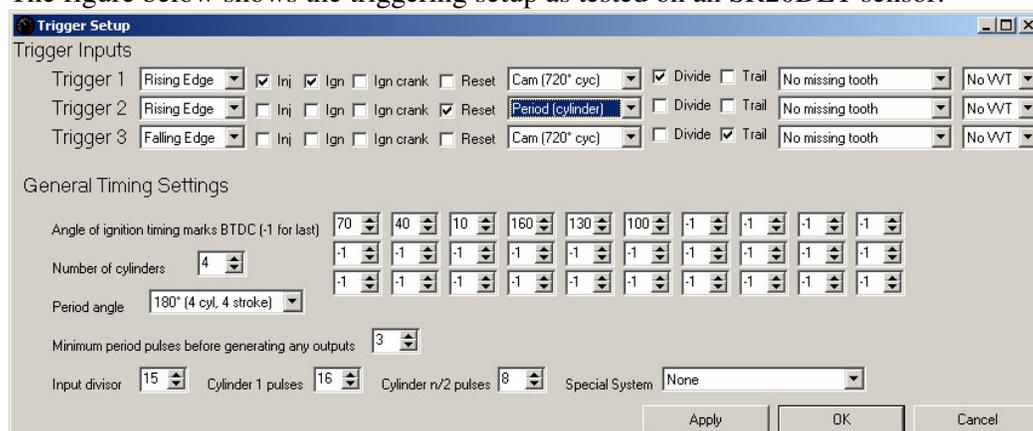
Set the "Input Divisor" to 15.

On Trigger 2, select "Rising Edge", "Reset", "Period (Cylinder)" only. This will cause the ECU to go to the start of the angle table when the rising edge of the input, which happens at a consistent angle.

On Trigger 3, select "Falling Edge", "Cam (720°)" and "Trail" only. This will cause the ECU to monitor the width of the pulse between rising and falling edges and set the cylinder count accordingly.

Set "Cylinder 1 pulses" to 16 and "Cylinder n/2 pulses" to 8.

The figure below shows the triggering setup as tested on an SR20DET sensor:



**Figure 14: Trigger Example for Nissan SR20DET engine**

### 2.0.3. Cam angle sensor example - 24 + 1 + 1

Consider the following sensor:

- Mazda B5 DOHC (4-cylinder) sensor mounted on camshaft (same as 4AGE sensor and many other Toyota sensors)
- 3 retractor coils
- One triggers every 30° of crankshaft rotation (24 teeth on camshaft), one of the pulses is at 10° BTDC (connected to channel 1).
- Another triggers every 720° of crankshaft rotation (1 tooth), at about 20° BTDC (connected to channel 2). This one triggers when cylinder 1 is firing.
- Another triggers every 720° of crankshaft rotation as above, but 360° of crankshaft rotation out of phase (connected to channel 3). This one triggers when cylinder 4 is firing.

Because the sync triggers occur at 20° BTDC, the first timing pulse after this occurs at 10° BTDC. The next one occurs 30° later, which is at 20° ATDC. 20° ATDC is 160° BTDC of the next period (on a 4-cylinder, the period is 180°). The next is 130°, and so on.

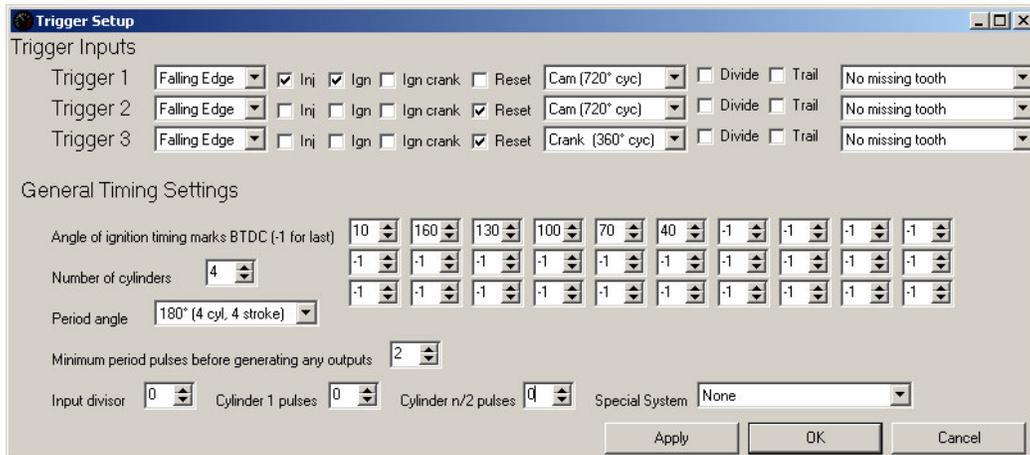
This means that the angles seen by the ECU, in order, starting with the first one after the reset pulse, are 10, 160, 130, 100, 70, 40.

The third channel, which triggers when cylinder 4 is firing, will trigger when cylinder 1 is about to perform its induction stroke. Therefore, it will reset the cylinder count back to 1, so that the next injector fired is 1, during its induction stroke. This will be done by setting this channel to "Reset", "Cam (720°)".

The second channel, which generates a pulse when cylinder 1 is firing, will be used to reset the cylinder count to 3. That is, it will jump to the third cylinder in the sequence (which is cylinder number four on the engine, but will correspond to output number three on the ECU). This will be done by setting the second channel to "Reset", "Crank (360°)". If the third channel is not available (eg, during cranking, the engine has not reached that position yet), it may reset the cylinder count to 1, however this will only affect injection timing during cranking if "batch on crank" is not enabled, and leave ignition timing unaffected.

The advantage of using this channel to reset to cylinder 1 or 3 is that during cranking, the ECU needs only two periods to be guaranteed a synchronisation pulse. Only after a synchronisation pulse has been received can the ECU generate accurate timing pulses. Therefore, only 3 period pulses are required before generating outputs (5 would be required without this channel). Because the timing information is relatively accurate and there is no separate output for timing during cranking, no channels should have the "Ign crank" selected.

The final trigger settings are as shown in Figure 17:

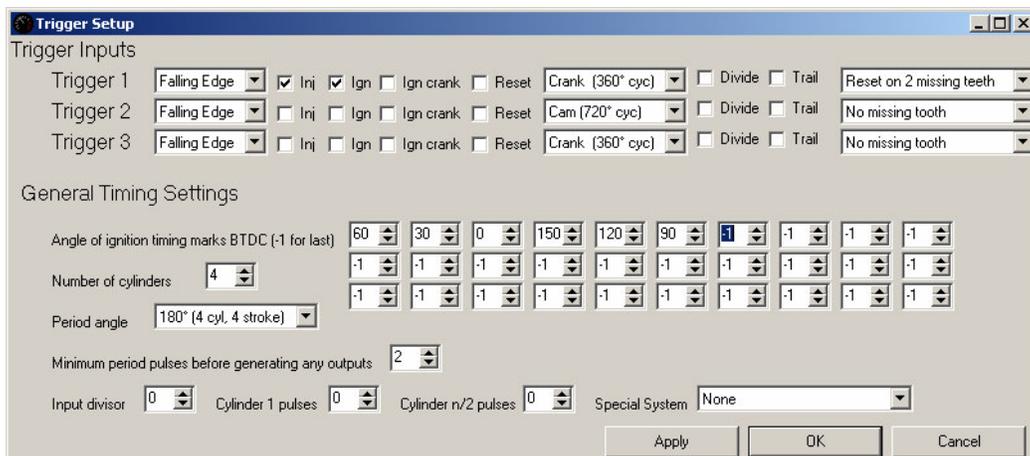


**Figure 15: Trigger Example for Mazda B5 DOHC engine**

#### 2.0.4. Crank angle sensor example - Honda CBR600

- Honda CBR600 4-cylinder motorcycle engine, sensor mounted on crankshaft.
- Single retractor output.
- 9 teeth, spaced at 30° (3 missing teeth).
- The first tooth after the gap occurs at 60° BTDC, the next at 30°, and so on.
- Because it is a sensor on the crankshaft, the reset pulse will occur every revolution instead of every 2 revolutions.

The angles as seen by the ECU, starting with the first tooth after the gap, are 60, 30, 0, 150, 120, 90. Selecting a gap size of two teeth provides a good compromise between false detection of the gap and detecting a gap when it's not there, in the face of changing engine speeds. Only a single channel is needed. Two periods are required before generating any pulses, because the gap will occur within the first 360° of cranking. The configuration is shown below:



**Figure 16: Trigger Example for Honda CBR600 Crank angle Sensor**

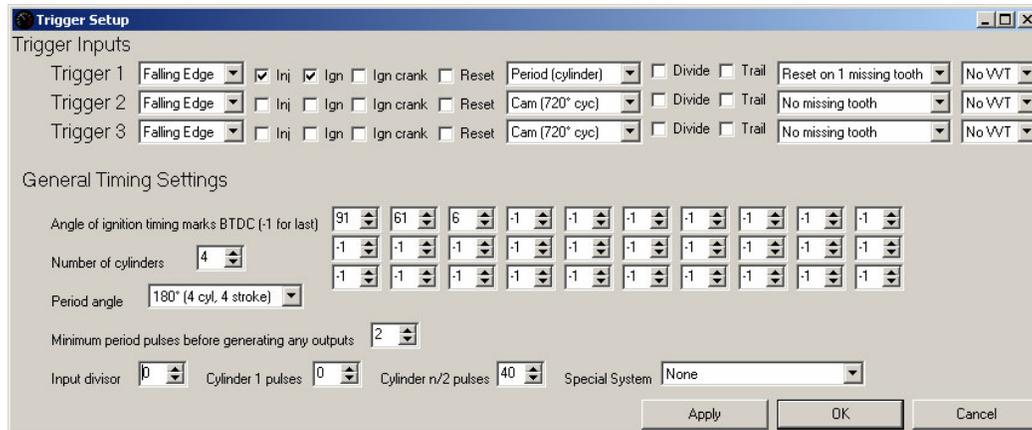
#### 2.0.5. Cam angle sensor example - Suzuki G13B

The G13B engine (ex Suzuki Swift GTi and Suzuki Cultus) has 3 teeth per 180° period. These occur at 91°, 61° and 6° BTDC (reference: workshop manual). There is

no cylinder information given by the distributor, and hence the "Period reset" method will be used. The trick is then to get the ECU to recognise which tooth the sensor is up to.

The gap between the 6° pulse and the following 91° pulse will be 186-91 = 95°. This is larger than the other two gaps (30° and 55°), and hence the ECU will detect that as a missing tooth. The first entry in the angle table should be the first tooth after the tooth gap, which in this case is 91°.

The following shows the triggering configuration for the G13B engine:



**Figure 17: Trigger Example for Suzuki Swift GTi Sensor**

Also need to put in:

- Subaru 99-00
- Subaru 01-03 / Suzuki Baleno
- Honda Aquatrax
- S2000
- 2-pulse reset, eg Mitsubishi / MX5

## 2.0.6. Injector Outputs

The Adaptronic has four independent injector drivers. The wiring topologies suggested are described in section 1.8. The settings in the ECU allow several different configurations, which will now be described.

The injector output pattern can be changed. The pattern is flexible enough to cover a myriad of different configurations. The table below shows which injectors are fired on the different periods of the engine cycle (2 revolutions). The table will be truncated depending on the number of cylinders selected.

Period	All at once	Alternate 12-34-12-34	Full seq 1-2-3-4	Alternate 12-__-34-__	Half speed seq 1-_-2-_-3-_-4-_-	Third speed seq 1-_-_- 2-_-_- 3-_-_- 4-_-_-	Quarter speed seq 1-_-_-_- 2-_-_-_- 3-_-_-_- 4-_-_-_-	Batch on cyl 1 1234-_-_-_- ..... 1234
1	1234	12	1	12	1	1	1	1234
2	1234	34	2					
3	1234	12	3	34	2			
4	1234	34	4			2		
5	1234	12	1	12	3		2	
6	1234	34	2					
7	1234	12	3	34	4	3		
8	1234	34	4					
9	1234	12	1	12	1		3	
10	1234	34	2			4		
11	1234	12	3	34	2			
12	1234	34	4					
13	1234	12	1	12	3	1	4	
14	1234	34	2					
15	1234	12	3	34	4			
16	1234	34	4			2		

In general, one should seek to have each injector firing only once throughout the cycle. This minimises the impact of injector dead time (the time between the current being applied to the injector and the injector delivering fuel) on fuel delivery, allowing better control of the engine. It would be preferable to have the injectors firing out of synchronisation with the cylinders, and one at a time, than to deliberately make each injector fire more than once throughout a cycle to ensure consistent timing between cylinders.

The current for the injectors can be set. This would typically be set at 0.9A, although higher currents can be used if more injectors are installed. The outputs can be set to peak-hold type or constant current. Peak-hold is preferred, as it decreases the injector dead time. Some injectors (the standard Suzuki Swift GTi come to mind) require a higher current (1.5A) to open properly.

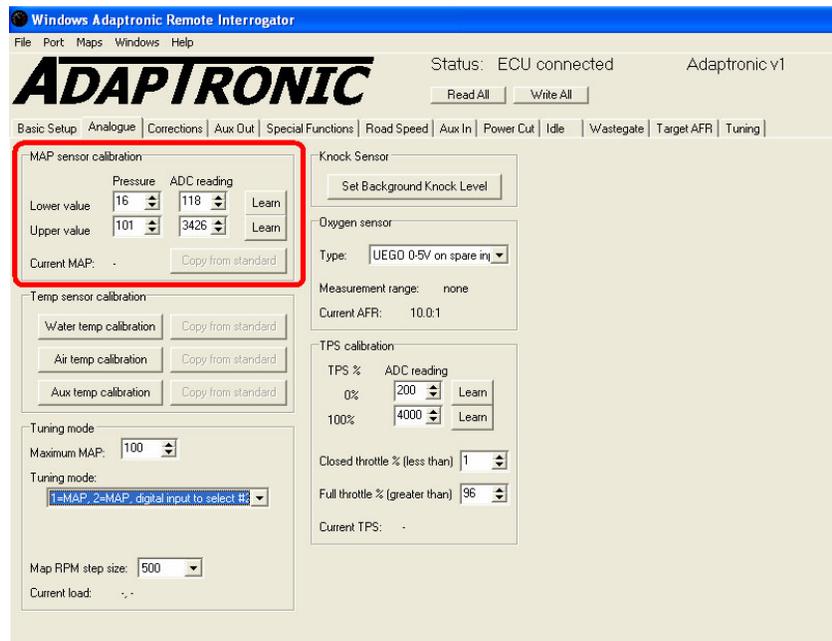
Lastly, the ECU only "knows" when it is cranking by the engine speed. Once the engine has reached a certain speed, the ECU should switch over to normal operation. However when it goes below a certain speed, the ECU should switch back into cranking mode to ensure that it recovers. These two RPM points should be set in the Cranking RPM section on the basic setup tab.

## 2.1. Configuring the Analogue Sensors

### 2.1.0. Manifold Absolute Pressure (MAP)

If you are using a MAP sensor, the sensor must be calibrated.

- Open the Analogue tabsheet.
- Enter the minimum readable pressure to the "Lower Value" box. You must then apply this pressure to the MAP sensor. A value such as 16 kPa would be typical (see below):



**Figure 18: MAP sensor calibration value in kPa**

- Apply this vacuum to the MAP sensor, and click the "Learn" button.
- Enter the maximum pressure of the MAP sensor into the "Upper value" field. This will be 100 for a 1 Bar MAP sensor, 200 for a 2 Bar MAP sensor and 300 for a 3 Bar MAP sensor.
- Release the vacuum from the sensor so that it reads atmospheric pressure (100kPa).
- Adjust the "Upper value ADC reading" value until the "Current MAP" reads 100 kPa.
- Note: If you can apply the maximum pressure to the sensor (either it is a 1 Bar sensor, or you have access to a regulated pressure source), you can just do this and then click the "Learn" button.
- Apply different pressures to the sensor and verify that the correct pressures are shown at "Current MAP".

Some typical values for standard MAP sensors are given below:

Pressure	Low pressure (kPa)	Low ADC value	High pressure (kPa)	High ADC value
1 bar	16	237	101	3347
2 bar	16	116	200	3384
3 bar	16	154	300	3384

### 2.1.1. Temperature Sensors

The default table in the ECU suits a common type of sensor. In practice, it is easiest to do a "sanity check" when the engine is stopped (and verify that it reads approximately ambient temperature), and then verify the readings with a thermometer as the engine warms up. This is most easily done with the water temperature sensor.

To calibrate the sensors properly, you must perform a temperature sweep.

- It can be easiest to start at the hottest temperature by heating the sensor up to just above the maximum temperature (125°C). Stop heating the sensor.
- With a thermometer installed, monitor the temperature of the sensor.
- As the temperature falls through its operating range, click the "Learn" button for each appropriate temperature as that temperature is reached.
- Ensure that the sensor cools slowly so that the thermometer is reading the sensor temperature accurately. This may be facilitated by heating it gently, or immersing the sensor and thermometer in oil or water (not water at 125°).
- Once the sensor gets down to ambient temperature, repeat the process by freezing the sensor to its lowest reading, and allowing it to heat up to ambient, clicking the "Learn" button as it reaches the appropriate temperatures.
- During this process, verify the temperature reading at "Current Temp".

If you have a table or graph that gives the resistance values of the sensor at different temperatures, the ADC value can be calculated from this resistance. The formula is given below (for Resistance in Ohms):

$$\text{ADCValue} = \frac{4095 \times (\text{Resistance})}{(\text{Resistance} + 4700)}$$

Note that this must be performed for all temperature sensors in use (water temperature sensor, air temperature and auxiliary temperature). There is no need to enter values for a sensor which will not be connected.

### 2.1.2. Load Sensing (Tuning mode)

The ECU must be instructed as to how it will determine load of the engine. In version 1.0, there are 13 modes: based on TPS and MAP (and in some cases a digital input to select which one at the time).

As a rough guide, the following modes should be used:

Mode	Application
1 = MAP 2 = unused	Single throttle, plenum engines (ie, most street engines) - tuned by MAP sensor. Appropriate for 98% of street engines.
1 = MAP 2 = MAP Digital input to select #2	As above, but when two maps are required for alternate tunes (digital input can select the alternate map)
1 = unused 2 = TPS	Tuning by TPS only. Used by some tuners on large cam engines. Must only be used on NA engines. Generally gives poor idle mixture control so really only suited to race engines.
1 = TPS 2 = TPS Digital input to select #2	As above, but when two maps are required for alternate tunes (digital input can select the alternate map)
1 = MAP 2 = TPS MAP x TPS	Tune by combination MAP and TPS. Use on multi-throttle body engines (with a manifold to collect the port pressures for the MAP sensor) or engines with no plenum. When tuned correctly gives excellent mixture consistency on individual throttle body engines.

For more information on the specific functions of each of the settings refer to the section “Tuning modes”.

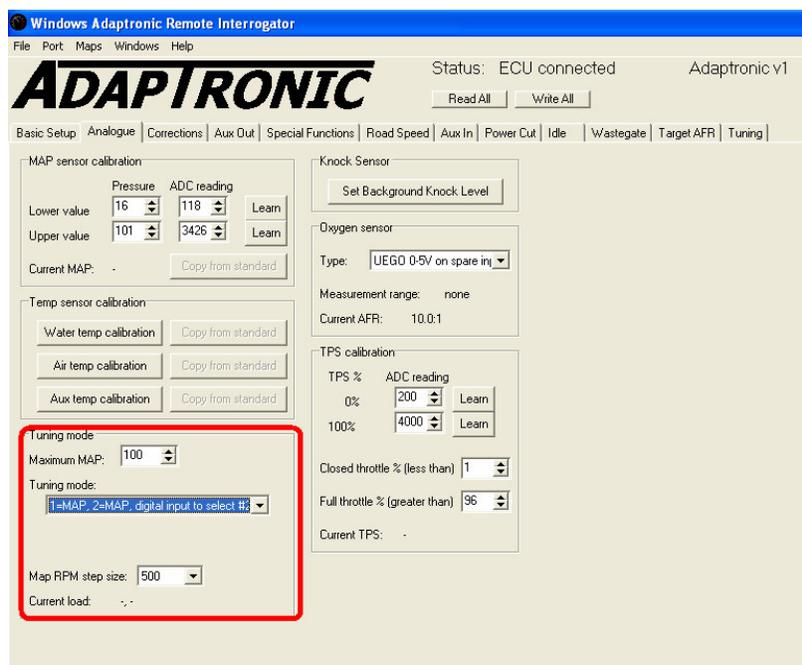


Figure 19: Load Sensing Options

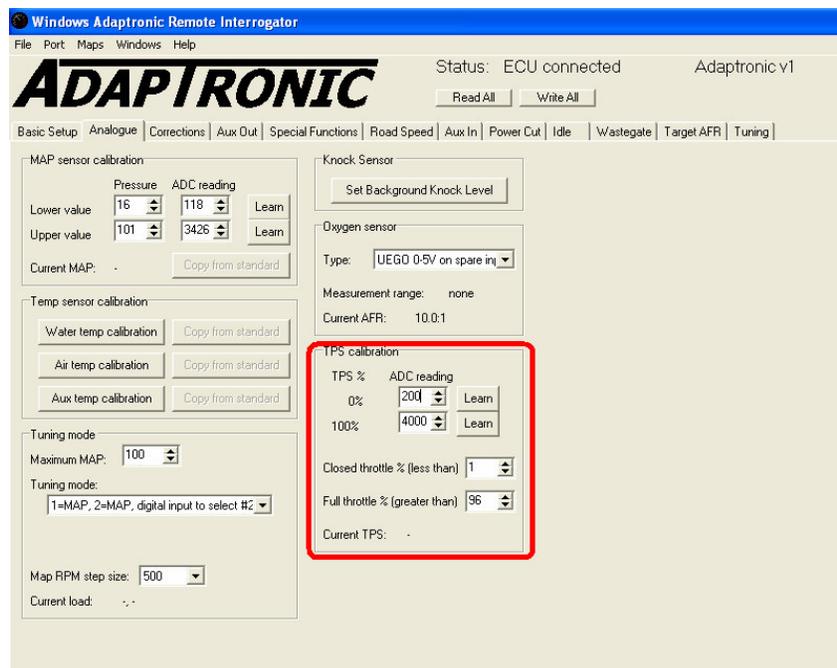
The maximum MAP and map RPM step size should also be set here to determine the ranges for tuning, keeping in mind that the maximum RPM is the map RPM step size multiplied by 31. The table below shows the mapping of RPM step to maximum RPM:

RPM Step	Max RPM
500	15500
300	9300
250	7750
200	6200

### 2.1.3. Throttle Position Sensor (TPS)

If you are using a throttle position sensor, you will need to calibrate it.

- Go to the Analogue tabsheet.
- Make sure the throttle is fully closed.
- Click the "Learn" button next to the TPS 0% reading (see below)



**Figure 20: Location TPS calibration**

- Verify that the number to the left of the button changes. It should be somewhere between 100 and 1000.
- Open the throttle completely (on a car, push accelerator all the way to the floor), and click the "Learn" button next to the 100% reading.
- Verify that the reading changes. It should be somewhere between 1900 and 4000.
- If the 100% reading is lower than the 0% reading, this indicates that the TPS has been wired back to front.
- If the two readings are very close, it indicates that one or more of the wires to the TPS is not connected or the sensor is faulty. Check the wiring.
- The 0% calibration may have to be repeated once the engine has warmed up, because on some engines the throttle is moved by a thermosensitive device to increase the idle air when the engine is cold.

- Verify that the "Current TPS" reading reflects the position of the throttle actuator (push the throttle a few times to check its operation).
- If you are using a TPS switch this will need to be set under the Aux in tab.

#### 2.1.4. EGO (Exhaust Gas Oxygen) Sensor

If you intend running the engine in closed loop fuel control mode, you will need to install and configure an oxygen sensor.

- From the drop-down menu, select the type of oxygen sensor.
- If you are using a serial-connected wideband oxygen sensor, you will need to select your analogue oxygen sensor in the analogue tab, and the serial-connected wideband sensor under the special functions tab. This means that if you have the serial device only and no analogue input, the analogue sensor type should be set to "none".
- If a serial-connected wideband oxygen sensor is selected and connected, the AFR from it overrides the AFR calculated from the analogue input. However if there is no data from the serial device for a given period of time, the value calculated from the analogue input is used instead.
- When the engine is running, the AFR readings can be verified. There will usually be no sensible output from an oxygen sensor when the engine is not running, and usually no reading will be displayed on the software.

#### 2.1.5. Knock Sensor

The knock sensor picks up detonation but also picks up a lot of engine noise. This mechanical noise depends mainly on the engine speed, therefore to avoid the knock sensor interfering with normal engine operation set the background knock level to a level slightly above normal engine noise.

### 2.2. Corrections

The Corrections tabsheet controls all of the fuel and ignition control functions of the ECU. These are all described in the behavioural section.

### 2.3. Auxiliary Outputs

The easiest outputs to configure are general-purpose digital outputs. The first four (1-4) are high current types, intended for driving solenoid valves directly (3A inductive max, 7A resistive max). The first three of these (1-3) are PWM capable. The next four (5-8) are simple on/off, low current outputs, intended to drive LED lights or relay coils. The last three are the lights on the ECU.

A general-purpose output can be configured in a number of different ways. There are two main methods:

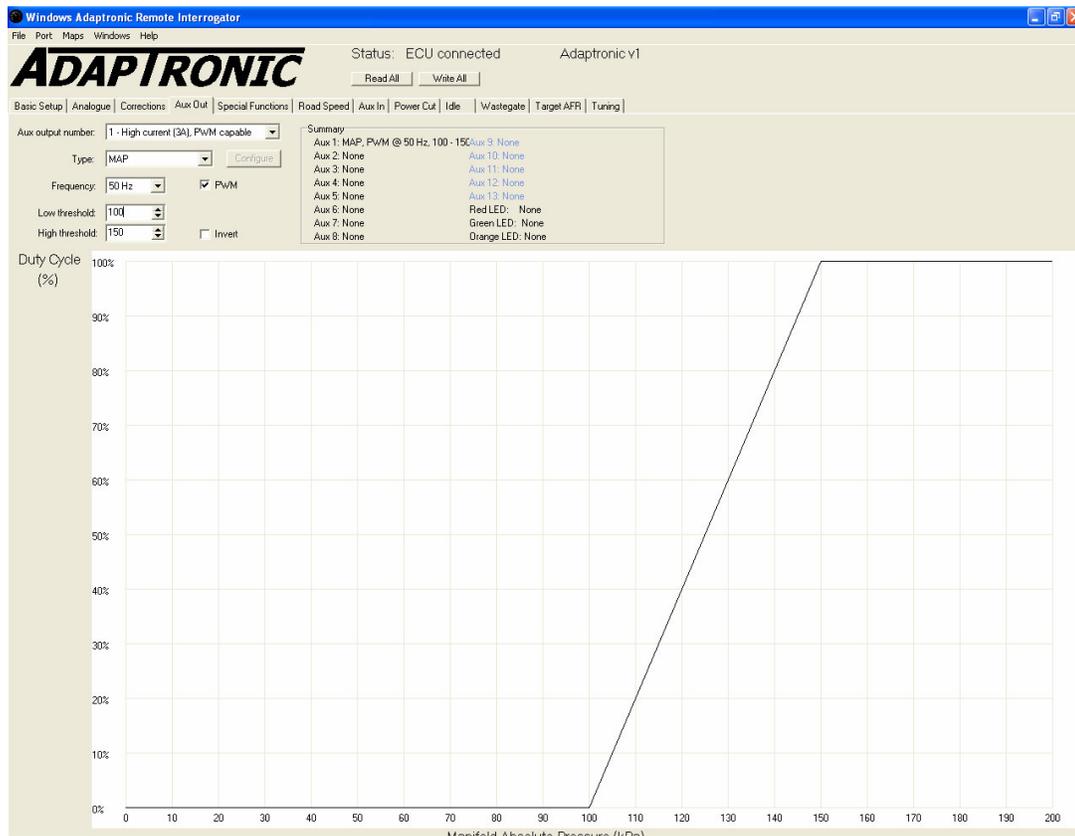
- Based on a measured quantity; and
- Based on some specific behaviour programmed into the ECU.

Any output can be set to either of these. If the output is set to a specific behaviour, some specific behaviour, as configured in the Special Functions window (F11) will be effected.

For a measured quantity, there are two types of control:

- PWM; and
- Digital.

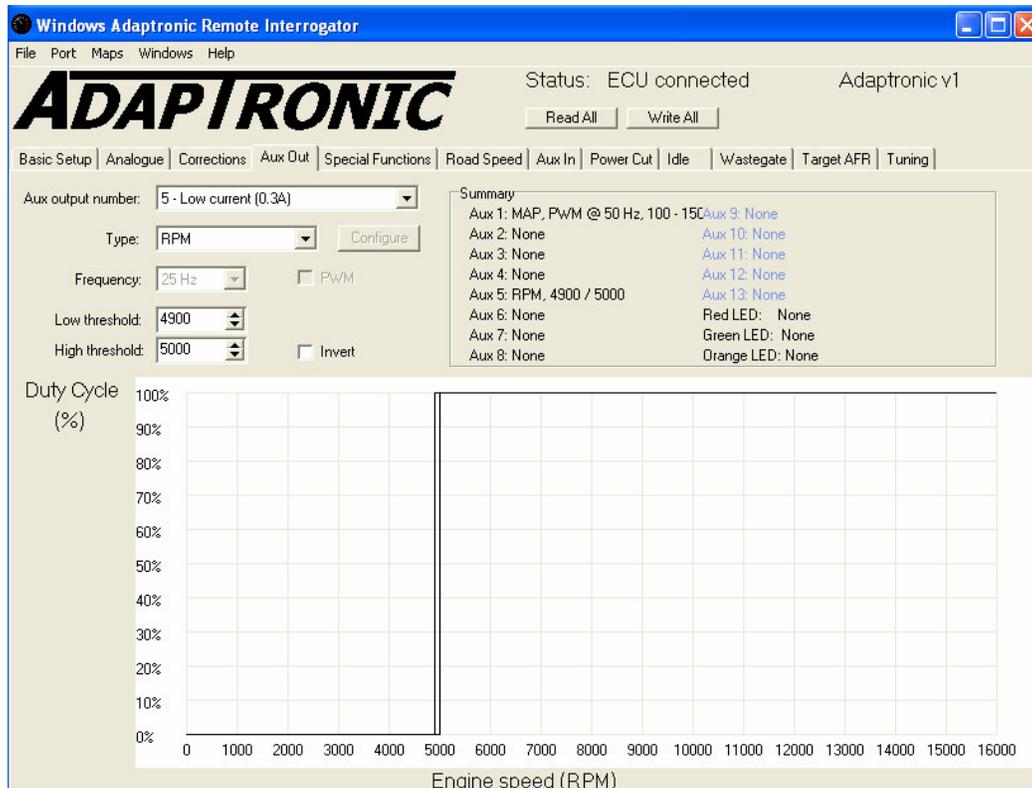
For the PWM modes, the operator can select the high and low points of the measured quantity over which the output will change its duty cycle. For example, if you wanted a water injection pump to vary its injection rate based on MAP, from off completely at 100 kPa to on completely at 150kPa, you would set it up as shown in Figure 21:



**Figure 21: Water Injection Auxiliary Output Example**

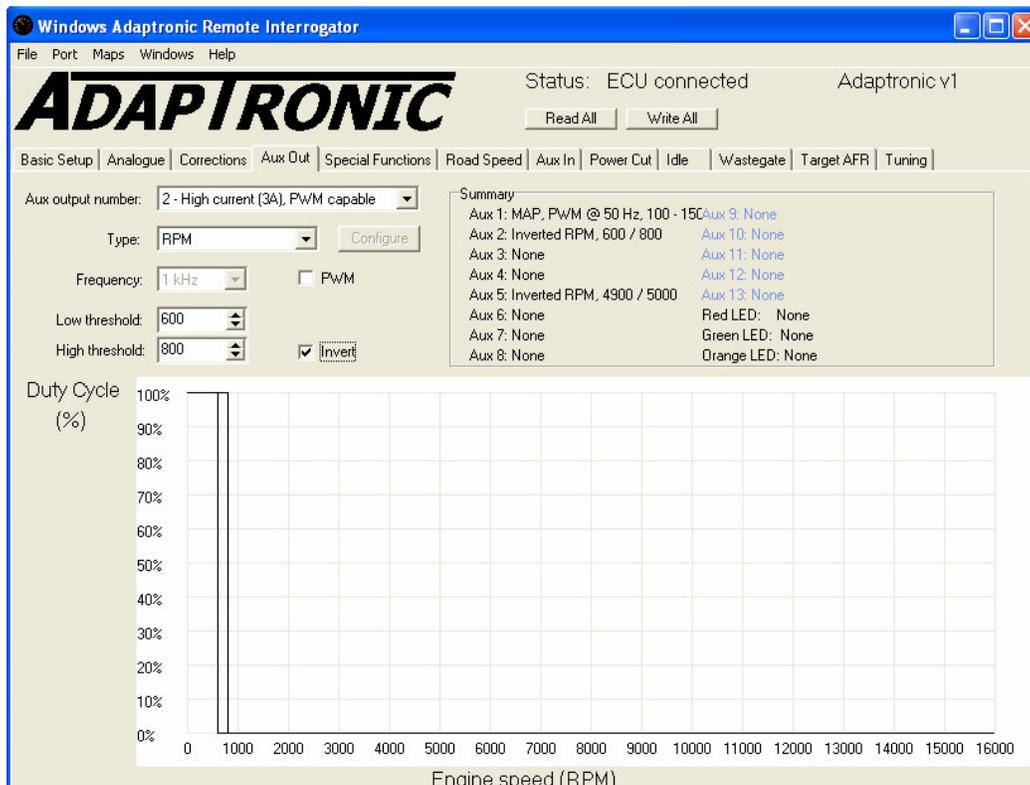
Below 100kPa, the output will be off all the time, and above 150kPa, the output will be on all the time. The PWM frequency will be 50Hz, and this can be changed as well.

In digital modes, the two numbers represent hysteresis limits. Because all signals have noise, the threshold at which the output should come on should differ from the turn-off threshold. If you want a shift light, for example, you may want it to come on above 5000 RPM, but if you turn it off below 5000 RPM, this means that the light will flicker when the engine is around 5000 RPM due to the noise. Therefore, you would configure it to turn off at a lower value, say 4900 RPM, as shown in Figure 21:



**Figure 22: Shift Light Auxiliary Output Example**

There is another flexibility, which is the logical inversion of the output. When the "Invert" option is selected, the output will be on when it would otherwise be off, and vice versa. If you wanted some kind of "stall saver", which comes on below 600 RPM, and turns off above 800 RPM, you would configure it as in Figure 22 (note that in practice you would simply set up the idle speed control correctly, however this serves as an example):



**Figure 23: Stall Saver Auxiliary Output Example**

After wiring the outputs, the first stage is to go to the Aux Out tabsheet and set all the outputs to "None", and deselect the "Invert" and "PWM". This ensures that all the outputs are disabled.

The next step is to turn each output on in turn, and verify that it does what it is supposed to do (start the fuel pump, activate the thermofan, open a purge valve etc). This can be done by selecting the "Invert" option with the type still set to "None" (this will activate the output).

Once this is done, the outputs should be configured as desired for the particular installation. Some tips:

- One output should be configured as a fuel pump. This will normally be one of the last four, and fed via a relay. The timing of the fuel pump (duration at start and duration after receiving the last crank angle pulse) can be controlled in Special Functions.
- One output would normally be configured as a purge valve for road going cars. The behaviour of this can be controlled in Special Functions.
- If you are attempting adaptive fuel control, it may be beneficial to connect up two or three LEDs to some of the outputs; the learning states (RPM OK, Load OK and Wait) can be easily seen, which can help greatly in tuning quickly.

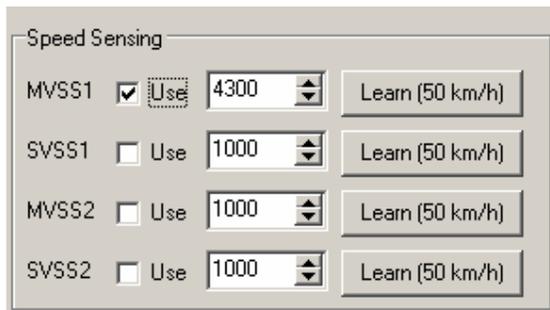
## 2.4. Special Functions

The Special functions tabsheet contains settings for various specific behaviours that the ECU can perform. These are all described in the behavioural section.

## 2.5. Road Speed

The vehicle speed sensors: master vehicle speed sensor (MVSS1) and slave vehicle speed sensor (SVSS1). These are both input to the ECU as digital signals. The ECU measures the period between pulses and divides this into a number to arrive at a number proportional to road speed. If the ECU receives no pulses in a one second period, the speed for that input is set to zero.

To calibrate the proportionality and achieve the VSS reading in km/h, either drive at 50km/hr and press the learn button, or enter an arbitrary number and adjust it until the vehicle speed indicated at the ECU corresponds to the actual vehicle speed. Note that the input must be enabled using the tickbox for the ECU to calculate the speed:



Sensor	Use	Value	Action
MVSS1	<input checked="" type="checkbox"/>	4300	Learn (50 km/h)
SVSS1	<input type="checkbox"/>	1000	Learn (50 km/h)
MVSS2	<input type="checkbox"/>	1000	Learn (50 km/h)
SVSS2	<input type="checkbox"/>	1000	Learn (50 km/h)

**Figure 24:** Sample Road Speed setup for a vehicle with a single speed sensor

Only MVSS1 and SVSS1 are implemented on the e420c, and correspond to the MVSS and SVSS inputs on the 16-pin connector.

## 2.6. Auxiliary Inputs

These should be configured as required. Each input can be selected in terms of its function, and its logical sense (active high or active low).

If multiple inputs are configured to the same function, they are logically OR-ed together. That is, either input will activate the function. By this logic, if no inputs are configured to a particular function, the function will not be enabled. This allows a neutral switch and a clutch switch to be connected to separate inputs, and both can be selected as "Clutch", effecting the same behaviour. Similarly, many electrical loads can be connected to various inputs and configured as electrical loads.

These are configured in the "Aux In" tabsheet.

## 2.7. Power Cut, Idle, Waste gate

Refer the equivalent sections in the ECU operation section.

## 2.8. Target AFR

The desired AFR can be configured in this tabsheet. The values in the boxes are actually the AFR multiplied by 10. If the oxygen sensor installed is a narrowband one, only values of 147 (stoichiometry) have real meaning.

The software will give a warning if the target AFR is set beyond the range of reading of the selected oxygen sensor. In these conditions, the ECU will automatically go to open loop mode.

## 2.9. Fuel and Ignition Maps (Tuning)

The e420c ECU has two fuel and two ignition maps. The fuel and ignition maps can be activated and swapped between by pressing F5. Each of these is a two-dimensional array, with RPM as one independent variable and load (either MAP or TPS) as the other. The entry in the array (represented by the height of the graph) is the injector pulse width, in milliseconds, or the ignition angle, in degrees BTDC.

The keys used to navigate the fuel and ignition maps are shown below:

Key	Function
F5	Swap between the four maps
Cursor keys	Move currently selected cell (cursor)
Space	Move cursor to closest cell to current engine operation condition (load and speed)
Page Up/Down	Increase/decrease fuel duration by 0.1 ms. Increase/decrease ignition timing by 1 degree.
Ctrl PgUp / Ctrl PgDn	Increase/decrease fuel duration by 0.01 ms. Increase/decrease ignition timing by 0.2 degree.
Shift + cursor keys	Select a region of the map (as in Excel)
Number keys and decimal point	Direct entry of new value
Escape	Abort entry of new value
Enter	Confirm entry of new value (will confirm automatically if all digits are entered)

Additionally, the graphic maps have a green line that represents the current load, and a red line that represents the current engine speed. The intersection is the current point in the map being used by the ECU.

Clicking on cell within the text map with the mouse will also move the cursor. Dragging out an area with the mouse will select the bounding rectangle. Right-clicking brings a submenu, which allows the following functions:

- Interpolate: For a single column or single row selection, the values are linearly interpolated between the two endpoints  
For a rectangular selection, the four corners are used and the values interpolated between these
- Select All: Select entire map (for making overall changes)
- Add/Subtract percentage: Add or subtract a percentage value to the selected region. An offset can be added or subtracted using the PgUp/PgDn keys.
- Mark as tuned: Any cell can be marked as tuned or as untuned. This allows the tuner to record which cells have been tuned

and which have not. Whether a cell is tuned or untuned also has significance for the adaptive tuning modes.

If you are unsure of the fuel map of your engine (this will generally be the case), the fuel map should be set up initially in a planar fashion, with the pulsewidth dependent only on the load. That is, all RPM points at the same load point should have the same value. As a first approximation, it is best to start off the map between 0 and 2500 RPM as a linear relation with about 75% to 100% of the maximum pulsewidth at the maximum load (15-20ms on a fully sequential engine that revs to 6000 RPM), and tapering down to 2-4ms at idle condition (around 30 kPa, or 0% TPS).

Once you have the engine idling, you can get a feel for the other load points within that rev range of up to 2500 RPM, and extrapolate these to higher RPMs. This will be explained in greater detail in Section 4.

The ignition timing is harder to test than fuel mixture strength, except for presence of knock at high loads. A flat map of 15° across the board gives fairly conservative ignition timing, however this will reduce power production compared to the optimal, and will increase heat produced inside the engine. In practice, adding an extra 10° or so at full load (arriving at 25°) between 1000 and 3000 RPM, and leaving it at 25° from there upwards, seems to be a good first approximation. Adding some vacuum advance (up to 35° total at 66kPa and below) seems to work well also, although to do it properly one would need to dyno tune the engine to determine the ignition timing that produced maximum torque. This is all highly dependent on the engine. Boosted engines need the ignition retarded substantially when on boost; especially turbocharged high compression engines.

## 3. Starting the Engine

### 3.0. Getting Started

After the ECU has been configured, you can perform some "sanity checks". On turning on the ignition, the sensors should all be verified for reading sensible values. Once this is done, you should try disconnecting fuel from the system (eg unplugging the injectors, disabling the fuel pump, deselecting "Inj" from the trigger setup or similar) and crank the engine. During this time, you should observe a stable and believable RPM while cranking (normally 250 - 350 RPM). Set up a timing light to verify the ignition timing during cranking; it should be as specified in the trigger/output window. If it is not, or the spark does not occur at a consistent angle, you have a triggering problem.

Assuming that is OK, you can try to start the engine. Switch both fuel and ignition into open loop mode. Crank the engine with the throttle closed. Don't be disappointed if it doesn't start first time; they rarely do.

Some things to check when trying to start the engine are:

- Stable and credible RPM reading during cranking
- Stable ignition timing during cranking (check with timing light)
- Fuel pump activated during cranking
- Injectors are all clicking (check with screwdriver or stethoscope)
- All the sensors are reading sensible values (check gauge window)
- All the outputs are giving sensible values (gauge window)

If the timing is a normal amount (around 10°), and the engine never fires, chances are you have far too much fuel, far too little fuel, or something trivial wrong (such as no fuel pressure or stuck injectors).

If the engine fires occasionally but does not start, chances are that it's a fuel mixture problem. Check that the ECU is still in cranking mode during cranking (check the cranking heuristic RPM limits in the Trigger / Output window), and adjust the fuel pulse width in the cranking table in the Control window. Try adjusting it upwards at first. With too much fuel, the engine should start if the throttle is opened.

If the engine fires properly under cranking but stalls very soon (within a second or two) after starting, chances are it's a fuel mixture problem in the map. Given that an engine will still run with about double the "proper" amount of fuel, but will misfire if it's only given 70% or so of its required amount of fuel, it's often safer to increase the mixture in the fuel map. If you have trouble reading all the gauges at once during the time it takes to start and subsequently stall, you can hold down the space bar in the fuel map to see which points it visits, or alternatively log the event to a file and open the log in a spreadsheet. The most expedient method to experiment with fuel amounts is to adjust the master trim value until you have a setting that works, and then to apply this trim to the fuel map.

If you have trouble getting the engine to idle, it may be beneficial to adjust the throttle bypass (or throttle stop, though this may require you to recalibrate your TPS later) so

that it idles higher than it would normally. This condition is usually more forgiving to mistuned fuel maps.

Make sure that you either set the deceleration fuel cut to a fairly high RPM so that it doesn't cut in, or set the minimum coolant temperature for the overrun fuel cut to a very high value (eg 120 degrees).

After a certain amount of experimentation, it should be possible to get the engine to idle, even if it is hunting (idle speed oscillating).

### 3.1. Initial Tuning

The engine hunting at idle is usually due to poor tuning of the fuel map. As it cycles through different parts of the map, it reaches rich parts and lean parts. Inspecting the AFR reading in the gauge window should show the mixture oscillating wildly. If this is not the case, we would expect to see the mixture either too rich all over the range (expect to see 14.2 or less using a factory sensor, or 11.0 using a 4-wire "wideband" sensor) or too lean all over the range (expect 15.3 or more using a factory sensor, or 17.0 using a 4-wire "wideband" sensor). If the mixture is too lean over the entire range, try adjusting the cells the ECU is visiting upwards (page up or type in a new value) to see if it makes a difference. If the AFR reading stays on the lean side, there may be a problem with the EGO sensor (eg: not connected, not heated type running too cold, etc).

The idle is often best tuned by hand to minimise the hunting at idle. Unless it is tuned properly at idle, the engine will hunt. This is due to mixture strength changing in different parts of the map. Some experimentation with the four points closest to the idle condition will be necessary.

Remember that you can artificially load up the engine at idle by applying electrical loads to bring the engine directly to a map point. This will enable you to set that value precisely, and then adjust the load value on the other side of the idle condition.

After tuning the idle condition, the next logical step is to tune the no-load condition. Gradually open the throttle to hold the engine at 1500 RPM, and tune this point. Then do the same for 2000 RPM and so on up the rev range.

The next step is to tune the rest of the fuel map. With the engine still running, perform the following steps:

1. Change the temperature range for the rapid learning mode so that the current water temperature falls within the range
2. Set the minimum RPM required for learning to 1500 RPM
3. Set an AFR proportional constant of 0 and an integral constant of 4
4. Set the maximum integral correction to 8% (if you are using a tailpipe probe, a maximum value of 4% may reduce wild hunting at idle)
5. Set the Rapid Learning RPM tolerance to 150 and the load tolerance to about one third of your load step difference (for example, if your map has points every 6 kPa, set the load tolerance to 2)
6. Set the Rapid Learning initial delay to 150ms, and the interval to 150ms.
7. Set the mode to Rapid Learning.

This is shown below:

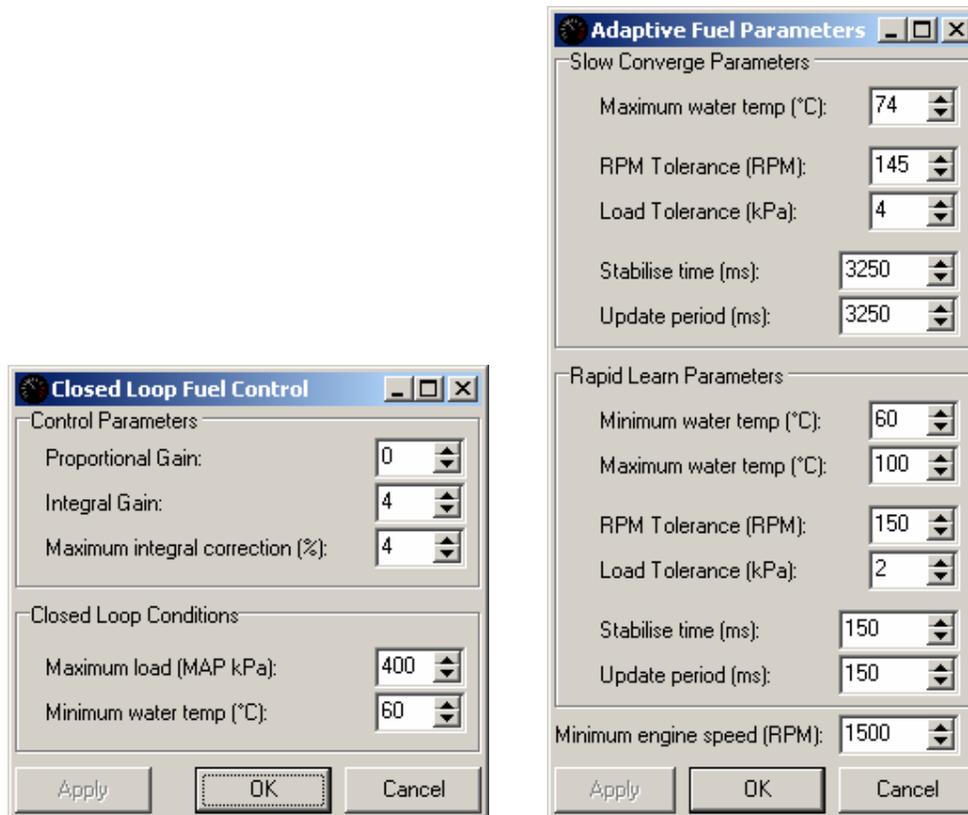


Figure 25: Rapid Learn Settings

Once you have enabled Rapid Learn mode, go back to the fuel map (press F5). You can now attempt to drive the vehicle and see how much of the map has to be changed.

**NOTE: During this time, you would be advised to install a thermometer on a radiator coolant hose or some such place and monitor the engine temperature as it warms up. This should be periodically compared to the water temperature as indicated in the gauge window. If it differs by more than a few degrees, the sensor may need to be calibrated (unless it has already been calibrated rigorously). If the reading is unstable when the engine is running, chances are that you have a ground loop somewhere which should be addressed before you go any further. Ground loops can affect all kinds of sensor readings and can therefore interfere with the tuning process.**

### 3.2. Adaptive Fuel Tuning Explained

There are several conditions that must be met before adaptive fuel tuning will take place. These are all explained in the behavioural section, but are repeated here:

1. The water temperature must be within specified limits;
2. There must be a valid AFR reading (EGO sensor must be installed and configured);
3. One of the adaptive tuning modes must be selected (Rapid Learn or Slow Converge);

4. The minimum engine speed must be exceeded;
5. The ECU must not be in fuel or ignition cut mode.

These constraints are fairly intuitive to the tuner as to whether they are met or not. In addition, there are three other constraints which are not so obvious:

1. The current RPM must be "close enough" to the RPM point in the map;
2. The load value must be "close enough" to the load point in the map;
3. If the ECU has recently moved into a new cell in the map, a certain delay must have expired.

The RPM and load tolerances are configurable in the Control Window. Rapid Learn and Slow Converge have separate RPM and load tolerances. The tolerances range from 0 to half the step size (250 for RPM, and the load step depends on the maximum MAP value).

- Larger tolerances allow the ECU to learn more quickly, simply because the engine spends a larger proportion of the time within the tolerance regions.
- Smaller tolerances allow the ECU to learn more accurately, because the contribution from the adjacent cells is lower when the engine is closer to the load point.

Thus, it is best to start off rough tuning with wide tolerances (say 150 - 200 RPM, and  $\frac{1}{3}$  of the load step), but for normal driving, a lower values are recommended.

Once the engine reaches a new map point, the ECU delays a small amount of time to wait for initial transients to settle before applying the adaptive fuel behaviour. This delay is configurable. Similarly, you can set the interval between fuel map corrections.

- Shorter time delays and intervals allow for more rapid tuning, because the ECU can learn on transient conditions such as hunting at idle.
- Longer time delays allow the Adaptronic to learn more accurately, as any contributions from transient conditions will be minimised.

It is best to start with very small time delays such as 150ms/150ms when initially tuning. During normal driving, once tuned, a delay of 500ms and an interval of 200ms are recommended.

Because it is very difficult to read the gauges on the window and tell at a glance whether or not these tolerances are met, the Adaptronic has special outputs intended to help with tuning. If you configure an auxiliary output as a "Learning - RPM OK" type output, it will be activated when the RPM tolerance is met. Similarly, the "Learning - Load OK" feature can be used to tell when the load tolerance is met. Any output configured as a "Learning - Wait" output will be on during the initial delay period after the ECU changes map cells. Connecting some high speed lights such as LEDs (with series resistors) to these outputs can make tuning much easier.

The adaptive fuel control mechanism is a form of a closed loop controller. The parameters for the closed loop controller can also be configured in the Control window. These are the "proportional constant" and "integral constant" terms:

- High proportional constants lead to fast reactions of the ECU to AFR error.
- High proportional constants lead to large fluctuations in mixture strength.
- High integral constants lead to faster convergence of the mixture strength, both in adaptive modes and normal closed-loop modes.
- Low integral constants lead to less overshoot in mixture strength.
- The maximum integral value, along with the integral constant and proportional constant, controls the maximum amount of trim that can be added by the fuel feedback mechanism.

For initial tuning, the recommended values are:

- Proportional constant: 2
- Integral constant: 4
- Maximum integral: 4% - 8%

For normal driving, with a tuned map, the recommended values are:

- Proportional constant: 2
- Integral constant: 1
- Maximum integral: 4% - 8%

These of course may require some experimentation. For example, you may want to reduce the constants if your EGO sensor is mounted a large distance from the exhaust ports (as on a system with extractors, rather than a normal exhaust manifold).

### 3.3. Further Tuning

If you have opened the idle bypass to increase the idle speed, you should now close it again until the desired idle speed is obtained, and a smooth idle is obtained at this speed. You should now open the throttle further and tune the no-load conditions up to about 2500 RPM.

**NOTE: It may be beneficial to connect up LEDs to show the learning state, as described above.**

**NOTE: If you are having trouble getting the fuel map to converge, here are a few tips that may help:**

- Try using different gain values; if the map is changing too fast and oscillating back and forward, try smaller gain values and/or smaller maximum integral. If the map is not changing at all, try using higher gain values.
- Try using different tolerances. If the map is oscillating (that is, the ECU changes the values one way, then revisits the site and changes them back again), it may help to reduce the tolerances. First try reducing the load tolerance, then the RPM tolerance. If the map is not changing at all, try increasing the tolerances. Try to avoid going above 96 for load or RPM; if the Load OK or RPM OK LEDs are not coming on, you will need to artificially place the engine under that condition (by adjusting the throttle, turning on electrical loads etc).
- Try using different timings. If the map is changing too quickly and oscillating, try using longer delays and intervals.

- You can help the ECU by adjusting the map values by hand to speed up the process. Humans are particularly good at spotting anomalies in the fuel map (especially a graphic map).

Now that the no-load conditions are relatively tuned, once the engine is warmed up, it should be running properly in closed loop mode. That is, the AFR should be oscillating about 14.7, but the engine should be running steadily. Save this map on your laptop/PC!

Now that you know better what the no-load values of the fuel map are, you may want to readjust some adjacent values by hand before putting the engine on a load.

Assuming you have done this, and that you can blip the throttle to raise the revs (at least up to 2500 RPM), the next stage is to do some tuning with a load on the engine. This is best done by leaving the engine at a constant speed, for example 1500 or 2000 RPM, and methodically stepping through the load table, tuning each site at a time.

Here is one approach to do this:

- Set the vehicle up on a dynamometer in speed-hold mode so that the engine speed is very close to the desired point (1500 or 2000 RPM).
- If possible, reduce the RPM and load tolerances to 64 and 2.
- Verify that when the throttle is open and the dynamometer is holding the speed, that the RPM OK light is on solidly and that the RPM shown on the gauge window is very close to the target RPM (vehicle tachometers are not usually accurate).
- Open the throttle just wide enough to allow the RPM OK light to come on solidly.
- Open the throttle slowly until the Load OK light comes on solidly.
- Observe the AFR on the gauge window and the fuel map window. When the AFR starts oscillating about 14.7, and the fuel map stops changing dramatically, that point is finished.
- Open the throttle slowly until the Load OK light goes out, and then comes on again solidly.
- Observe AFR and fuel map again until it stabilises.
- Repeat this procedure until full throttle is reached.

Once this is done, you have a better estimate of the fuel map values for the given load points. Unless you have a good reason not to, it would be advised to copy these values across to the other RPM points for the same load points.

**NOTE: If you find it difficult to get the Load OK light to come on solidly, it is possible that there is a wiring problem with the MAP sensor (such as a ground loop), or that the MAP sensor pick-off point is in a bad location (such as right at the throttle, instead of in the body of the plenum). There is a filter built into the ECU to filter out the effects of pressure fluctuations caused by individual cylinders' induction strokes.**

If you do not have access to a dyno, there is another means of achieving a similar result:

- On a private road, start the vehicle and accelerate up to 2nd gear at 1500 or 2000 RPM.
- Perform the same steps as above, except that you have to perform the speed regulation using some other means (eg finding hills in your private road, left foot braking (**NOTE: this will wear out the brakes**) etc).

Another means, although not as methodical, is as follows:

- On a private road, start the vehicle and accelerate up to the desired engine speed in whichever gear is suitable for the terrain.
- Hold the speed steady by controlling the throttle, over a wide range of load conditions (hills).

This last method is not as methodical as the previous ones because the load sites are not visited in turn and there is no guarantee that any load site has actually been finished, or even visited. If you log the procedure using WARI, you will be able to see the AFR that was achieved, and the load and RPM (and injector pulse width) at the same time.

Once you have a basis for the pulse width as a function of load only, you can copy this to the other RPM points in the fuel map. Then you can continue tuning the other points.

Alternatively, once the values have been copied, you can try driving the vehicle (on a private road) normally and have it tune itself. To speed up the process, you can monitor the three tuning LEDs during driving and try to keep both the OK LEDs on solidly for as high a proportion of the time as possible.

During normal driving, closed loop mode only is recommended:

### 3.4. Ignition Tuning

Ignition timing is a compromise between emissions, torque production and engine safety. The following are some basic guidelines:

- For any given load and speed combination, there is an ignition timing that will provide the optimum torque.
- Firing the ignition after or before this angle will cause a torque reduction.
- Around this peak, the timing is often not very sensitive. For example, at 2000 RPM on one engine a change of 5 degrees around the optimum torque point only corresponded to a torque reduction of 2%
- At higher loads, there will often be an angle at which any greater ignition advance will cause knocking. This may be less advanced or more advanced than the maximum torque point.
- Tuning to the optimum torque peak will often lead to very high NOx emissions.

Based on all these requirements, manufacturers generally tune to a point several degrees retarded from the optimum torque point to control NOx emissions. Sometimes the tuning will be retarded from this point to control knocking.

Often the best means of tuning the ignition timing is the old-fashioned way; adjusting it by hand and observing which gives greatest torque. This is best performed on a dynamometer so that the torque can be measured.

The closed loop and adaptive ignition timing controls are described in the ECU reference section.

## 4. Software

This section contains information on some of the features of the software both (WARI and FlashIt).

### 4.0. WARIVI

#### 4.0.0. General

WARIVI is the software link between the ECU and your computer, to be able to setup anything in the ECU you will need a straight through DE9 serial cable. If you do not have a serial port on your computer, you can use a USB port with a USB to serial adapter and the associated drivers.

Once WARI is installed it can be started, if the WARI window reads no ECU connected then one of the following is happening:

- There is no ECU connected
- There is no power to the ECU
- The serial port selected is incorrect (select at first window)

If everything is connected correctly WARI will begin reading the settings from the ECU. The alternative is to load the settings from a file on the PC.

#### 4.0.1. WARI Menus

The WARI menus offer a number of useful features. Under "File" you can:

- Open a saved ECU file. Take care when using this option, as loading a file will automatically update any connected ECU with the new settings. (shortcut ctrl + O)
- Save the current settings. This should be done periodically during setup of a new ECU, and should also be done if you are about to make any major changes in the settings (shortcut ctrl + S)
- Save as, which will allow you to save the current settings under a different name (shortcut ctrl + A)
- Log data from ECU (shortcut ctrl + L). Click stop data logging when you are done (shortcut ctrl + K), this file can then be opened using Microsoft Excel.
- Exit (shortcut ctrl + Q)

Under the "Port" menu, you can select the COM port to communicate with the ECU. This should only be needed if you entered the program by loading a file. You will know when if the correct COM port was selected as the main screen will show "Status: ECU connected". Under this menu you can also designate the communications protocol, unless you are having problems with communicating with the ECU this should be left as MODbus mode (100ms).

Under the "Maps" menu you can choose to copy from fuel map 1 to fuel map 2 or vice versa, and the same for the ignition maps. This can be useful as a starting point when using two maps.

Under the "Windows" menu you can view the current gauge information which is important for engine tuning and general diagnosis (shortcut F2). This data can also be

displayed in the gauges if you have purchased a Vidigauge (refer to [www.vidigauge.com](http://www.vidigauge.com) or contact us for more info).

Many of the values in the Gauges window are self explanatory. Those that aren't are given below:

**AFR: xx.x (yy.y, zz.z)**

The actual value used by the ECU for the closed loop calculations is given by xx.x. This is taken from the wideband serial input, if connected and operating. Otherwise, the input from the analogue input is used by default. The first figure (characterised by xx.x in the above format) is the value used by the ECU. The second figure (yy.y in the above format) is the value from the analogue input, irrespective of any wideband serial devices connected. The third figure (zz.z) reads "open" if the ECU is currently in open loop mode, or the target AFR if the ECU is in closed loop mode.

**Ign: xx.x (yy.y)**

In normal operation, the two values (xx.x and yy.y) will read the same value, which is the ignition timing in degrees before top dead centre. In rotary mode, the first value (xx.x) represents the timing of the leading plug and the second (yy.y) is the timing of the trailing plug.

**Inj: xx.x (yy.y)**

In normal operation, the two values (xx.x and yy.y) will read the same value, which is the injection duration in milliseconds. In staged injection modes, the first value (xx.x) is the primary injection duration and the second value (yy.y) is the secondary injection duration.

**VVT1 / VVT2: xx.x (yy.y° zz%)**

The first value (xx.x) indicates the angle sensed from the engine offset from the reference value. The second value (yy.y) indicates the angle setpoint interpolated from the VVT target position table. The third value (zz) indicates the duty cycle applied to the VVT solenoid.

To jump to the fuel/ignition maps you can use the fuel/ign option under this menu, or simply press F5. It is also possible to view some of the current technical information by selecting ECU data, (shortcut F11) this can be very useful in diagnosing installation problems.

As a more rigorous method of using the adaptive tuning function of the ECU, open the fast tuner under this menu (shortcut F12), make sure adaptive tuning mode is on (check your settings), and follow the steps on the left. At the bottom left of the screen you will be able to see the points you have already tuned as they turn bright yellow.

Finally the "Help -> About" menu item shows the software version.

## 4.0.2. WARI Settings Management

WARI stores an image of the ECU settings in the PC's memory. This is required to display the ECU settings on the PC screen. To prevent operator confusion, these should be synchronised with the settings in the ECU.

WARI uses the following rules to synchronise the settings:

- Upon loading a file, all settings are marked as needing to be written to the ECU
- At startup of the WARI software, the settings are marked as needing to be read from the ECU (unless the first action is to load a file)
- When a setting is modified, that setting is marked as needing to be written to the ECU

If any settings are marked as needing to be read from or written to the ECU, the status line will indicate "Reading settings (xx%)" or "Updating settings (xx%)", where "xx" is 100% minus the percentage that remains to be written or read (for example, if 99% of the settings have been read and 1% remains, the status indicator will read "Reading settings (99%)").

Any settings on the main form will change and be written automatically as they are changed. Any settings in a dialogue box (a new window which is brought up in front of the main form) will need to have "Apply" selected before the changes are sent to the ECU.

If the ECU is disconnected when the settings are changed, the ECU settings will not be updated until the ECU is reconnected and a connection is re-established.

Also there are a number of shortcuts incorporated into WARI to aid in tuning, refer to section 2.9 fuel and ignition maps for details on these shortcuts.

## 4.0.3. ECU Data Window

The ECU Data Window can be reached using the menu "Windows -> ECU Data". It gives much useful diagnostic information to aid in setup. Below is a screen shot.

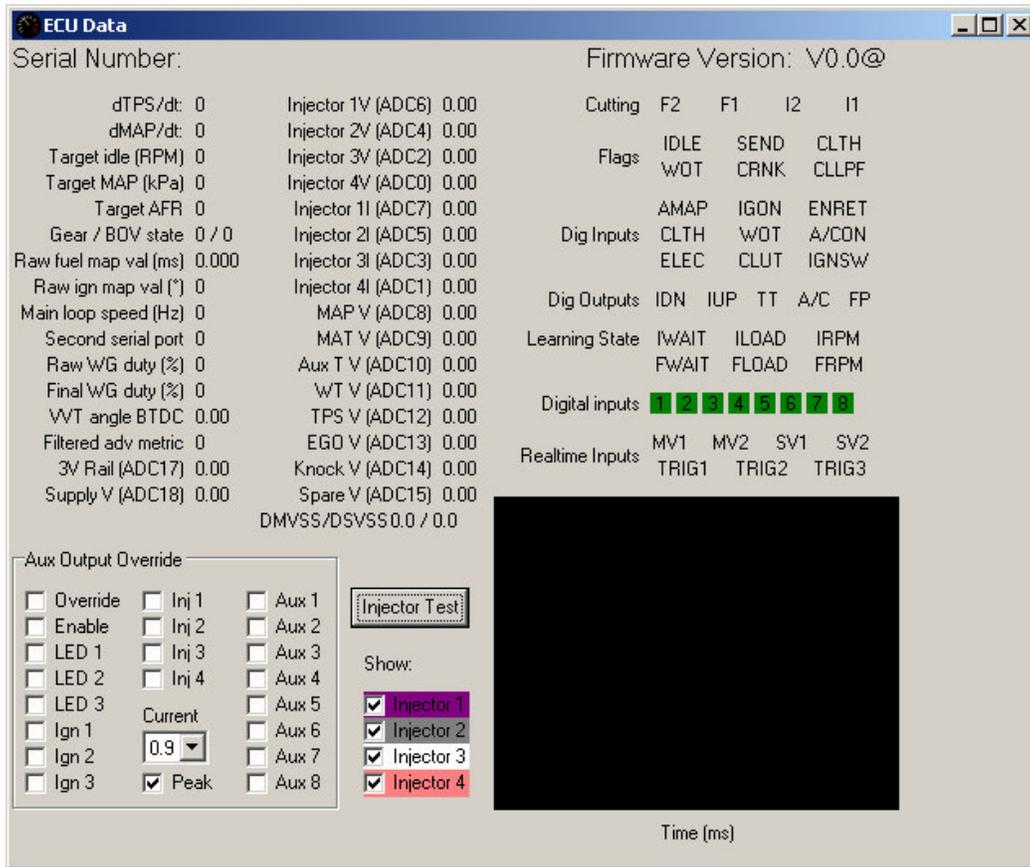


Figure 26: ECU Data Window

Label	Meaning
Serial Number	Serial number of the ECU hardware itself.
Firmware Version	ECU Firmware version loaded into the ECU.
dTPS/dt	Rate of change of throttle position (how quickly throttle is being opened)
dMAP/dt	Rate of change of MAP
Target idle (RPM)	The target idle RPM (see idle function)
Target MAP (kPa)	The target MAP (see boost control function)
Target AFR	The target AFR. If the ECU is currently in open loop mode (due to a setting or a condition), this will not give a reading.
Gear / BOV State	The number before the slash is the detected gear number from correlation of RPM and vehicle speed. The number after is the blow-off valve control state.
Raw Fuel Map Val (ms)	Injector millisecond value interpolated from the fuel map (s), before application of any trims.
Raw Ignition Map Val (degrees)	Ignition degree value interpolated from the ignition map (s), before application of any trims.
Main Loop Speed (Hz)	Speed of main loop calculation (varies with functions selected)
Second Serial Port	State of second serial port (values and their meanings not documented)
Raw WG Duty (%)	Raw wastegate control duty cycle interpolated from RPM dependent table
Final WG Duty (%)	Final wastegate control duty cycle after closed loop control changes. This is the same as on the Gauge window.

VVT Angle BTDC	VVT angle sensed. This is the same as on the Gauge Window.
Filtered Advance Metric	This is the same as on the Gauge Window (Adv).
3V Rail	The measured value of the internal 3V rail within the ECU. Note that the maximum this can read is 3.00V.
Supply V	The supply voltage. This is the same as in the Gauge Window (Batt).
Injector 1-4 V	The voltage sensed at the injector pin on the ECU. This would normally read around 12V when the engine is not running. If this reads 0V, that indicates lack of 12V supply to the injectors.
Injector 1-4 I	The current sensed at the injector output.
MAP V - Spare V	The voltage measured at the analogue inputs of the ECU.
DMVSS / DSVSS	The difference between the two master vehicle speed sensor inputs (only one MVSS is implemented on the e420c), and the same difference for the SVSS inputs.
Cutting : F2 / F1	These show the status of the fuel cuts within the ECU. If one of these is active (green background), every second cylinder has fuel disabled. If both are active, the engine is in a complete fuel cut state.
Cutting : I2 / I1	These behave the same as the F2 and F1 flags except that they correspond to the ignition cut status.
Flags : Idle	When this flag is enabled, the ECU is in closed loop idle state.
Flags : SEnd	This flag is enabled once the ECU has fully opened the idle stepper motor at startup.
Flags : ClTh	This flag indicates that the throttle is closed, either due to an active digital input set as closed throttle or the TPS falling below the closed throttle threshold.
Flags : WOT	This flag behaves the same as ClTh except for the wide open throttle condition.
Flags : Crnk	This flag indicates that the ECU is in cranking mode.
Flags : CLLpF	This flag indicates that the ECU is in closed loop fuel control mode.
Dig Inputs:	These flags indicate when various digital inputs are activated: AMAP (Alternate Map) IGON (Ignition On) ENRET (Enrich / Retard) CLTH (Closed Throttle) WOT (Wide Open Throttle) A/CON (Air conditioner request) ELEC (Electrical load on engine) CLUT (Clutch / Neutral)
Dig Inputs : IGNSW	Ignition switch sensed by input battery voltage
Dig Outputs	These flags indicate when special function digital outputs would be activated if an output were set to that function: IDN (Idle Down, DC motor) IUP (Idle Up, DC motor) TT (Turbo Timer) A/C (Air Conditioner) FP (Fuel Pump)
Learning State	These flags indicate when given conditions are met required for learning: IWAIT (Ignition learning, waiting after changing cell)

	<p>ILOAD (Ignition learning, load is close enough to map point to learn)</p> <p>IRPM (Ignition learning, RPM is close enough to map point to learn)</p> <p>FWAIT (Fuel learning, waiting after changing cell)</p> <p>FLOAD (Fuel learning, load is close enough to map point to learn)</p> <p>FRPM (Fuel learning, RPM is close enough to map point to learn)</p>
Digital inputs	Each of these 8 values correspond to the 8 digital inputs. An active (green background) input indicates one pulled low.
Realtime inputs	<p>Each of these inputs correspond to the realtime inputs:</p> <p>MV1 (Master vehicle speed sensor)</p> <p>MV2 (not implemented on e420c)</p> <p>SV1 (Slave vehicle speed sensor)</p> <p>TRIG1 (Digital or reductor input 1)</p> <p>TRIG2 (Digital or reductor input 2)</p> <p>TRIG3 (Digital or reductor input 3)</p> <p>A background colour of green indicates that the input is high. A colour of red indicates that the input is low. A colour of yellow indicates that the input has been both high and low since the last time the screen was updated. If an input stays green the whole time, that indicates that the input is not being triggered.</p>
Aux Output Override :	If this tickbox is selected, the normal ECU output driving the outputs (including auxiliary outputs, ignition and injector outputs) will be bypassed, allowing manual control of the outputs.
Aux Output Override : Enable	If this tickbox is selected, the outputs of the ECU are enabled. If not, the outputs are disabled, as though the ECU were being reflashed.
Aux Output Override : LED 1-3	These tickboxes allow the operator to have manual control over the LEDs at the end of the ECU.
Aux Output Override : Ign 1-3	These tickboxes allow the operator to have manual control over the ignition outputs of the ECU. An output being selected allows the output to be pulled high by the internal resistor (ie, deselected means the output is low).
Aux Output Override : Inj 1-4	These tickboxes allow the operator to have manual control over the injector outputs of the ECU.
Aux Output Override : Current	This combobox allows the operator to control the current set for the injector outputs in override mode.
Aux Output Override : Peak	This tickbox allows the operator to have manual control over the peak-hold or constant current state of the injector outputs in override mode.
Aux Output Override : Aux 1-8	These tickboxes allow the operator to have manual control over the auxiliary outputs of the ECU.
Injector Test	Pressing this button will perform an injector test by exercising each injector output in turn and monitoring the injector voltage and current. The current is set to that specified in the aux output override pane. The resulting waveforms are graphed in the black area. Each injector trace can be enabled or disabled by the tickboxes underneath the Injector Test button.

## 4.1. FlashIt

**Note: Firmware upgrades can only be performed when the engine is not running. Reprogramming firmware should not be done lightly. This is why it is a separate program, rather than being integrated with WARI.**

During the firmware upgrade process, the auxiliary outputs will be in the "off" state. The ignition outputs will be "high impedance": under normal operation they are electrically the same as an open collector output pulled to 12V via a 560 Ohm resistor, and during flashing this open collector transistor is switched off and the 12V supply to the resistor is disabled.

To upgrade the firmware of an Adaptronic ECU, you will need to run the FlashIT software first, then select the COM port of the ECU. The software will then display "No comms with ECU. Connect and reset the ECU". The ECU should then be powered up (or powered down then up again) while FlashIt is still running. The software should then display "ECU connected" and a boot/hardware version string and ECU serial number.

Next the firmware should be loaded into FlashIt. The latest version can be downloaded from the website. It will be in the form of an encrypted "adf" file. The "Load" button on the FlashIt window should be clicked, and the firmware file should be loaded. Once the file has been loaded, the ECU can be programmed by clicking the "Program" button. After this completes, the programming should be verified by clicking the "Verify" button. If there were no errors, the programming operation was successful.

Clicking the "Run" button will cause the ECU to exit programming mode, and revert to normal operation. Upon clicking this button, the software will revert to the "No comms" message, because the ECU is no longer able to be programmed (until it is reset).

To resume normal operation, close the FlashIt window and run WARI.

## 4.2. Specifications

Physical	
Connectors	Two RS232 connectors (PC and auxiliary), one 16-way and one 20-way connector for low current sensors and outputs, one high current 8-way SIP connector for power and injectors, one 6-way SIP high current connector for high current outputs
Physical Dimensions (mm)	147 x 93 x 48
Mass	0.4 kg

Sensor Interfaces	
Crank angle sensor type	3 programmable inputs, configurable as triggering ignition timing, injector drive, ignition timing during cranking, or cylinder 1 marker, configurable as crank or cam trigger (360° or 720° or the period), optional input divisor and missing tooth detection
Crank angle trigger waveforms	Sync / trigger / multitooth / missing tooth, programmable angles up to 30 teeth per period (120 tooth cam wheel).
Manifold absolute pressure input	0 - 5V, 2-point linear calibration, range 0 to 400 kPa (requires external sensor, 5V supplied by ECU)
Air, water and aux temp inputs	4k7 pull-up (requires separate thermistor connected to ground), 32-point linearly interpolated calibration, range -30°C to 125°C
EGO input	0 - 1V factory narrowband, or Bosch "wideband" - input impedance 10MΩ, UEGO style analogue, M&W LSU4, TechEdge and Innovative LC-1 serial interface
Knock input	High impedance input, bandpass filtered
Throttle position input	20kΩ input impedance, 0-5V (5V supplied by ECU), 2-point calibration
Auxiliary digital inputs	8 inputs, each configurable as active-high or active-low, internal pull-up
Actuator Interfaces	
Number of injector drivers	4
Injector driver waveforms	Full sequential, batch, semi-sequential every period, or semi-sequential every second period, optional batch fire during cranking
Injector driver current	Optional constant current or peak-hold drive, selectable steady-state current of 0.5A, 0.9A, 1.5A or 1.9A
Number ignition outputs	3
Ignition output waveforms	Selectable as firing on rising edge or falling edge, both ignition outputs at once, alternating outputs or sequential.

Ignition output type	Open-collector with 560Ω pull-up (allows direct connection to OEM transistor or separate ignitor)
Number of auxiliary outputs	8 (4 high-current, 4 low-current)
High current outputs	Max current 7A (or 3A inductive), 3 of these PWM capable, PWM frequency selectable (25Hz - 2kHz)
Low current outputs	Max current 200mA - suitable to drive relay coils
<b>Control Characteristics</b>	
Map points	512 - every 200, 250, 300 or 500 RPM (0 - 6200 / 7750 / 9300 / 15500 RPM) and 1/15th of maximum load (TPS or MAP)
Load determination	TPS, MAP or several combinations thereof. Two maps to allow selection of alternate map if only single load source is load.
Injector pulse width resolution	0.7μs (0 - 44ms)
Ignition resolution	0.2° (0 - 51°)
Dwell time resolution	0.1ms (0.1ms - 5ms)
Accelerator pump	TPS or MAP based (configurable proportionality), and asynchronous RPM based pump
Fuel control strategies	Open loop, closed loop, and two adaptive modes (requires EGO sensor)
Ignition control strategies	Open loop and closed loop (requires knock sensor)
Main loop speed	200Hz approx (depends on number of sensors, fuel and ignition tuning mode and control policies in use)

## 5. ECU Operation

### 5.0. Introduction

This section describes the behaviour of the ECU. This can be skipped over and used merely as a reference, however it is important information so has been presented here rather than as an appendix.

The basis of the ECU operation can be summarised into three parts:

1. Reading inputs
2. Performing calculations, control policies and special behaviour
3. Driving outputs

### 5.1. Reading Inputs

#### 5.1.0. Analogue Inputs

The analogue inputs are read as voltages from the connector pin using a 12-bit ADC. These are then converted to the actual gauge measurements used in the ECU calculations.

#### 5.1.1. Temperature Inputs

The temperature sensor inputs are pulled up to an internal 3V rail through a 4.7 k $\Omega$  resistor. The input is also filtered using a 100nF capacitor to 0V, to reduce high frequency noise.

The temperature is calculated by linearly interpolating the measured ADC value (from 0 to 4095, corresponding to 0V to 3V) between the temperature points specified in the analogue sensor calibration table.

Temperature (°C)	ADC Value	Temperature (°C)	ADC Value
-30	3200	50	605
-25	3200	55	514
-20	3200	60	422
-15	2975	65	384
-10	2750	70	347
-5	2525	75	330
0	2300	80	320
5	2054	85	210
10	1809	90	200
15	1564	95	143
20	1318	100	100
25	1148	105	100
30	978	110	100
35	883	115	100
40	788	120	100
45	696	125	100

**Table 1:** Example temperature table

As an example, suppose the input voltage on the water temperature sensor input is 1.5V. The ADC reading will be  $4095 * (1.5 / 3.0) = 2047$ . The calculated temperature will therefore be  $10^{\circ}\text{C} - (2047-1809)/(2054-1809)*(5^{\circ}\text{C}) = 6.1^{\circ}\text{C}$ .

If the ADC value is less than 40 or greater than 4055, that temperature sensor input is declared as invalid, and that input will have no reading.

If the measured voltage is outside the range in the table, but still within the acceptable range of 40 - 4055, the reading is clipped rather than extrapolated. In the above example, a reading between 40 and 100 will always read a temperature of  $125^{\circ}$ , and between 3200 and 4055 will always read a temperature of  $-30^{\circ}$ .

### 5.1.2. 0-5V Inputs (TPS, MAP and Ext)

To scale the 0-5V range into the 0-3V range, the input circuitry multiplies the voltage by 11/21. From the outside of the ECU, the input looks like a 21 k $\Omega$  resistor to 0V. There is again a 100nF capacitor decoupling the input to reduce high frequency noise.

The Ext input is used as an alternative for analogue oxygen sensor inputs and as a general purpose 0-5V input.

The TPS input is linearly interpolated in the same way as the temperature reading above, however there are only two ADC values, fixed at 0% throttle and 100% throttle.

<b>0% ADC reading</b>	327
<b>100% ADC reading</b>	2609

**Table 2: Example TPS calibration values**

Let's assume we have a voltage of 2V at the wiper of the TPS. This will be multiplied by 11/21 at the ECU input, giving a voltage of 1.048V. This will give an ADC reading of  $1.048/3 * 4095$ , which is 1430. Using the above calibration values, this will correspond to a TPS value of  $(1430-327)/(2609-327)*100\% = 48\%$ .

As with the temperature sensor, an ADC reading less than 40 or greater than 4055 will correspond to an invalid reading (or no TPS connected), and will mean that there is no TPS reading by the ECU. In the above example, a reading between 40 and 327 will always correspond to 0% throttle, and 2609 to 4055 will correspond to 100%.

Within the ECU, there are two flags indicating throttle position extremes (one for closed throttle, one for full open throttle). The closed throttle flag is activated when the TPS value is *less than* the closed throttle threshold. For example, if the closed throttle threshold is set to 1%, the ECU will consider the throttle is closed when the TPS is 0% only. If the closed throttle threshold is set to 0%, the TPS can not activate the closed throttle flag. The same condition occurs with the full throttle threshold.

The closed and full throttle flags can also be set by digital inputs. If any digital input is set to be a closed throttle input and that input is active (pulled to 0V if active low, or greater than 3V if active high), the closed throttle flag will also be set, irrespective of the TPS reading. The same applies for the full throttle condition. This allows the user to use a 4-wire TPS with an inbuilt switch (often the switch is slightly more sensitive than the pot) for closed throttle detection, or it allows use of a throttle switch

and maintain features such as idle control, flat shift and throttle-off fuel cut without a potentiometer based TPS.

The MAP sensor input is electrically the same as the TPS input. The calculations performed by the ECU are similar, except for two differences. The first is that the MAP sensor input has a large amount of filtering performed in the firmware. This helps maintain faithful fuel metering despite air pulsations within the inlet manifold. This is often required if there is no physical damper on the pressure line for the MAP sensor.

The second is that the minimum and maximum values can be set by the user over the range from 0 kPa to 400 kPa. This allows up to a 4-bar MAP sensor to be installed and read accurately. A higher pressure MAP sensor could be used however the ECU would not sense any pressure above 400kPa.

Again, the interpolation is clipped once the bounds of the ADC calibration values are exceeded, and the thresholds of the detection of sensor or wiring failure are the same as the other analogue inputs.

	<b>Pressure</b>	<b>ADC Reading</b>
<b>Lower value</b>	16	111
<b>Upper value</b>	200	3450

**Table 3: Example MAP sensor calibration table**

In the above example, let us assume there is a 4V output from the MAP sensor. This will correspond to an ADC count of 2860. This will then mean a pressure of  $16+(2860-111)/(3450-111)*(200-16)$  kPa = 167 kPa.

The external input also has upper and lower bounds in a similar manner to the MAP sensor however the range of the external input is much greater.

### 5.1.3. Oxygen sensor input and Air-Fuel Ratio

#### 5.1.3.0. Introduction

There are two basic sources of air-fuel ratio measurement. One is an analogue input on the EGO input while the other is via serial communications from the auxiliary ECU serial port.

The analogue input looks like a 10 M $\Omega$  resistor in parallel with a 100nF capacitor to 0V. It can accept an input in the 0V - 3V range.

The following sections show the calculations performed to obtain the AFR from the oxygen sensor voltage, depending on the mode selected.

Note that if a serial-connected wideband oxygen sensor is selected and connected, the AFR from it overrides the AFR calculated from the analogue input. This allows the installer to configure the ECU with a standard oxygen sensor, tune it using his/her wideband probe of choice and then disconnect the wideband probe without changing any wiring.

### 5.1.3.1. Oxygen sensor input: None

The AFR is set to "invalid".

### 5.1.3.2. Oxygen sensor input: OEM, Narrow Band

The AFR is set to "invalid" by default. When the sensor consistently provides a voltage greater than 0.22V, the ECU considers that the sensor has warmed up sufficiently and is producing valid output voltages. From then on, the input is interpolated according to the following table:

	<b>Voltage</b>	<b>AFR Reading</b>
<b>Lower value</b>	0.0	15.5
<b>Upper value</b>	1.0	14.0

**Table 4: Calibration table used by the ECU in OEM Narrow Band mode**

In practice, the actual AFR will vary by a much narrower range than this over this voltage range, however for operating an engine at stoichiometry, the control algorithm works effectively.

### 5.1.3.3. Oxygen sensor input: UEGO 0-3V

This mode assumes that following calibration:

	<b>Voltage</b>	<b>AFR Reading</b>
<b>Lower value</b>	0.0	10.0
<b>Upper value</b>	3.0	20.0

**Table 5: Calibration table used by the ECU in UEGO 0-3V mode**

This mode can be used in conjunction with a 0-5V linearised wideband oxygen sensor, provided a separate voltage divider is wired in (see the section on wiring the oxygen sensor). Many aftermarket wideband sensors have a programmable output which can be set up in this way. However with this mode there is no detection of a sensor not being up to operating temperature.

### 5.1.3.4. Oxygen sensor input: Bosch Wideband 0-1V

This mode was intended for the 0258 104 002 Bosch sensor. The following calibration table is used:

	<b>Voltage</b>	<b>AFR Reading</b>
<b>Lower value</b>	0.36	17.0
	0.84	13.0
<b>Upper value</b>	0.88	11.0

**Table 6: Calibration table used by the ECU in Bosch 0-1V mode**

This mode also has no detection of the state of the sensor, so may read lean for the first minute or so as it heats up. Care should be taken when installing this sensor; there have been reports that if it is mounted directly in the gas stream, the voltage output will reduce as the exhaust velocity increases, leading to a leaner reading.

### 5.1.3.5. Oxygen sensor input: Zeitronix (0.4 - 3V)

This mode was intended for the Zeitronix wideband lambda sensor. The following calibration table is used:

	<b>Voltage</b>	<b>AFR Reading</b>
<b>Lower value</b>	0.4	10.0
	1.1	11.0
	2.5	14.7
<b>Upper value</b>	3.0	19.0

**Table 7: Calibration table used by the ECU in Zeitronix mode**

Below 0.4V, it is assumed that the sensor is disconnected or an invalid value, and so the AFR reading is invalid.

### 5.1.3.6. Oxygen sensor input: UEGO 0-5V on spare input

This mode assumes that following calibration:

	<b>Voltage</b>	<b>AFR Reading</b>
<b>Lower value</b>	0.0	10.0
<b>Upper value</b>	5.0	20.0

**Table 8: Calibration table used by the ECU in UEGO 0-3V mode**

This mode can be used in conjunction with a 0-5V linearised wideband oxygen sensor, provided a separate voltage divider is wired in (see the section on wiring the oxygen sensor). Many aftermarket wideband sensors have a programmable output which can be set up in this way. However with this mode there is no detection of a sensor not being up to operating temperature.

### 5.1.3.7. Second Serial Port: M&W UEGO LSU4

When polled, the M&W UEGO LSU4 gives the AFR calculated for petrol and a metric of the sensor temperature. When the ECU is set to this mode, it sends the poll request every 88ms to the second serial port. If it receives a valid response, which requires the sensor to be warmed up, the AFR read from the UEGO overrides any value calculated from the analogue input. If there is no response, the value calculated from the analogue input is used.

### 5.1.3.8. Second Serial Port: TechEdge WBO2 2C0

The TechEdge 2C0 uses their propriety frame format version 2, which sends out data uncommanded. By configuring the device, the user can set the minimum and maximum air fuel ratios. By default, these are 9.0 and 19.0. To use this device, In the ECU settings for the second serial port, the TechEdge device must be selected, and the minimum and maximum AFR x 10 must be entered as the two parameters (eg 90 and 190 for 9.0:1 to 19.0:1). Again, if there is no data from the 2C0 device for a given period of time, the value calculated from the analogue input is used instead.

### 5.1.3.9. Second Serial Port: Innovative Motorsports LC1/LM1

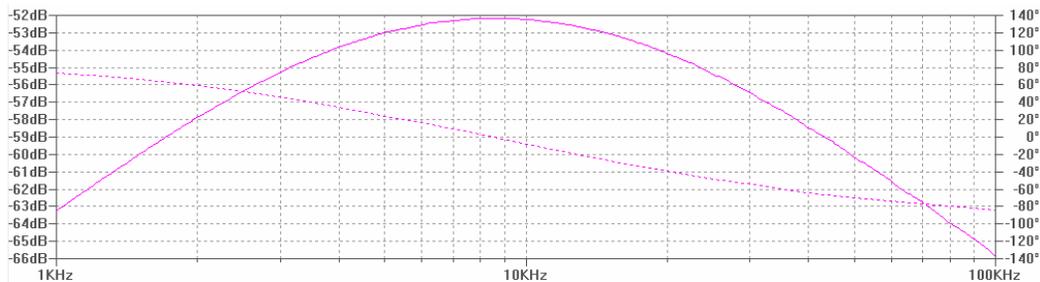
The Innovative Motorsports system uses a propriety frame format, which sends out data uncommanded. To use this device, in the ECU settings for the second serial port, the Innovative Motorsports device must be selected. Again, if there is no data from the LM1/LC1 device for a given period of time, or the packet indicates that the sensor is not yet warmed up or calibrated, the value calculated from the analogue input is used instead.

### 5.1.3.10. Second Serial Port: FJO (Beta version in 1.0I)

The FJO gives the AFR indication in ASCII format. The wideband input overrides the analogue input as with the other serial input types.

### 5.1.4. Knock Sensor Input

The Knock sensor input is first buffered, then fed into a bandpass filter/amplifier. The frequency response is given below:



**Figure 27: Response of Knock Filter**

The output of this filter is then envelope detected and fed into the ADC input. This is then sampled by the microcontroller to detect stationary signals (due to normal engine noise and vibration) and genuine knock (which makes spurious signals above that generated by normal engine vibration).

### 5.1.5. Digital Inputs

There are eight digital inputs, which can be setup under the tab Aux in. Each has a weak pull-up of 100 k $\Omega$  to the internal 3V rail, and a series resistor of 3.3 k $\Omega$  to protect the input. The inputs are 12V tolerant, and can be connected directly to electrical loads such as headlamps, or directly to an input that switches to ground (for example a power steering pressure switch). If the input is a switched positive line with no load connected, the input will always read "high". In this case, an external pull-down resistor must be connected so that when the input is disabled, it reads a low voltage. A 1 k $\Omega$  resistor to 0V will accomplish this.

Each input can be selected as active high or active low. The default is active low, as generally switches are connected to 0V on one side, and the ECU on the other side.

Each input also needs its function to be selected. If multiple inputs are selected as the one function, they are logically OR-ed together.

The following table gives an example of this behaviour:

	<b>Input 1</b>	<b>Input 2</b>	<b>Input 3</b>	<b>Resultant Electrical Load decision by ECU</b>
<b>Type</b>	Electrical load	Electrical load	Electrical load	
<b>Sense</b>	Active High	Active Low	Active Low	
<b>Comment</b>	Connected to headlamp (so will read 0V when headlamp is off)	Connected to blower switch, which connects to 0V when blower is enabled	Connected to power steering switch, which connects to 0V when power steering pump draws power from engine	
<b>Scenario 1</b>	High (headlamp on)	High (blower off)	High (power steering off)	True (electrical load is on)
<b>Scenario 2</b>	Low (headlamp off)	High	High	False (no electrical loads)
<b>Scenario 3</b>	High	Low (blower on)	High	True
<b>Scenario 4</b>	High	High	Low	True
<b>Scenario 5</b>	Low	High	Low	True

**Table 9: Example of OR-logic on electrical load inputs**

If no input is configured for any given function, that input is considered to be false. For example, if no input is configured as a clutch/neutral switch, the ECU will always consider the vehicle to be in-gear with the clutch engaged.

The input configurations for closed and full throttle are discussed in the TPS section. The ECU will consider the throttle closed if the TPS is below the "closed threshold" (typically 1%), or if a digital input configured as "Closed throttle" is active. The same goes for the full throttle condition, except that the TPS must be above the "full throttle threshold" (typically 98%) or a digital input configured as "Full throttle" must be active.

The possible auxiliary input types are as follows:

- Clutch : Used as a trigger to enable the idle control or for flat shifting.
- Electrical Load: Used as a trigger to increase idle effort and target idle speed.
- A/C switch: Used as a trigger to increase idle effort and enable A/C output
- WOT switch: Used as a trigger for flat shifting, to disable the A/C or flood clear.
- Closed Throttle Switch: Used as a trigger enable the idle flag and deceleration fuel cut.

- Enrich/Retard Switch: Used as a trigger to a fixed fuel enrichment and ignition retard (for example when using nitrous oxide)
- Ignition switch: Used as a trigger to cut power to injectors and ignition output if the ECU has permanent power.
- Turbo Timeout cancel: Used as a trigger to abort the turbo timeout.
- Alternate fuel ignition map: Used as a trigger to select the alternate fuel and ignition map, e.g. a power/economy switch, for different fuels, or for different tunes e.g. circuit vs drag racing.

### 5.1.6. RPM and Triggering

Each trigger channel input has two modes of activation; a retractor (analogue) input and a digital input. The retractor input includes an adaptive threshold to reduce false triggering, and pulls the digital input low when it detects a rapid drop in the input voltage. This also has a large amount of filtering to reduce effects of ignition noise from the distributor, on vehicles with a distributor fitted.

The digital input is held high through an internal pull-up of 1 k $\Omega$ , and is then filtered by a 3.3 k $\Omega$  in series with a 470 pF capacitor. When the Hall Effect or photodiode is triggered, it pulls this input low. The input then returns to a high state at the end of the trigger.

Because the retractor input pulls the digital input low when triggered, the input must be selected as a negative/falling digital/retractor input to operate correctly with a retractor pickup.

Each trigger event is flexible in its function, as to whether it represents cylinder phase information or triggers an ignition/injection event. This is explained in the ECU setup section of this manual.

While trigger events still occur, the ECU will consider that the engine is still running. This will be the case even if trigger events occur on an input which is not selected to perform any function.

A trigger event resets the fuel pump timer to keep the fuel pump running. Once this timer has elapsed, the fuel pump is stopped and the RPM is set to zero.

While the engine is running, the RPM is calculated by measuring the time difference over a "period". This period is the angle between ignition and injection events, and for a four stroke engine is 720° divided by the number of cylinders (180° for a four cylinder, four-stroke engine). This is averaged over the previous two periods, that is, one revolution on a four-cylinder engine, to reduce noise.

The ECU has a flag for whether it considers the engine to be in a "cranking" mode or not. This flag is set when the RPM falls below "Min Run RPM", and is cleared when the RPM rises above "Max Crank RPM".

For information on the specific settings i.e. cam/crank/etc, divide, trail, VVT, special system, and general timing settings refer to section 2.0 Basic setup.

### 5.1.7. Vehicle Speed Sensing

There are two vehicle speed sensors inputs (master vehicle speed sensor 1, and slave vehicle speed sensor 1). Both are electrically the same as the digital trigger inputs. Vehicles will usually have a reed switch or Hall Effect switch that shorts to ground, generating a pulse train as the wheel rotates.

The ECU measures the period between pulses, this is then divided into the number given by the user to arrive at a number proportional to road speed.

If the ECU receives no pulses in a one second period, the speed for that input is set to zero.

Under gear options, the user can set the ratio between rpm and road speed, to do this enter the road speed that correlates to 1000rpm in the appropriate gear, the tolerance the ECU will allow for it to be in each gear is set below. This information can then be used to alter shift light outputs depending on gear, alter maximum MAP and duty, etc (none of which is currently available)

### 5.1.8. Supply voltage

The supply voltage is sensed at the input to the ECU. Note that this may read lower than the actual battery voltage due to voltage drops in wiring, fuses and switches in the vehicle.

## 5.2. Calculations, Control Policies and Special Behaviour

### 5.2.0. Introduction

This section describes calculations and special behaviour performed by the ECU. This is intended so that installers have a thorough understanding of how the ECU operates and exactly what each of the settings refers to.

#### 5.2.1. Fuel Calculation

All fuel values in the fuel map, cranking tables and asynchronous accelerator pump correspond to the injection duration in milliseconds.

In calculating the fuel to send to the injectors, the first step is to ascertain whether to read the cranking table or the fuel map. This is based on whether the engine is cranking or not (see section on RPM calculation).

If the ECU is in cranking mode, the water temperature is consulted. If there is no water temperature available, a value of 27° is assumed. This value is then used to look-up and interpolate the appropriate crank pulse width from the table, if batch fire during cranking is selected then it will continue to fire in batch mode until the cranking flag is dropped.

If while cranking, the engine does not start in a certain number of counts, or the throttle is at WOT, the fuel pulse width is changed to the override value, specified on the Power Cut tabsheet. This only occurs if the feature is enabled.

Otherwise, if the engine is not in cranking mode, the fuel pulse width is looked up from the fuel map based on RPM and load. The method for the calculation is dependent on the tuning mode selected. The options are explained in the upcoming section "Tuning Modes".

The calculated "trim value" (in %, refer to sections 2.2.4 for more information) is then applied to this fuel amount (only when NOT in cranking mode) and this final figure is applied to the injectors.

NOTE: This is the calculated fuel value. It may be the case that the fuel has been cut for some reason, in which case there will be no fuel delivered. The calculated value remains, however there is no fuel applied.

### 5.2.2. Ignition Calculation

When in cranking mode, the ignition figure is taken from the Crank Timing (° BTDC) (on the Corrections tabsheet). Note that the ignition angle in the gauges will read this value when cranking, even if a special "ignition crank" trigger input is enabled. Note that the timing lock option (see Basic Setup tabsheet) does not apply when the engine is in cranking mode.

When the engine is running, the ignition figure is taken from interpolation of the ignition map, as the fuel is taken from the fuel map. The "ignition trim" is calculated from the following inputs:

- Master ignition trim
- Digital input retard, if an input configured as such is currently active
- Coolant temperature based ignition trim
- Air temperature ignition trim
- Knock sensing retard

If the timing lock is enabled (see Basic Setup tabsheet), the calculated value is replaced with the timing lock value.

If the ignition output pattern is set to rotary mode, ignition output 1 becomes the trigger for the leading plug and ignition output 2 becomes the trigger for the trailing plug. The ignition timing value calculated corresponds to the timing of the leading plug. The spark split, defined as a function of load and RPM in the Basic Setup tabsheet, is subtracted from the leading plug ignition angle to arrive at the trailing plug advance angle. This is clipped at TDC, meaning that if the split would cause the trailing plug to be fired after TDC, it will instead fire at TDC.

Note: The ignition may be cut at some stage (see Power Cut tabsheet), however this value will still be calculated.

### 5.2.3. Tuning Modes

The RPM increment in the fuel and ignition maps is variable. Currently it can be selected as 200, 250, 300 or 500 RPM steps, with the spaces between steps interpolated. Smaller step size means greater tuning resolution, but increases tuning time and limits the maximum tunable RPM. The maximum RPM is merely the step size multiplied by 31, as in the table below:

<b>RPM Size</b>	<b>Max Tunable RPM</b>
200	6200
250	7750
300	9300
500	15500

**Table 10: Maximum tunable RPM using different RPM step sizes**

Regarding load sensing, there are several different tuning modes that the ECU can use. These are configured in the Analogue setup page. They are described below:

#### 5.2.3.0. 1 = MAP, 2 = unused

In this mode, the load is sensed from the MAP sensor. The lowest load in the map corresponds to 0 kPa, and the maximum load is set in the "Tuning mode" pane of the Analogue tabsheet. The value is looked up directly from Fuel Map 1 and Ignition Map 1. Fuel Map 2 and Ignition Map 2 are not used. If no MAP value is available, the maximum value is assumed.

#### 5.2.3.1. 1 = MAP (default), 2 = TPS (fallback)

This mode is the same as "1 = MAP, 2 = unused" except that if the MAP value is not available, the TPS is read and the second fuel and ignition maps are consulted. Hence in this mode, the first fuel and ignition maps are a MAP map, and the second are a TPS map. The TPS map is only used as a fallback option if the MAP value is unavailable (eg, due to sensor failure).

#### 5.2.3.2. 1 = MAP (fallback), 2 = TPS (default)

This mode is the same as "1 = MAP (default), 2 = TPS (fallback)" except that the TPS map (fuel and ignition maps 2) is the default map that is consulted when both sensors are operational. The MAP map is a fallback option, only used when the TPS value is unavailable.

#### 5.2.3.3. 1 = MAP, 2 = TPS, max (MAP, TPS)

In this mode, both the MAP and TPS sensors are used. The MAP sensor reading is used in conjunction with fuel and ignition map 1 to obtain the fuel and ignition from Table 1 (MAP). The TPS reading is used with fuel and ignition map 2 to obtain the fuel and ignition from Table 2 (TPS). These two values for the fuel quantity are compared, and the greater of the two is used. Similarly, the greater of the two ignition values is used.

#### 5.2.3.4. 1 = MAP, 2 = TPS, avg (MAP, TPS)

This is the same as "1 = MAP, 2 = TPS, max (MAP, TPS)" in that both MAP and TPS are used in conjunction with both fuel and ignition maps, however instead of the greater of the two values being used, the average of the two is used.

#### 5.2.3.5. 1 = MAP, 2 = TPS, min (MAP, TPS)

This is the same as "1 = MAP, 2 = TPS, max (MAP, TPS)" in that both MAP and TPS are used in conjunction with both fuel and ignition maps, however instead of the greater of the two values being used, the smaller of the two is used.

#### 5.2.3.6. 1 = MAP, 2 = TPS, MAP + TPS

This is the same as "1 = MAP, 2 = TPS, max (MAP, TPS)" in that both MAP and TPS are used in conjunction with both fuel and ignition maps, however instead of the greater of the two values being used, the sum of the two is used.

#### 5.2.3.7. 1 = unused, 2 = TPS

The TPS is consulted, and the fuel and ignition map 2 are used to determine the fuel and ignition quantity. The low end of the map corresponds to TPS = 0%, whereas the high end corresponds to TPS = 100%. If no TPS value is available, a value of 100% is assumed.

#### 5.2.3.8. 1 = MAP, 2 = TPS, use MAP if TPS = 0

In this mode, fuel and ignition map 1 are used in conjunction with the MAP sensor, if the engine is in the closed throttle state (a digital input of type "closed throttle" is active, or the TPS reading is less than the closed throttle threshold). Otherwise, the second map is used in conjunction with the TPS.

#### 5.2.3.9. 1 = MAP, 2 = MAP, use Digital Input to select #2

In this mode, both sets of maps are configured as MAP based tables spanning 0 kPa to the maximum set. Map 1 is used unless a digital input, selected as "Alternate fuel/ignition map" is active. In that case, Map 2 is used instead (still using the MAP sensor).

#### 5.2.3.10. 1 = TPS, 2 = TPS, use Digital Input to select #2

In this mode, both sets of maps are configured as TPS based tables spanning 0% to 100%. Map 1 is used unless a digital input, selected as "Alternate fuel/ignition map" is active. In that case, Map 2 is used instead (still using TPS).

#### 5.2.3.11. 1 = MAP, 2 = TPS, use Digital Input to select #2

In this mode, Map 1 is configured as a MAP based map, and Map 2 is configured as a TPS based map. Map 1 is used, in conjunction with the MAP sensor, unless a digital input, selected as "Alternate fuel/ignition map" is active. In that case, Map 2 is used instead (using TPS).

#### 5.2.3.12. 1 = MAP, 2 = TPS, MAP x TPS

This is the same as "1 = MAP, 2 = TPS, max (MAP, TPS)" in that both MAP and TPS are used in conjunction with both fuel and ignition maps, however instead of the greater of the two values being used, the product of the two is used.

## 5.2.4. Fuel Trim Calculation

### 5.2.4.0. Introduction

There are many components that together make up the fuel trim. They are simply added together to arrive at the final trim value, which is then applied to the injectors. These will now be described.

#### 5.2.4.1. Master Trim

The master trim is found in the Corrections tabsheet. It provides an overall trim control. This should be zero, however non-zero numbers can be useful for quickly determining power gains by enriching or enleaning the mixture.

#### 5.2.4.2. Water Temperature

The water temperature is measured. If no water temperature value is available, a value of 27° is assumed. This is interpolated from the coolant enrichment table (see Corrections tabsheet), and contributes to the trim value.

#### 5.2.4.3. Air Temperature

The air temperature is measured. If no air temperature is available, no correction based on air temperature is performed. Otherwise, the trim is adjusted by the value interpolated from the "air temp correction" table.

#### 5.2.4.4. Short Post-crank

During cranking, the fuel value is read directly from the cranking table and no corrections apply. However, most engines need a large amount of enrichment shortly after they fire to avoid stalling. Typical values would be 30% and 3 seconds. This additional trim value begins when the engine transitions from "cranking" to "running" mode, and is linearly decreased to zero over its duration. For example, if it is set to 30% and 3 seconds, the trim addition would be 30% at first, then 20% 1 second after firing, 10% 2 seconds after firing and then no additional trim from 3 seconds onwards. The values for this are found on the Corrections tabsheet

#### 5.2.4.5. Long Post-crank

The long post-crank behaves the same as the short post-crank correction above, however it gives a longer time-scale. This helps avoid problems such as vapour lock, fuel and air heat-soak and so on. Many engines do not need this. It is also found on the Corrections tabsheet.

#### 5.2.4.6. Transient Throttle

There are two possible sources of acceleration enrichment. One is MAP, the other is TPS. The time-derivative of each of these variables (how quickly each is increasing) are multiplied by the appropriate numbers in the settings (again, in the Corrections tabsheet). This is then fed into a peak-hold algorithm, which allows the enrichment to occur once the throttle has reached its final position. This enrichment also decays linearly over the prescribed time period, and can be seen by the trim value changing as the throttle is quickly applied.

Once the TPS exceeds the TPS cutoff value, no additional enrichment is applied. Similarly, once the MAP exceeds the MAP cutoff value, no additional enrichment is applied.

As well as acceleration enrichment, the ECU also supports deceleration enrichment. This is calculated the same way as enrichment, however the rate of change of TPS and MAP decrease (how quickly the throttle is being closed, or how quickly the vacuum is increasing) is used.

#### 5.2.4.7. Digital Input Enrich/Retard

The parameters for this feature are found on the Special Functions tabsheet. If a digital input is configured as an enrich/retard input and that input is active, the enrichment/retardation value from this feature will be added to the appropriate trim value.

#### 5.2.4.8. Closed Loop Fuel Adjustments

The contribution to the trim based on AFR measurements warrants its own section, however it is mentioned here because it does contribute to the overall trim value.

#### 5.2.4.9. WOT Enrichment

Under the Corrections tabsheet, there is an option to force an enrichment and run open-loop at WOT. If this is enabled and the ECU considers the throttle to be fully open, this enrichment will be added to the trim value.

### 5.2.5. Ignition Trim Calculation

Like the fuel trim, there are many components that together make up the ignition trim. They are simply added together to arrive at the final trim value, which is then applied to the injectors. These will now be described.

#### 5.2.5.0. Master Trim

The master trim is found in the Corrections tabsheet. It provides an overall trim control. This should be zero, however non-zero numbers can be useful for quickly determining power gains by advancing or retarding the ignition.

#### 5.2.5.1. Water Temperature

The water temperature is measured. If no water temperature value is available, a value of 27° is assumed. This is interpolated from the coolant trim table (see Corrections tabsheet), and contributes to the trim value.

#### 5.2.5.2. Air Temperature

The air temperature is measured. If no air temperature is available, no correction based on air temperature is performed. Otherwise, the trim is adjusted by the value interpolated from the "air temp trim" table.

### 5.2.5.3. Digital Input Enrich/Retard

The parameters for this feature are found on the Special Functions tabsheet. If a digital input is configured as an enrich/retard input and that input is active, the enrichment/retardation value from this feature will be added to the appropriate trim value.

### 5.2.5.4. Closed Loop Ignition Adjustments

The ignition trim value calculated by the feedback loop is added to the ignition trim depending on the mode (closed, rapid learn or slow converge), for more information refer to 5.2.9 and 5.2.10.

### 5.2.6. Asynchronous Accelerator Pump

This is an additional feature which is quite separate to the fuel calculation and trim calculation. It allows an extra jet of fuel to be supplied when the throttle is first opened, similar to a power jet on a carburettor. This extra squirt of fuel is completely asynchronous with the rest of the injection sequence, and so can give quite effective transient performance on an engine, even without sequential injection.

The time-derivative of the TPS (how quickly the throttle is being opened) is measured. The current RPM value is measured, and then the asynchronous accelerator pump duration is interpolated from the table. This table has its own dialogue box, and is accessed from the Corrections tabsheet. It gives the accelerator pump duration in milliseconds as a function of the engine speed. This value is then corrected by the air and water temperature trim percentages.

This is then scaled against the TPS rate. The effect of this is that the maximum fuel pulse provided will be that in the table, but if the throttle is not being opened quickly enough, this will be reduced (for example, it may only give half of this value).

The status of each injector is then checked. If the injector is currently "on", then the duration of this pulse is added to the pulse that the injector is currently performing. If the injector is "off", a new pulse is triggered. This is done on all injector outputs simultaneously.

### 5.2.7. Closed Loop Fuel Control

For closed loop fuel control to occur, the following conditions must be met:

1. The engine must be running mode (not stationary);
2. The engine must not be in any fuel or ignition cut mode;
3. The engine must not be at WOT (if WOT enrichment/open loop is enabled);
4. The ECU must be in either Closed Loop, Rapid Learning or Slow Converge modes for fuel control;
5. The water temperature must be above the minimum closed loop operation temperature (if there is no water temperature available, open loop mode is forced);
6. The RPM must be below the max rpm value;
7. There must be a valid AFR reading from an oxygen sensor input or the second serial port;

8. The load value (TPS or MAP) must be below the maximum load for closed loop operation;
9. The target AFR must fall within the range of reading of the currently active oxygen sensor (including the serial sensors);
10. The engine must have been running for the "Delay before closed loop" duration.

If all of the above conditions are met, the ECU will operate in closed loop fuel mode.

In closed loop mode, the target AFR is calculated from the target AFR lookup table as a function of RPM and load (see Target AFR tabsheet). The actual AFR is measured, and the difference between these two gives the AFR error.

The parameters for the control are given in the "Closed Loop Parameters" dialogue box. The error is multiplied by the proportional gain, and integrated using the integral gain. The maximum integral value is calculated so that the maximum trim addition (in percent) is that given in the dialogue box. For normal operation, the proportional gain would normally be about 2 - 10, the integral gain about 1, and the maximum trim about 10%. For fast tuning, the proportional gain should be 0, the integral gain about 4, and the maximum trim about 4%.

The values in the advanced parameters section "Closed Loop Parameters" dialogue box have the same effects as those listed above however they are four times as sensitive, this is to allow greater control over large injectors at idle.

The delay before closed loop is the amount of time before the fuel control will go into closed loop mode once all the conditions are met.

Injector dead is the amount of time it takes for the injector to start flowing after power is applied, this is a function of the voltage applied to it and as such we can set the dead time correction for both primary and secondary injectors as a function of battery voltage under the corrections tab.

### 5.2.8. Adaptive Fuel Control

For adaptive fuel control (map self learning) to occur, the above conditions for closed loop operation must be met. In addition, the following conditions (parameters are set in the "Adaptive Mode Parameters" under fuel control) must be met for adaptive fuel control:

1. The temperature must be in the specified range;
2. The engine speed must be above the minimum required;
3. An adaptive mode (Slow Converge or Rapid Learning) must be selected.

Once these conditions are met, the ECU will be in adaptive mode.

In adaptive mode, the ECU starts a timer every time the engine changes "cells" (ie, the closest RPM and load point in the fuel and ignition maps). This timer allows the engine to stabilise, so that the ECU is not performing corrections to transient events. This timer elapses after the "Stabilise time" has occurred (this figure can be set differently for Rapid Learning and Slow Converge modes). During this time, the

Learn Wait flag will be set, so one aid to tuning is to connect a light to an auxiliary output, and configure it to be a "Learning wait" type output.

The ECU also checks the RPM and load values to check how close the engine is to the actual map point. When they are within a certain tolerance (this tolerance is specified in the Adaptive Mode Parameters dialogue box), the "Learning load OK" and "Leaning RPM OK" outputs will be enabled.

If the stabilise timer has elapsed, and both RPM and load are within the specified tolerance, the ECU will sample the correction made to the trim based on the closed loop correction, and apply this to the fuel map. The ECU will then reset the timer, however rather than setting it to elapse after the "Stabilise time", it will elapse after "Update period". This figure then sets how often the ECU updates the fuel map with corrections.

The selection "update other parts of map" is used for tuning, it will give a base point equal to the current value, for all untuned points of the same load as the one being tuned. "Ensure higher loads have more fuel" ensures the fuel curve vs load is monotonic, by checking all values below the current point and trimming them if necessary and all values above the current point and adding to them if necessary.

#### 5.2.9. Closed Loop Ignition

When the ECU is in closed loop ignition mode, the knock level is sampled. Provided the RPM is below the maximum, the sampled knock level is divided by the knock level to retard 1 degree (in the ignition "Closed Loop Parameters" dialogue box), so as to determine the degrees needed to be retarded and scaled appropriately. This is then clipped to a maximum of 20 degrees, the maximum retardation that can occur from detection of knock. This figure is peak-held so that retardation persists even after the knock has been cured. This is held for the retard period set in the dialogue box.

#### 5.2.10. Adaptive Ignition

The adaptive ignition should be used as a tuning aid as in some cases left to its own devices it can retard/advance ignition to non-optimum levels. It works by dithering the calculated ignition timing by a fixed amount "angle", and back to the calculated value every set of ignition events ("no of engine periods"). Because the engine drives a compliant load (through flexible engine mounts and tyres), a change in torque will cause a phase shift in the engine's rotation. Over a small period of time this corresponds to a small change in RPM. The RPM is sampled at the beginning, middle and end of every ignition dither cycle. The difference is calculated; if the RPM is greater when the ignition is more advanced, this corresponds to an increase in torque during the advanced ignition period. If the RPM is the same, there is no torque increase. This RPM shift is referred to as the "Advance Metric", and will have a positive value if the torque will be increased by advancing the ignition.

By default, the ignition dithering will only take place if the conditions for adaptive ignition are met (that is, minimum/maximum engine speed and minimum/maximum coolant temperature). When the ignition dithering is not in effect, the Advance Metric will read zero. Under the "Always sense torque" tickbox is enabled in the Adaptive Ignition parameters, the dithering will always be active and the Advance Metric will

always be calculated. This is disabled by default as it has a poor effect on idle smoothness.

Once the advance metric gets above the higher threshold, the advance metric is reset and the current cell in the ignition map is advanced by 0.2 degrees (slow converge) or 1.0 degrees (rapid learning). The other adaptive parameters such as the RPM and load tolerance are set as per adaptive fuel control parameters.

- The knock threshold determines the level of knock allowed before the ignition will be retarded.

- The minimum and maximum rpm values set the conditions for entry into the adaptive ignition loop.

- Always sense torque will dither the ignition regardless of the conditions, when it is off dithering will only occur when in adaptive ignition mode.

- Update other parts of map will check that all loads and rpm's higher are equal or more advanced, all loads and rpm's lower are equal or more retarded, if not they will be changed.

The adaptive ignition system is noisy, to remove some of this noise, there is a filtering option which uses the number set to determine the percentage that comes from the sample taken, while the remaining percentage comes from the previous value. The lower and higher thresholds set the minimum and maximum values that the adaptive ignition can change the map, the stabilise time sets the time that the ecu needs to be held at a set rpm and load for the adaptive ignition to occur.

### 5.3. Power Cut

The power cut is a feature which allows power production of the engine to be cut. This can be done by either cutting fuel, cutting ignition or both. This cut is performed as the output is to be fired, so the calculations of fuel and ignition quantities are still performed whether the engine is in power cut mode or not.

The following conditions can cause a power cut:

1. Bringing the engine speed above the "Hard Rev Limit" (engine speed must be brought below this figure minus the "Hard Hysteresis" to reinstate engine power);
2. Bringing the engine speed above the "Soft Rev Limit" will cause a partial cut (every second cylinder, and then engine speed must be brought below this figure minus the "Soft Hysteresis" to reinstate engine power);
3. Bringing the engine speed above the "Cold Rev Limit" when the water temperature is below the "Cold Temperature" (if there is no water temperature input available, this test is skipped);
4. Bringing the engine speed above the "Turbo Timeout Rev Limit" when the turbo timer is in operation;
5. Bringing the engine speed above the "Flat Shift Min RPM" when the engine is at full throttle and a clutch/neutral input is active;
6. Bringing the MAP above the "instant overboost power cut" value;
7. Bring the MAP above the 1 sec overboost power cut value
8. Holding WOT condition while cranking (if the feature is enabled, and "Don't cut but reduce fuel pulse width" is disabled);
9. After the prescribed number of cranks if the engine does not fire (if the feature is enabled, and "Don't cut but reduce fuel pulse width" is disabled);

10. Under throttle-off conditions (see below).

The throttle-off power cut (also called overrun) requires that the following conditions are met:

1. The engine speed must have gone above "RPM Higher" (power will be reinstated when the engine speed falls below "RPM Lower");
2. The throttle must be closed (either by TPS being below "Closed Throttle", or a digital input configured as a Closed Throttle input being active);
3. The water temperature must be above the "Minimum water temperature" (if there is no water temperature available, this test is skipped);
4. The air conditioner output must be disabled, if the "Not when A/C is on" option is selected;
5. There must be no input configured as a clutch/neutral input which is active, if the "Only when in gear" option is selected;
6. These conditions must be met for the "Time Delay" before the fuel cut occurs.

A special power cut can also be added to cut fuel and ignition if the ignition switch is off.

## 5.4. Special Functions

### 5.4.0. Fuel Pump Control

The fuel pump is activated for the "prime time" (see the Special Outputs tabsheet) when the ECU is first powered up, and for "trigger timeout" after each trigger pulse. This means that the fuel pump will stop "trigger timeout" after the engine stops.

If this "trigger timeout" figure is set less than the duration between triggers at the lowest operational speed (ie, during cranking), the engine will not be able to start. A value of about 200ms is recommended.

### 5.4.1. Air Conditioner

The air conditioner output flag is set if the following conditions are all met:

1. An input set as an air conditioner input is active;
2. The engine speed is above the "Min RPM" value (Special Outputs tabsheet);
3. The engine is not at full throttle.

Then if an auxiliary output is set to be an air conditioner, that output will be activated when the above conditions are met. The A/C output flag being set will also affect the idle control and the throttle-off power cut.

### 5.4.2. Purge Valve

The purge valve is a common component of pollution management on many vehicles. It allows the engine vacuum to purge fuel vapour from the charcoal canister. The purge valve will come on under the following conditions:

1. The RPM must be above the "Minimum RPM" (in Special Outputs tabsheet);

2. The TPS must be above the "Minimum TPS" (in Special Outputs tabsheet - if there is no available TPS value, this test is skipped);
3. The water temperature must be above the "Minimum water temp" (if there is no available water temp value, the purge valve is disabled);
4. If any input is configured as a clutch/neutral input, none of them may be active (ie, vehicle must be in gear if there is a clutch/neutral switch configured).

#### 5.4.3. PRCV Control

Some older Nissan engines run a PRCV (Pressure Regulator Control Valve). This disconnects the vacuum reference of the fuel pressure regulator from the inlet manifold for the first few minutes after starting the engine. The actual purpose of this is unknown however there is an option in the Adaptronic to perform this function.

On the Special Outputs tabsheet, there is an option for the duration, in seconds, of the PRCV. Any auxiliary output selected as a PRCV output will be activated while the engine is stopped, and for that duration after the engine fires (that is, leaves the "cranking" state).

#### 5.4.4. Second Serial Port

At this stage the second serial port is only being used for input from an oxygen sensor, this is described in the oxygen sensor section.

#### 5.4.5. Blow-off Valve

The ECU can be set to control an electronic blow-off valve. This will activate the blow-off valve output for a fixed amount of time to allow the turbocharger rotor to spin down gracefully.

The normal state of the blow-off valve state machine is "cruising". This happens at light loads (including idle). When the MAP goes above the "MAP Prime" value, a transition is made to the "boosting" state. During "cruising" state, the blow-off valve output is off. The state will always be "cruising" if there is no valid MAP value.

In the "boosting" state, the blow-off valve output is also off. If the MAP falls below the "MAP Prime" value, the TPS is checked. If there is no valid TPS reading, or the TPS is below the "TPS threshold", a transition is made to the "venting" state. Otherwise, if the MAP falls below the "MAP Prime" value and the TPS is above the "TPS threshold", the ECU returns to the "cruising" state. If the MAP remains above the "MAP Prime" value, it remains in the "boosting" state.

In the "venting" state, the blow-off valve output is as the mode is selected. This can be on (for "Normal" mode), off (for "Off" mode) or changing between on and off (for "Flutter" mode). Any of the following events will take the ECU back to the "cruising" state:

1. The blow-off valve has been venting for the specified duration;
2. TPS goes above the "TPS threshold";
3. MAP goes above "MAP Prime".

#### 5.4.5.0. Digital Input Enrich/Retard

The parameters for this feature are found on the Special Functions tabsheet. If a digital input is configured as an enrich/retard input and that input is active, the enrichment value from this feature will be added to the fuel trim value.

#### 5.4.6. Turbo Timer Control

##### 5.4.6.0. Introduction

The function of a turbo timer is to keep the engine running for an amount of time to allow the oil to cool down after a hard run. There are two modes of operation of the turbo timer feature of the ECU, which will now be explained.

##### 5.4.6.1. Catch Mode

This is the traditional mode of operation of an aftermarket turbo-timer. In this mode, the turbo timer relay is connected across the ignition switch terminals. During normal operation, the relay is off, and the EFI system (including the ECU) is powered by the ignition switch. When the ignition switch is turned off, the ECU keeps running due to its internal charge store, detects that the ignition switch has been turned off, and activates the turbo timer relay. This happens quickly enough that the engine does not stall and the ECU continues running. The engine keeps running until the ECU disengages the relay.

Note that during turbo timeout operation, the ECU can no longer detect the state of the ignition switch, as the switch is being short circuited by the relay. If the user wishes to reapply the ignition, he or she can do so, however the ECU will remain in turbo timeout mode until it is taken out of turbo timeout mode.

For this mode to operate, no auxiliary input may be configured as an "Ignition Switch" (doing so will cause the ECU to use Series Mode). An auxiliary output should drive a relay coil, the contacts of which connect in parallel with the ignition switch contacts. This auxiliary output should be configured as a turbo timer.

##### 5.4.6.2. Series Mode

In Series Mode, the ECU actually powers up the rest of the EFI system through a relay. The ECU must be powered from both the ignition switch and the EFI system (ie, after the relay contact), through two diodes. The ignition switch must be connected to an auxiliary input, and that input must be configured as an active high ignition switch, with a pull-down.

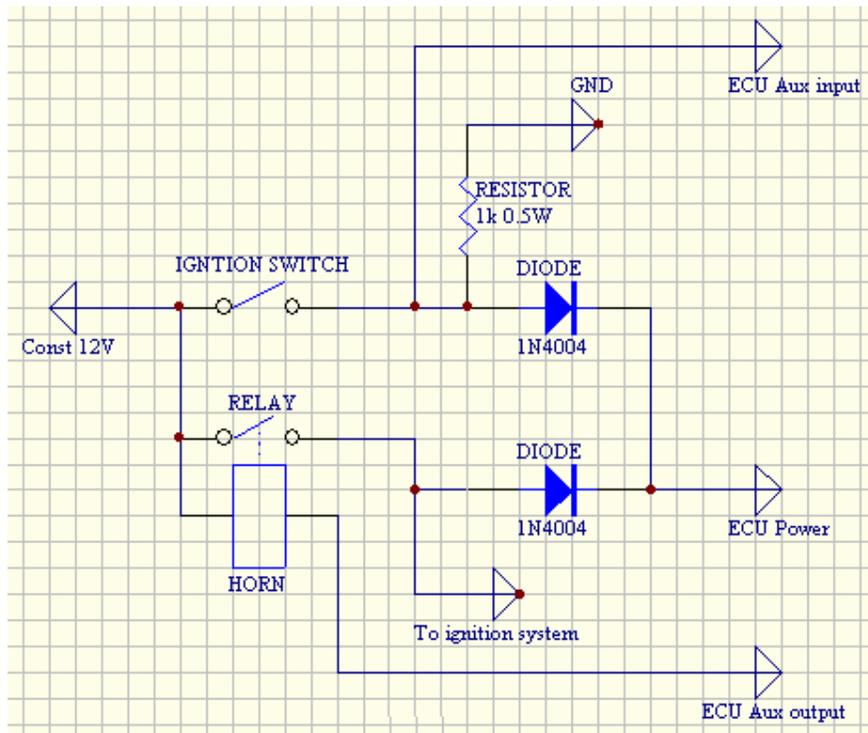


Figure 28: Series Mode turbo timer configuration

#### 5.4.6.3. Behaviour

The turbo timeout period will be activated when the ignition switch is turned off, and shall remain in place until one of the following occurs:

1. The water temperature falls below the specified "Minimum Water Temp" (if there is no water temperature value available, this test is skipped);
2. The auxiliary temperature falls below the specified value "Minimum Aux Temp" (if there is no auxiliary temperature value available, this test is skipped);
3. The engine stalls;
4. The time period elapses;

Note that during a turbo timeout, an additional rev limit will apply. This is intended to reduce risk of theft of the vehicle during turbo timeout, although this may have no real benefit in practice.

#### 5.4.7. Variable Valve Timing

The variable valve timing functions are currently in the BETA stage however they consist of a PID controller to control the rate of change and stability of the change, a duty cycle function to implement the change in timing, a map for cam angle vs rpm which defines the target angle that is used by the PID, a cam angle trigger and a home point for the cam (the ref points, designated in degrees BTDC). Minimum and maximum set the minimum and maximum values for the solenoid valve so that it can be controlled over the narrow range required, the offset should be set to the point at which the cam starts to move from the home position, reverse changes the changes the

feedback logic so that the direction of change of the cam is the reverse, this is used on vehicles with a separate exhaust cam.

## 5.5. Generic Outputs

Auxiliary outputs can be configured as "generic" types, which allow an output to be programmed with respect to an input variable. These include RPM, Air Temp, Water Temp, Aux Temp, TPS and MAP. There are two modes of operation: hysteretic and PWM.

In PWM mode, the output will be at 0% duty cycle (ie, off) below the lower threshold, and at 100% duty cycle (ie, on) above the upper threshold. Between these two values, the duty cycle is linearly interpolated. This is shown graphically in the software.

In hysteretic mode, the output will come on when the variable exceeds the upper threshold, and will turn off when the variable falls below the lower threshold.

## 5.6. Idle Control

### 5.6.0.0. Introduction

Idle control is a difficult problem, because of the different amounts of idle air that an engine will need under different conditions, the difficulty in knowing when to control the idle speed, the number of different idle actuators available and the time delay between making a change to idle bypass value and the engine changing speed.

The ECU uses a combination of open loop forward compensation and closed loop correction to control idle speed.

Because the idle may be controlled using a PWM solenoid valve (which has a duty cycle) or a stepper motor (which has a number of steps), the generic term "effort" will be used to refer to either duty cycle or step number.

### 5.6.0.1. Cranking Condition

While the engine is stopped, or during cranking, the idle valve is always fully opened. This allows easier starting of the engine than the alternative. If a stepper motor is connected, the ECU begins by fully opening the motor. That is, the ECU provides the fully number of steps that the motor can execute. This will invariably cause some pole skipping as the motor reaches its end of travel, however is required so that the ECU knows the position of the valve.

### 5.6.0.2. Open Loop Idle Effort

The ECU has parameters which the installer should adjust to obtain adequate performance of the idle system before enabling closed loop idle control. To begin, disable closed loop idle control by setting the "Proportional Gain", "Integral Gain" and "Differential Gain" to zero.

The open loop value is calculated from the following settings:

1. Base idle effort these are the default values and should be the basic values that the engine needs to idle at the correct RPM with no electrical loads, this is shown graphically in the software if the graph selected is "Open loop idle effort vs temperature". If the water temperature value is not available, this extra effort will be added in full;
2. Extra effort after cranking - this allows the idle valve to open for a short period of time after the engine is started. This figure will linearly decay to zero over the set time period. During this time, closed loop idle speed control will be disabled, as the engine will idle higher than the target idle speed. This is shown graphically if the graph selected is "Open loop idle effort vs time", where zero seconds is the point of engine fire;
3. Extra effort for A/C - this allows some extra air to be admitted when the air conditioner output is on, and will be added to any other idle effort additions;
4. Extra effort for electrical load - this effort will be added if any input selected as an electrical load is active;
5. Extra effort for low batt - this effort will be added if the supply voltage at the ECU input is less than 12.0V;
6. Throttle Cracker - if the "Throttle Cracker" is enabled, a certain idle effort will be added to the idle value when the vehicle is in motion (ie, MVSS is not zero).
7. There is also an option to correct the idle effort based on the air temperature

The easiest way to set these up is to disable closed loop control, warm up the engine and set the base value. Then apply typical engine loads such as headlights and power steering loads, and settle on an appropriate electrical load idle effort value. Then do the same for air conditioning. After this has been sorted out and the engine has cooled down, the extra effort when cold can be determined.

### 5.6.0.3. Performing Closed Loop Idle Speed Control

Ideally the ECU will control idle speed when the engine is idling. The ECU has a few cues as to when this occurs, such as the engine speed, neutral/clutch position, vehicle speed and throttle position.

The ECU will only actively control idle speed under the following conditions:

1. The throttle is closed;
2. The clutch/neutral input is active, or the "Throttle cracker" is enabled and the vehicle is stationary;
3. The actual RPM is less than the target RPM plus the "Control Band" (note that there are two control bands; one for normal operation and the other for when the air conditioner output is on), or the other conditions have been met for the period of the "Neutral Timeout".

Once these above conditions are met, the closed loop idle speed will be controlled in a closed loop mode by the ECU.

### 5.6.0.4. Closed Loop Idle Speed Parameters - Target Idle Speed

The target idle speed is governed by the following settings:

1. Target idle speed when engine is hot and cold, as a function of water temperature (if there is no valid water temperature value, the cold target idle speed is assumed);
2. An extra speed can be added for the case of electrical loads (this would normally be about 100 RPM);
3. An extra speed can be added for the case of A/C being on
4. An extra speed can be added for the case of a low battery supply.

#### 5.6.0.5. Closed Loop Idle Speed Parameters - Control System

Once the target idle speed has been determined and the ECU has determined that it should make an effort to control idle speed, the idle speed controller is activated. It is a basic PID controller, where the following occurs:

1. The difference between the target idle speed and the RPM is scaled by "Proportional Gain" to give an effort (this allows for quick corrections to idle speed, but values too high can lead to instability);
2. The integral of the error is scaled by "Integral Gain" to give an effort (this allows for long term corrections without so many instability concerns, but will not react as quickly as the proportional gain);
3. The rate of change of RPM is scaled by "Differential Gain" to stabilise the system.

One way to configure these values is to first increase the proportional gain until the system becomes unstable (idle speed hunts), then increase the differential gain to stabilise the system until it is sufficiently stable. The integral gain can then be increased as far as possible while maintaining stability - if necessary the differential gain can be increased.

The limiting factor will be the maximum amount of differential gain that can be added. If too much is added, the system will become unstable again. This places the maximum limit on the amount of proportional and integral gain that can be set, which ultimately limits how quickly and accurately the idle speed can be controlled.

Note that idle speed control should only be performed once the engine is tuned properly at the idle condition. If the engine is not tuned properly, it will hunt in any case, which makes idle control extremely difficult.

There are also two "Recovery" conditions, which give an extra amount of air that will be admitted when the engine speed is below a certain RPM. These should not be used for idle control; they should really only be used to stop an engine from stalling. These will react immediately, unlike the closed loop control algorithm

#### 5.6.0.6. Driving the Idle Valve

After the idle effort is calculated, it is clipped to fall within the "Minimum value" and "Maximum value" specified in the Idle tabsheet. On a PWM type solenoid valve, these will correspond to duty cycles as a percentage, and will be typically 0 and 100. On some engines (such as the Mazda B-series DOHC) the idle valve starts to behave non-monotonically below a certain duty cycle, so a minimum is specified to keep the duty cycle outside this range. On a stepper motor drive, the minimum should be 0 and the maximum should be the number of steps of the idle motor.

To drive a PWM solenoid valve, a capable auxiliary output should be configured as "Idle Control" and set to PWM mode. The actual frequency required will vary from one valve to another and will require some experimentation.

To drive a stepper motor, four auxiliary outputs will be required. There are currently two output options in the ECU, whose step patterns are shown below. In the following table, a "1" corresponds to an activated output (that is, an output held low):

Output	Step 0	Step 1	Step 2	Step 3
Idle stepper 1 – Hold	0	0	1	1
Idle stepper 2 – Hold	0	1	1	0
Idle stepper 3 – Hold	1	0	0	1
Idle stepper 4 – Hold	1	1	0	0
Idle stepper 1 – Pulse	1	0	0	0
Idle stepper 2 – Pulse	0	1	0	0
Idle stepper 3 – Pulse	0	0	1	0
Idle stepper 4 – Pulse	0	0	0	1

**Table 11: Idle stepper motor output patterns**

The step pattern for a standard 6-wire stepper motor (as used on Mitsubishi) is the "Hold" type output, which always energises two coils at a time. The "Pulse" type output energises one coil at a time, however it does not keep the coil energised.

Each step will be at least the duration of the "Step Period" specified in the Idle tabsheet. This is typically 11ms for a Mitsubishi type idle motor.

If the idle motor is at its end of travel, the ECU will deliver a pulse to it once every few seconds, to ensure that the motor actually remains there. The purpose of this is that if some poles are skipped during motor excursion, the position of the motor will not be as the ECU thinks it is. The situation could occur that under closed loop operation, the ECU may believe it has fully closed the idle valve, whereas the idle valve is actually still slightly open (due to the skipped poles). Hence by continuing to step in the "closed" direction, the motor's position will eventually match up with that expected by the ECU. It is only an issue at the ends of travel, because otherwise the closed loop control can be used to compensate for any skipped poles.

## 5.7. Wastegate Control

### 5.7.0.0. Introduction

The conventional mechanical arrangement on a turbocharged engine with electronic boost control is to have a pressure feed from the compressor outlet go to the servo

diaphragm via a T-piece and an electric solenoid bleed valve. Opening the valve allows some air to bleed off, reducing the pressure seen by the servo diaphragm. Closing the valve allows the full pressure to be seen by the servo diaphragm, and the standard wastegate pressure will be maintained.

As with fuel control, ignition control and idle speed control, a combination of feed-forward and feedback is used. Note that closed loop wastegate control is still experimental, however open loop wastegate control has been verified on road vehicles.

The wastegate output is configured as a PWM valve. Hence the solenoid valve must be connected to a high current, PWM-capable auxiliary output.

#### 5.7.0.1. Open Loop Wastegate Control

The open loop system is quite simple. Within the Wastegate tabsheet, there is a set duty cycle (as a percentage) for each 500 RPM from 0 to 7500 RPM. The ECU will interpolate these values, based on the current RPM, to arrive at a duty cycle which is fed to the wastegate output.

To force only open-loop control, the P, I and D gains in the Control pane must be set to zero.

#### 5.7.0.2. Closed Loop Wastegate Control

The installer can set a target MAP for each RPM point. The ECU will then attempt to regulate the wastegate duty cycle to achieve this MAP value.

If there is no valid MAP value, the closed loop operation is disabled and the open loop mode only is used.

For a discussion on the operation of the PID controller, see the description for closed loop idle control.

## 5.8. Driving Outputs

### 5.8.0. Ignition Outputs

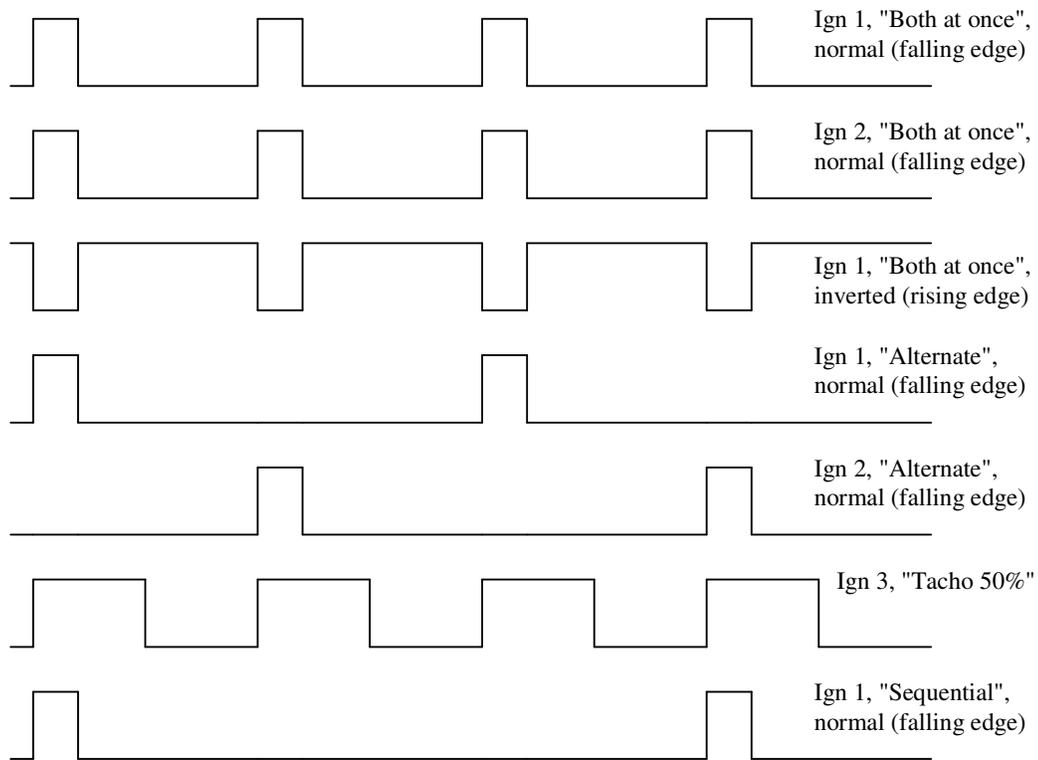
There are three dedicated ignition outputs, and one ignition capable auxiliary output on the Adaptronic. These can be configured to fire simultaneously (as on an engine with a distributor) or alternately (as on a 4 cylinder, wasted spark engine), leading/trailing as in a rotary with a distributor. In these modes, the third ignition output can be configured as a tachometer function. They can also be configured to fire in a cycle of three, which is suitable for direct fire ignition on a three cylinder engine, wasted spark on a six cylinder engine, or leading trailing with addressing on rotary with addressing igniters. In this mode, a tachometer output must be sourced from an auxiliary output. Ignition Output 1 will fire first after the reset pulse from the crank/cam trigger. They can also be configured to fire in a cycle of four, suitable for direct fire four cylinders or waster spark eight cylinders, in this situation ign 3 has to be set to Ign 3, and aux out 1 set to Ign 4.

When using a two-rotor engine, with addressing igniters, the coil address sets the plug to fire based on whether it is high or low, to offset this addressing so that it encompasses when the plug should be fired, changing the offset address from 0 to 1, 1 to -3, -3 to -4, -4 to -5, -5 to -6 shifts the addressing right one trigger event, changing the offset address from 0 to -1, 1 to -2, -3 to 2, -4 to 3, -5 to 4, -6 to 5 changes the phase. The split between the leading and trailing sparks can be changed based on load and rpm under the basic setup tab, the value entered will move the trailing plug back the specified degrees.

Each output will turn on a fixed amount of time (the "dwell time", configurable in the Trigger/Output window) before the spark is to fire. The output will then turn off at the angle at which the output is supposed to fire, discharging the coil and generating the spark.

The outputs can be configured as rising edge or falling edge sensitive. Most igniters will be falling edge sensitive; that is, the output goes high to begin charging the coil, and low again (falling edge) to generate the spark. This option is left in for certain igniters that were intended to work with Kettering ignition (points), and are triggered by the rising edge. Honda igniters seem to use this logical sense.

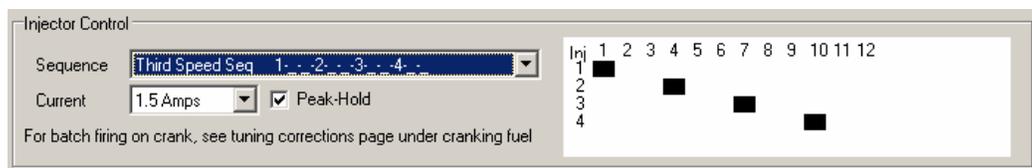
The following diagram shows some typical waveforms:



**Figure 29: Ignition Waveforms in Different Modes**

### 5.8.1. Injection Outputs

Each injector output will fire in accordance with the firing order and pattern selected in the software. The software gives a graphical indication of this firing order. An example is shown below:



**Figure 30: Injector Firing Pattern Example**

The above example shows a configuration for a twelve cylinder engine, where each injector output is fired once every three periods.

The current needed for most injectors is 1amp, to achieve this there are a number of selections which the user can make based on how their injectors are wired up, e.g. for direct 0.9A, for two injectors together 1.9A.

The staged injector limit sets the limit of the primary injector in terms of ms of the secondary injectors, the primary injector multiplier sets the percentage increase in size of the injector, this is all used to calculate the actual injector on time for each injector when using staged injection. Note also that when using injection in a staged situation that only all, alternate full speed, or batch should be used.

### 5.8.2. Auxiliary Outputs

Each output is driven low to activate it. There is no internal pull-up or high side driver, so these outputs can only sink current. If an output needs to be configured as a 0-12V signal (for example, to feed into a tachometer or another piece of equipment), a separate pull-up resistor of an appropriate value must be placed.

Not all auxiliary outputs are created equal, for this reason you must choose the correct channel for the correct output type, the specifics of this can be found in section 2.3.