ADAPTRONIC™

Adaptronic ECU Installer's Manual for ECU model e420b version 0.3

FIRMWARE VERSION: 0.3E
SOFTWARE VERSION: 0.16

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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 ECU. This document pertains to hardware version 0.3 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 UEGO 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.

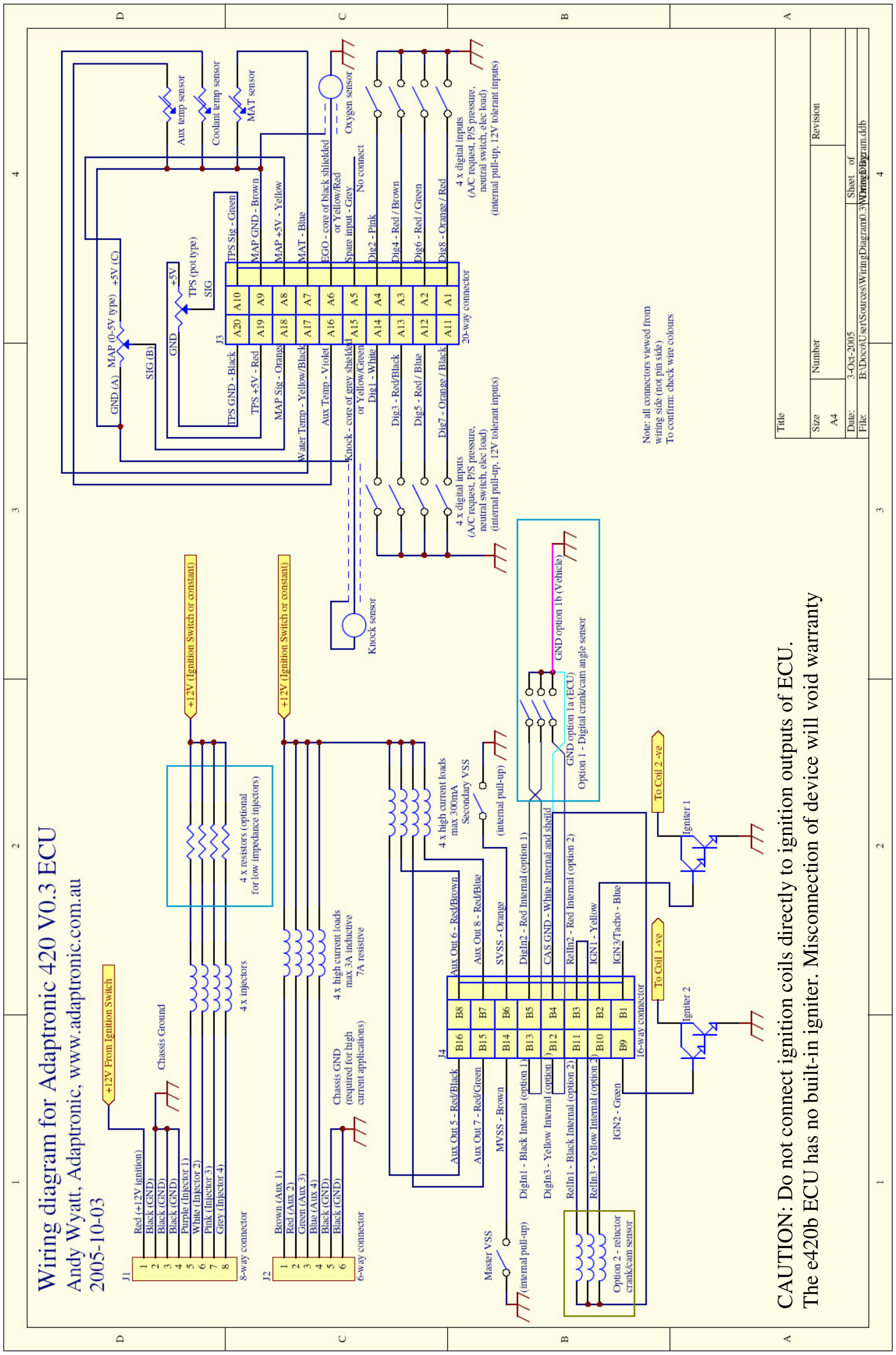

Figure 1: Wiring Diagram

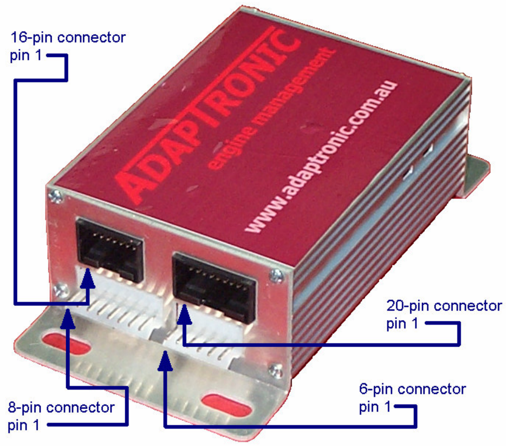

Figure 2: Connectors on the Adaptronic ECU

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 (thin green 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 1.5kΩ) 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.

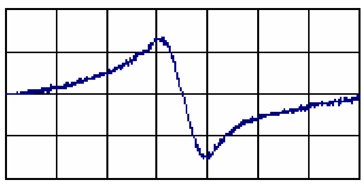

Figure 3: Reluctor Waveform (correct)

- 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 (2kΩ). 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 170Ω
    - pin 1 to pin 3 is 170Ω
    - pin 1 to pin 4 is 170Ω
    - pin 2 to pin 3 is 340Ω
    - pin 2 to pin 4 is 340Ω
    - pin 3 to pin 4 is 340Ω

  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).

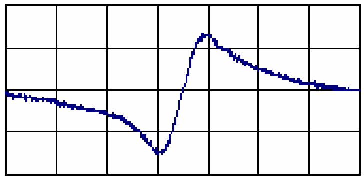

Figure 4: Reluctor Waveform (inverted, incorrect)

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.

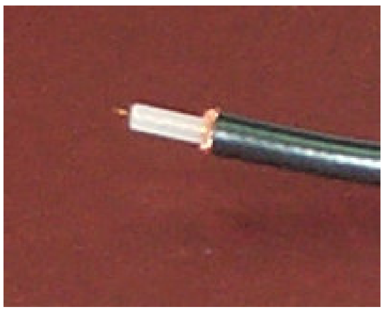

Figure 5: Stripped back sheath and cut braid

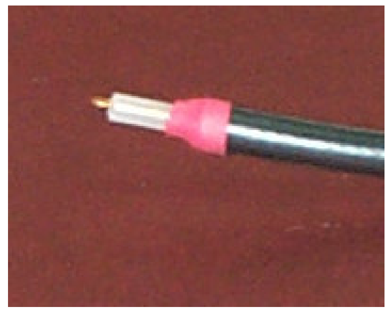

Figure 6: Stripped back sheath and insulated braid

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 6Ω, 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 (0Ω), 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.

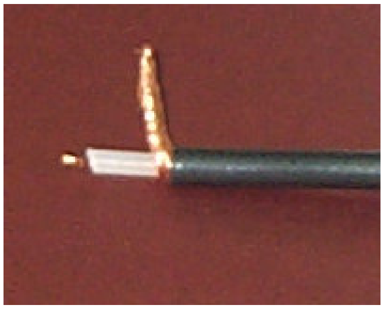

Figure 7: Stripped back sheath and twisted braid

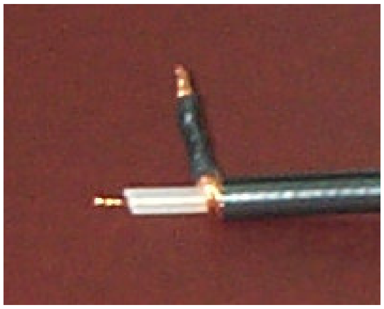

Figure 8: Heatshrink over braid

Figure 9: Heatshrink over join

There is another type of sensor, which comes with its own controller box. It gives a 0-5V output, which is linearised with respect to air/fuel ratio over the range of 10.0:1 to 20.0:1. To connect this sensor, the following must be performed:

- Connect a 10kΩ resistor in series with the analogue output of the controller box.
- Prepare the EGO sensor wire in the same manner as for the 4-wire sensor.
- Connect the other side of the 10kΩ resistor to the central conductor of the EGO sensor cable.
- Connect a 15kΩ resistor between the central conductor and ground.
- The other connections on the controller box should be wired up according to the manufacturer's recommendations (usually, this will entail connecting one

wire to ignition-switched positive, one wire to ground, and plugging in the sensor).

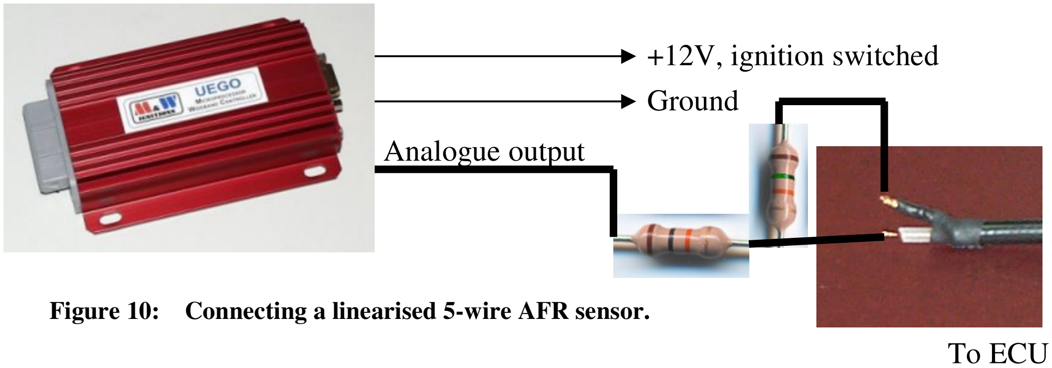

Figure 10: Connecting a linearised 5-wire AFR sensor.

1.12. Connecting a Wideband Oxygen Sensor

The M&W LSU4 module can actually be connected directly to the ECU by plugging it into the secondary serial port. The ECU will detect that the LSU4 is connected, and override the reading from the analogue oxygen sensor (if selected). This saves wiring, and is especially useful for installers with their own LSU4 system.

The TechEdge WBO2 2C0 sensor can also be connected directly to the slave serial port, provided the second serial port is configured for this use.

2. ECU Operation

2.0. 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

2.1. Reading Inputs

2.1.0. 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.

2.1.1. Temperature Inputs

The temperature sensor inputs are pulled up to an internal 3V rail through a 4.7 kΩ 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 ranges specified in the analogue sensor calibration table. For example, if the temperature table is as shown below:

Temperature (°C)	Water temp	Air temp	Aux temp
-20	3200	3200	3200
0	2300	2300	2300
20	1400	1400	1400
30	800	800	800
40	510	510	510
60	250	250	250
80	170	170	170
110	100	100	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 20-(2000-1400)/(2300-1400)*(20-0) = 6.7°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 110°, and between 3200 and 4055 will always read a temperature of -20°.

2.1.2. 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 kΩ resistor to 0V. There is again a 100nF capacitor decoupling the input to reduce high frequency noise.

The Ext input is not used by the firmware at the current stage, so no readings are taken from it.

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.

0% ADC reading	327
100% ADC reading	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.

	Pressure	ADC Reading
Lower value	16	111
Upper value	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.

2.1.3. Oxygen sensor input and Air-Fuel Ratio

2.1.3.0. 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 MΩ 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.

2.1.3.1. Oxygen sensor input: None

The AFR is set to "invalid".

2.1.3.2. 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:

	Voltage	AFR Reading
Lower value	0.0	15.5
Upper value	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.

2.1.3.3. Oxygen sensor input: UEGO 0-3V

This mode assumes that following calibration:

	Voltage	AFR Reading
Lower value	0.0	10.0
Upper value	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 an M&W UEGO, 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.

2.1.3.4. Oxygen sensor input: Bosch Wideband 0-1V

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

	Voltage	AFR Reading
Lower value	0.36	17.0
	0.84	13.0
Upper value	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/

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

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

	Voltage	AFR Reading
Lower value	0.4	10.0
	1.1	11.0
	2.5	14.7
Upper value	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.

2.1.3.6. 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.

2.1.3.7. 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.

2.1.4. Knock Sensor Input

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

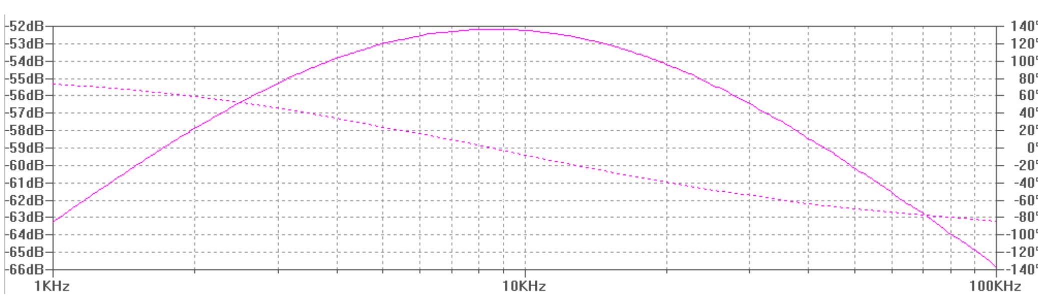

Figure 11: Response of Knock Filter

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).

2.1.5. Digital Inputs

There are eight digital inputs. Each has a weak pull-up of 100 kΩ to the internal 3V rail, and a series resistor of 3.3 kΩ 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 voltage voltage. A 1 kΩ 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:

	Input 1	**Input 2**	**Input 3**	**Resultant Electrical Load decision by ECU**
Type	Electrical load	Electrical load	Electrical load	
Sense	Active High	Active Low	Active Low	
Comment	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	
Scenario 1	High (headlamp on)	High (blower off)	High (power steering off)	True (electrical load is on)
Scenario 2	Low (headlamp off)	High	High	False (no electrical loads)
Scenario 3	High	Low (blower on)	High	True
Scenario 4	High	High	Low	True
Scenario 5	Low	High	Low	True

Table 8: 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.

2.1.6. RPM and Triggering

Each trigger channel input has two modes of activation; a reluctor (analogue) input and a digital input. The reluctor 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 kΩ, and is then filtered by a 3.3 kΩ 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 reluctor input pulls the digital input low when triggered, the input must be selected as a negative/falling digital/reluctor input to operate correctly with a reluctor 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 period, 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".

2.1.7. Vehicle Speed Sensing

There are two vehicle speed sensors. 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 an arbitrary number to arrive at a number proportional to road speed. Note that this does not represent the road speed in any particular units.

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

2.1.8. 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.

2.2. Calculations, Control Policies and Special Behaviour

2.2.0. 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.

2.2.1. 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 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 occcurs 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. If the RPM is above the maximum figure of 15500, it is clipped to this value. The load depends on the maximum load set under the Analogue tabsheet, and may be a pressure (typically 100 - 300 kPa), or can be disabled and "Use TPS" can be selected instead.

If "Use TPS" is enabled, the load is taken from the TPS input, and the fuel map is interpolated from 0% to 100% on the load axis. If there is no TPS value available, a default value of 100% is assumed.

If "Use TPS" is disabled, the load is taken from the MAP input, and the fuel map is interpolated from 0 kPa to the maximum load. If there is no MAP value available, a default value of the maximum load is assumed.

The "trim value" (in %) 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.

2.2.2. Ignition Calculation

When in cranking mode, the ignition figure is taken from the Crank Timing angle (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" (in degrees) is then added to this value, along with the digital input retard, if an input configured as such is currently active.

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

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

2.2.3. Fuel Trim Calculation

2.2.3.0. 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.

2.2.3.1. 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.

2.2.3.2. 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.

2.2.3.3. 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 modified by a fixed coefficient of -1% for every 3 K, with zero trim being applied at 27°.

2.2.3.4. 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

2.2.3.5. 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.

2.2.3.6. Accelerator Pump

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.

2.2.3.7. Digital Input Enrich/Retard

The parameters for this feature are found on the Special Outputs 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 trim value.

2.2.3.8. 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.

2.2.3.9. 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.

2.2.4. 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 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.

2.2.5. 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. There must be a valid AFR reading from an oxygen sensor input or the second serial port;
7. The load value (TPS or MAP) must be below the maximum load for closed loop operation;
8. The target AFR must fall within the range of reading of the currently active oxygen sensor (including the serial sensors).

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%.

2.2.6. 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 (for Slow Converge, this means it must be below the maximum, whereas Rapid Learning has its own minimum and maximum values);
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.

2.2.7. Closed Loop Ignition

When the ECU is in closed loop ignition mode, the knock level is sampled. This is multiplied by the "knock sensitivity" value (in the ignition "Closed Loop Parameters" dialogue box) 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 "knock persistence" duration in the dialogue box.

The adaptive ignition modes are still experimental and so are not documented here.

2.2.8. 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 "Overboost power cut" value;
7. Holding WOT condition while cranking (if the feature is enabled, and "Don't cut but reduce fuel pulse width" is disabled);
8. 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);
9. 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.

2.2.9. 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).

2.2.10. 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.

2.2.11. 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.

2.2.12. Turbo Timer Control

2.2.12.0. 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.

2.2.12.1. 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.

2.2.12.2. 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.

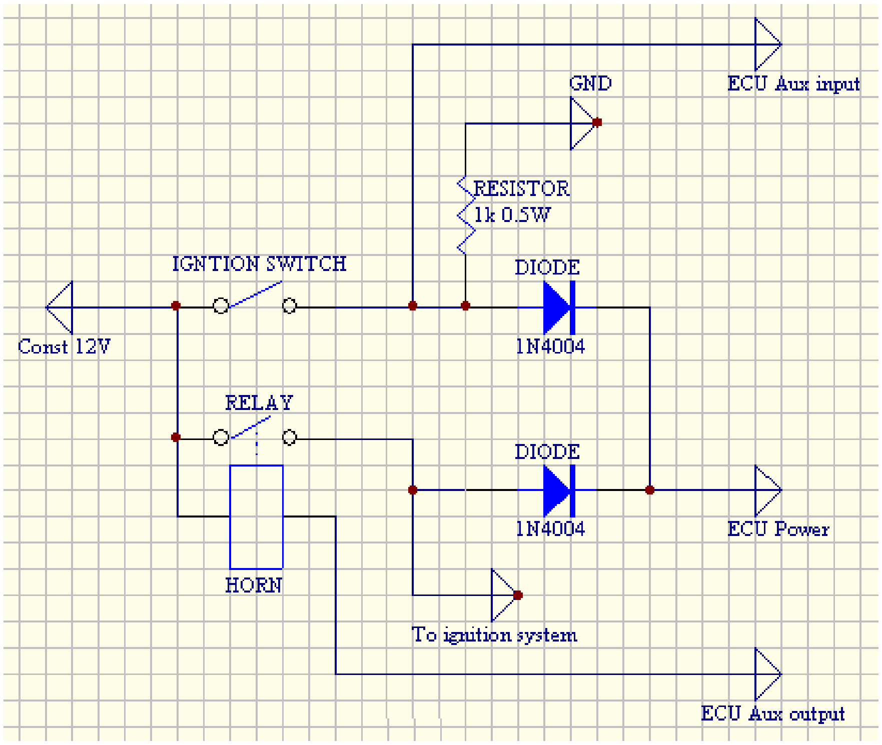

Figure 12: Series Mode turbo timer configuration

2.2.12.3. 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.

2.2.13. 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.

2.2.14. 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).

2.2.15. 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".

2.2.16. Idle Control

2.2.16.0. 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.

2.2.16.1. 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.

2.2.16.2. 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 (hot) - this is the default value and should be the basic, default value that the engine needs to idle at the correct RPM when it is warm, with no electrical loads;
2. Extra effort when cold - this extra effort will be added to the base value when the water temperature is below the "Cold Temperature". This will be linearly decreased to zero additional effort at the "Hot Temperature" and above. 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;
3. 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;
4. 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;
5. Extra effort for electrical load - this effort will be added if any input selected as an electrical load is active;
6. Extra effort for low batt - this effort will be added if the supply voltage at the ECU input is less than 12.0V;
7. 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).

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.

2.2.16.3. 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.

2.2.16.4. 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 low battery supply.

2.2.16.5. 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

2.2.16.6. 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 9: 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.

2.2.17. Wastegate Control

2.2.17.0. 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.

2.2.17.1. 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.

2.2.17.2. 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.

2.2.18. Settings Management

Version 0.3 of the ECU hardware stores its settings in RAM and in flash. The flash can not be written to when the engine is running without a misfire occurring, however changes made to the RAM copy will be lost when power is cut.

As the installer makes changes to the settings from the PC, the contents of the RAM are updated. This takes effect on the behaviour of the ECU immediately. However these changes need to be saves to flash before power is lost.

The ECU has modes available to update these settings in flash automatically under certain sets of conditions. These options can be found in the "Special Outputs" tabsheet. The conditions under which this can occur will now be described.

"Always write when cutting": The ECU will update the flash when the ECU is in fuel or ignition cut mode. In normal operation, this means that when the driver takes his/her foot off the throttle when the car is going along, the settings are updated. This may result in a couple of flicks of the tachometer needle as ignition pulses are missed, however this will not be felt by the driver as the engine is in fuel cut mode at the time.

"Always write when stopped": The ECU will update the flash when the engine is stopped.

"Write when running normally": This allows the ECU to update the flash when the following conditions are met:

1. The RPM is below the threshold of "Max RPM";
2. The throttle is closed (if this requirement is enabled);
3. The vehicle is in gear (if this requirement is enabled);
4. The vehicle is out of gear (if this requirement is enabled);
5. The vehicle is stationary (if this requirement is enabled).

The least invasive mode of updating the flash while the engine is running (apart from during a fuel cut) is to do so at idle when the car is in neutral. If the vehicle has a clutch or neutral switch, this can be used to allow the settings write. If not, vehicle speed must be used. A maximum RPM of 1200 also requires that the engine is idling before performing the update.

The period is the time delay, in main loop cycles, between updating various parts of the flash memory. Each part is updated separately to minimise the number of consecutive misfires and minimise risk of stalling. A value of about 90 requires slightly less than half a second between update cycles.

2.3. Driving Outputs

2.3.0. Ignition Outputs

There are three ignition outputs 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). In both of 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, or wasted spark on a six cylinder engine. 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.

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:

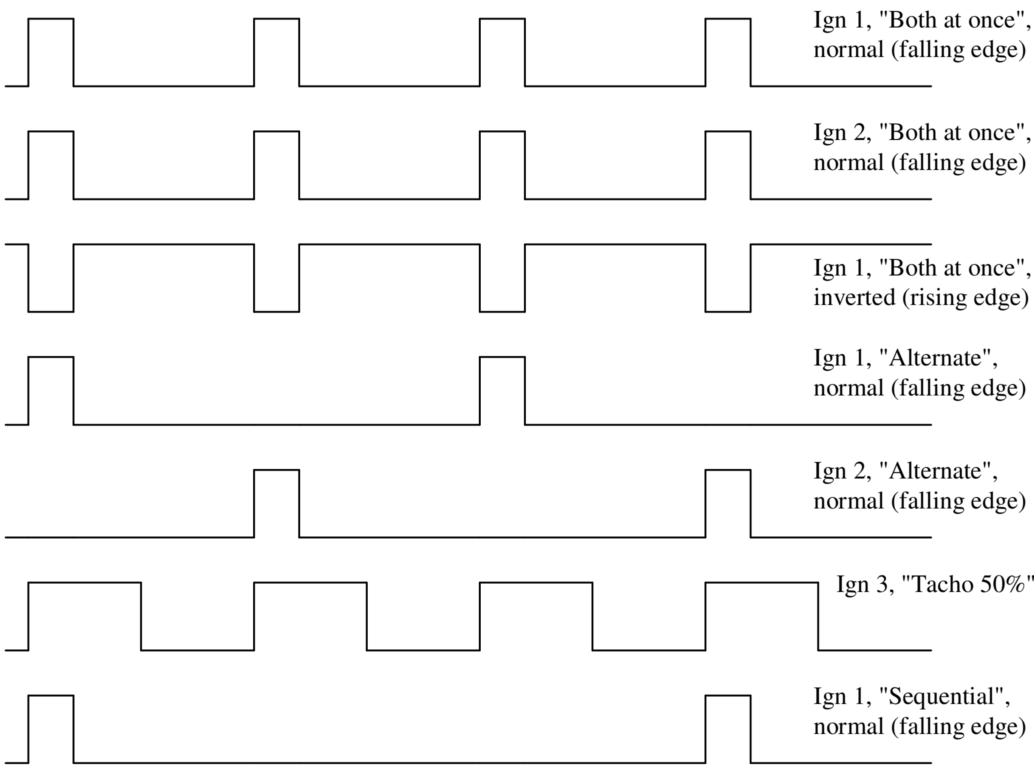

Figure 13: Ignition Waveforms in Different Modes

2.3.1. 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:

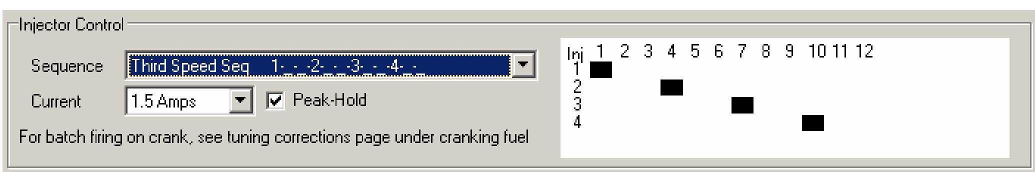

Figure 14: Injector Firing Pattern Example

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

2.3.2. Auxiliary Outputs

The way in which the output status (on, off, or the duty cycle) for the auxiliary outputs is calculated is described in detail in the behaviour and calculation section.

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.

3. Configuring the ECU

3.0. Getting Started

Once the ECU is wired up, power should be applied, and the ECU should 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 "Adaptronic V0.0" 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 can begin configuring the sensors.

3.1. Configuring the Sensors

3.1.0. 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):

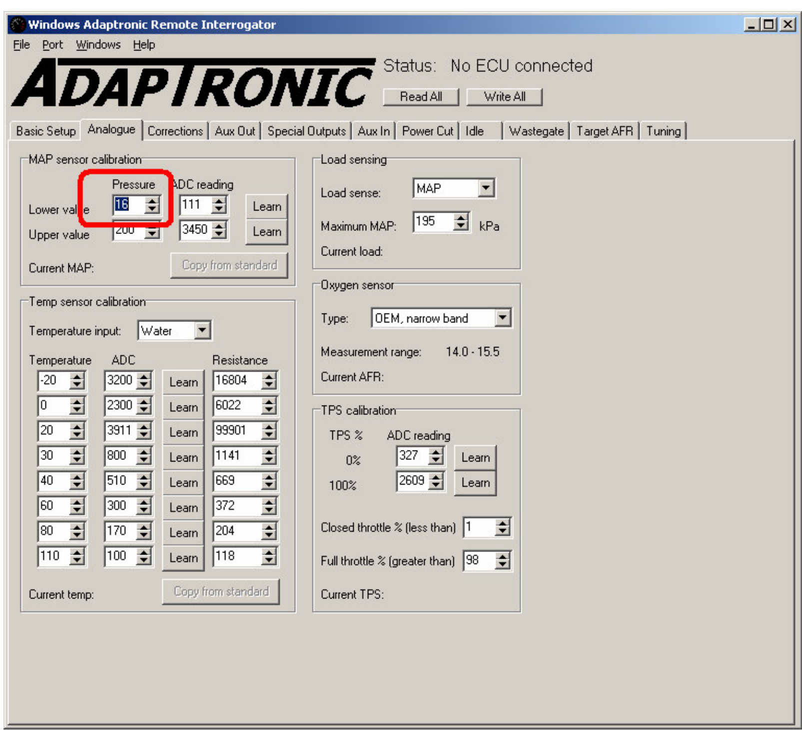

Figure 15: Maximum MAP value in kPa

- 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".

3.1.1. 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 (in Figure 12, 110°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 110°).
- 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, these can be entered under the "Resistance" heading. The software will then calculate the ADC values from knowledge of the resistance value.

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.

3.1.2. Load Sensing

The ECU must be instructed as to how it will determine load of the engine. In version 0.3, there are two modes: TPS and MAP. In TPS Mode, the load is sensed from throttle position from 0% to 100%. In MAP mode, the load is sensed from the MAP sensor, from 0 kPa to the maximum MAP in the Load Sense pane (see below).

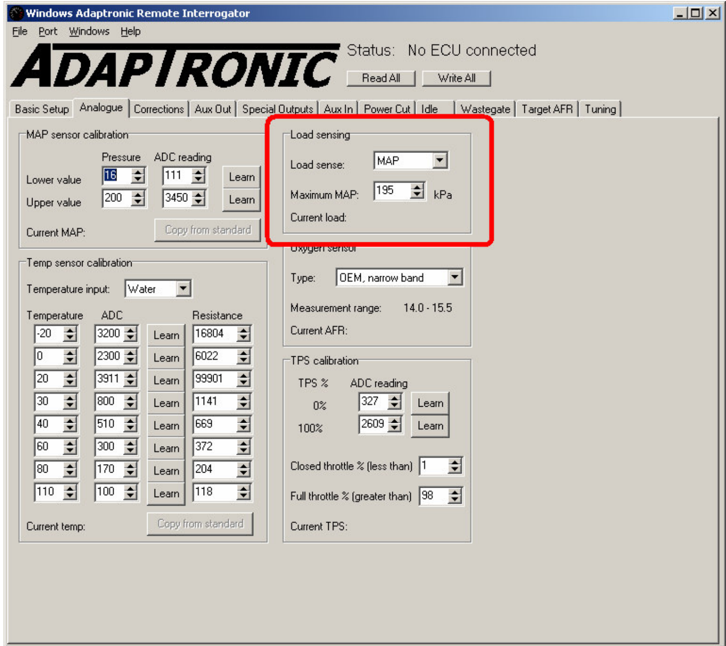

Figure 16: Load Sensing Options

3.1.3. 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)

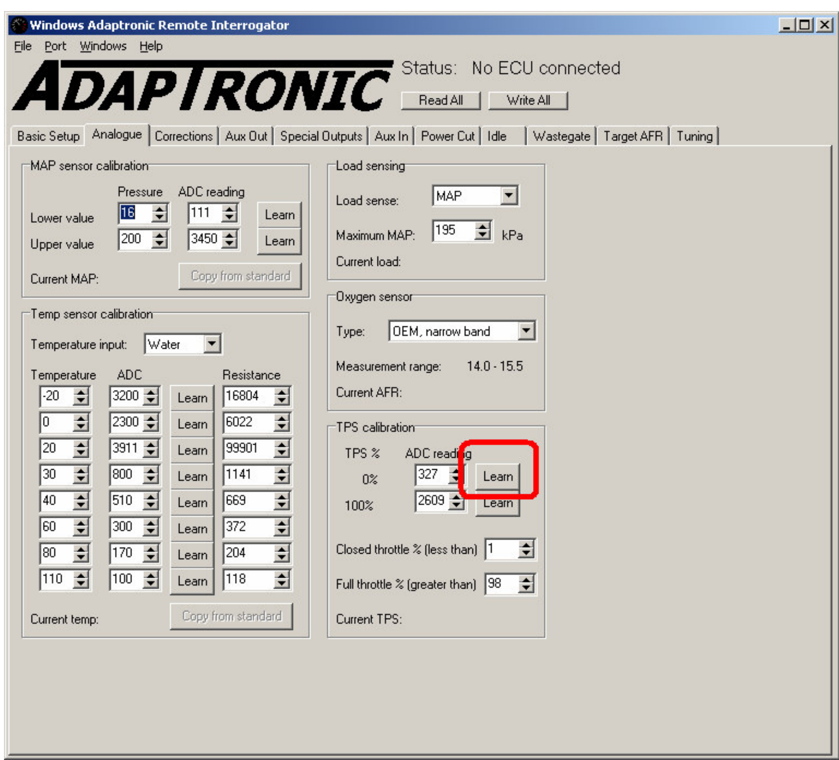

Figure 17: Location of learning button for TPS 0%

- 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 2500 and 4000.
- If the 100% reading is lower than the 0% reading, this indicates that the TPS has been wired back to front. This still should work, however.
- 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).

3.1.4. 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.
- When the engine is running, the AFR readings can be verified.

3.1.5. 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 reluctor 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 reluctor 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.

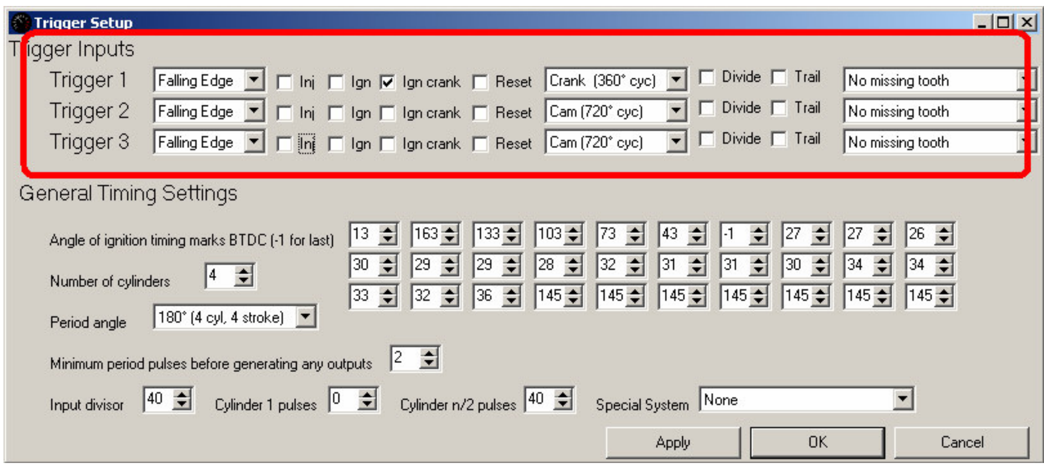

Figure 18: Configuration for checking the timing during cranking

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-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. The others should be used to stabilise the timing by resetting the count. 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. The ECU can also reset its position within the period by detection of missing teeth. This channel should have "Fire Inj" and "Ign / Timing" selected. If it is has no missing teeth, then "No missing tooth" should be selected, and whether Cam or Crank is selected makes no difference. Otherwise, a certain number of missing teeth should be selected for the ECU to detect, and Cam should be selected if it is a camshaft sensor, and Crank should be selected if it is a crankshaft sensor.

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 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 cylinder 3 on a 4-cylinder, or cylinder 1 or cylinder 4 on a 6-cylinder, or cylinder 1 or cylinder 5 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.

Unless a Nissan style optical sensor is used, the Trail and Divide check-boxes should be deselected on all inputs.

Any unused inputs should have all boxes deselected.

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 "Trigger Check" 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.

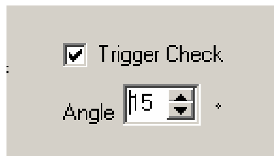

Figure 19: Trigger check option box

3.1.6. 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. 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 (around 70 degrees on the 4-cylinder sensors). 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:

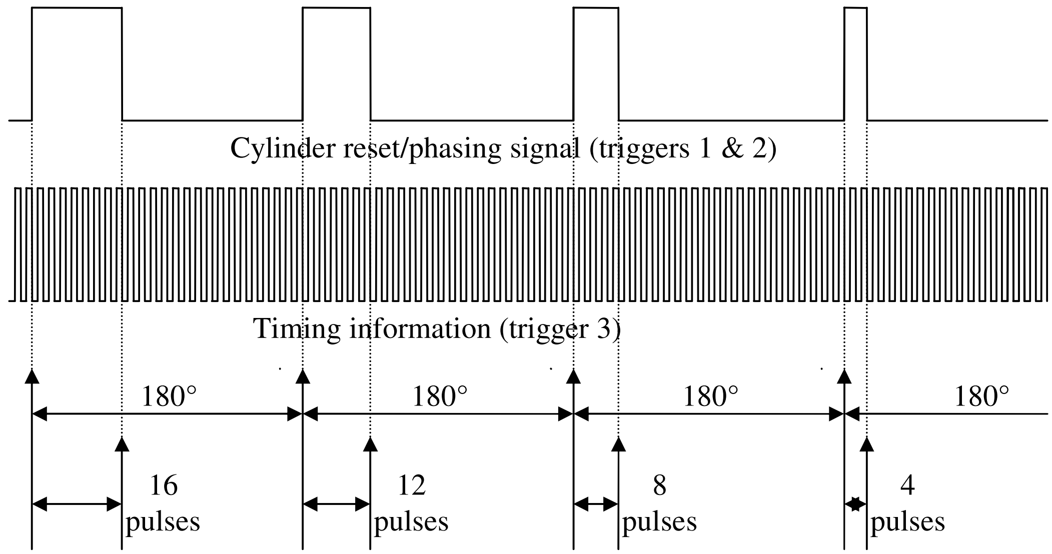

Figure 20: Stylised Nissan cam angle sensor waveform

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

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

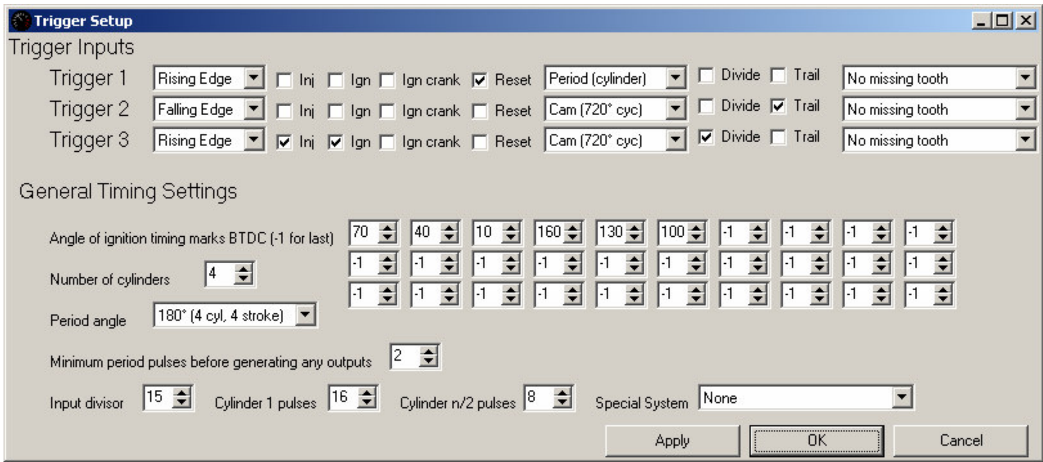

Figure 21: Trigger Example for Nissan SR20DET engine

3.1.7. Cam angle sensor example - 24 + 1 + 1

Consider the following sensor:

- Mazda B5 DOHC (4-cylinder) sensor mounted on camshaft (same as 4AGE sensor)
- 3 reluctor coils
- One triggers every 30° of crankshaft rotation (24 teeth), 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 2 period pulses are required before generating outputs (4 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:

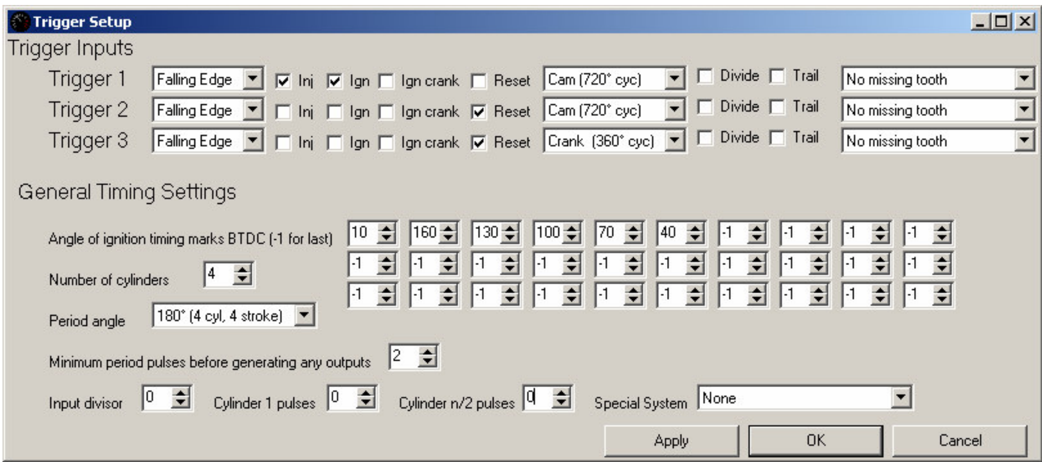

Figure 22: Trigger Example for Mazda B5 DOHC engine

3.1.8. Crank angle sensor example - Honda CBR600

- Honda CBR600 4-cylinder motorcycle engine, sensor mounted on crankshaft.
- Single reluctor 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:

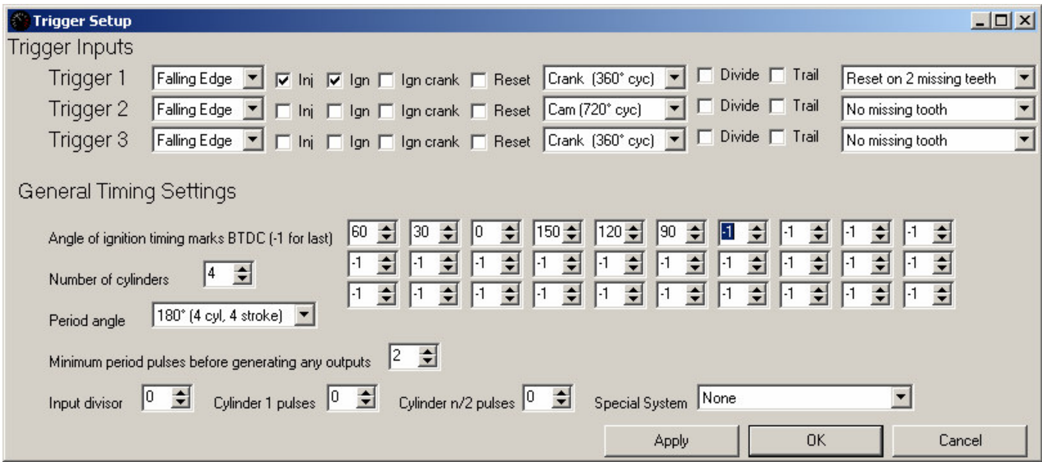

Figure 23: Trigger Example for Honda CBR600 Crank angle Sensor

3.1.9. 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:

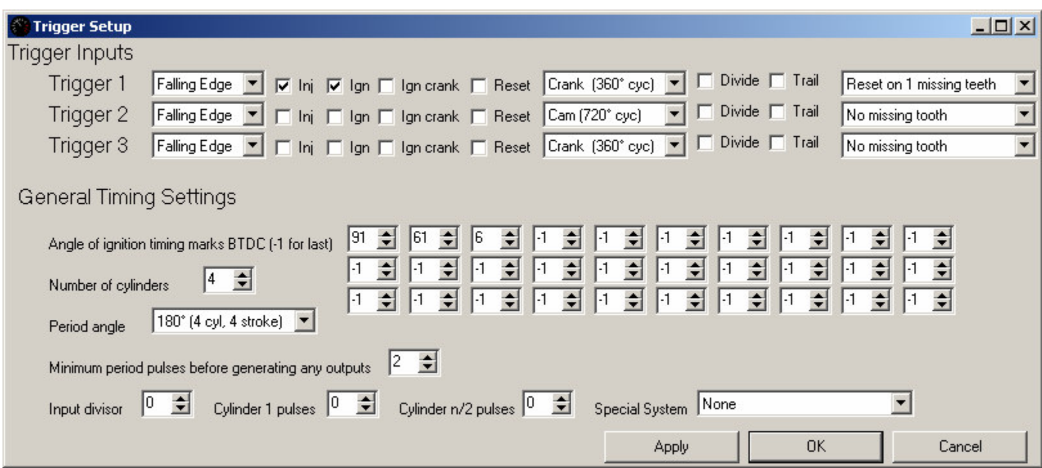

Figure 24: Trigger Example for Suzuki Swift GTi Sensor

3.2. Configuring the Outputs

3.2.0. Injection

3.2.1. Injector Outputs

The Adaptronic has four independent injector drivers. The wiring topologies suggested are described in section 2.7. 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-_-_-_-.....**
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 can be set in the Basic Setup tabsheet.

3.2.2. Ignition Outputs

There are three ignition outputs 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). In both of 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, or wasted spark on a six cylinder engine. 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.

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.

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. Adatronic igniters will shut down after 10ms of a high signal to avert damage to the igniter and the coil, however many, especially those in production cars, will not do this.

The dwell time is the time for which the coil is charged before firing. Typically values between 3000µs (3ms) and 3500µs (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 can be 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.

Clicking the "Configure" button under the Ignition Control pane in the Basic Setup tabsheet allows these values to be configured. It will bring up the following window:

Figure 25: Ignition Configuration Dialogue Box

If a rising edge ignition output sense is selected, a warning message will be brought up.

The Timing Lock feature allows the ignition timing to be fixed when the engine is running to verify the ignition timing.

3.2.3. General Purpose Outputs

The first 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 last four (5-8) are simple on/off, low current outputs, intended to drive LED lights or relay coils.

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 20:

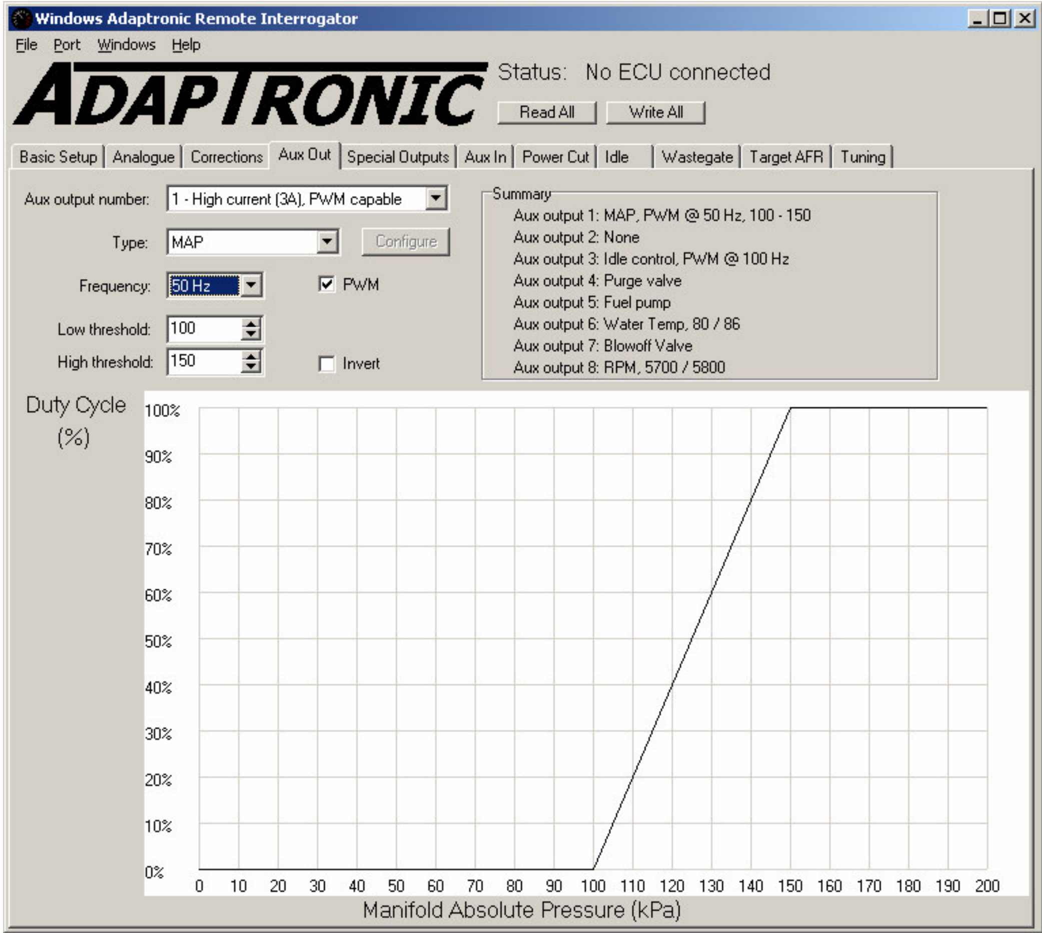

Figure 26: Water Injection Auxiliary Output Example

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:

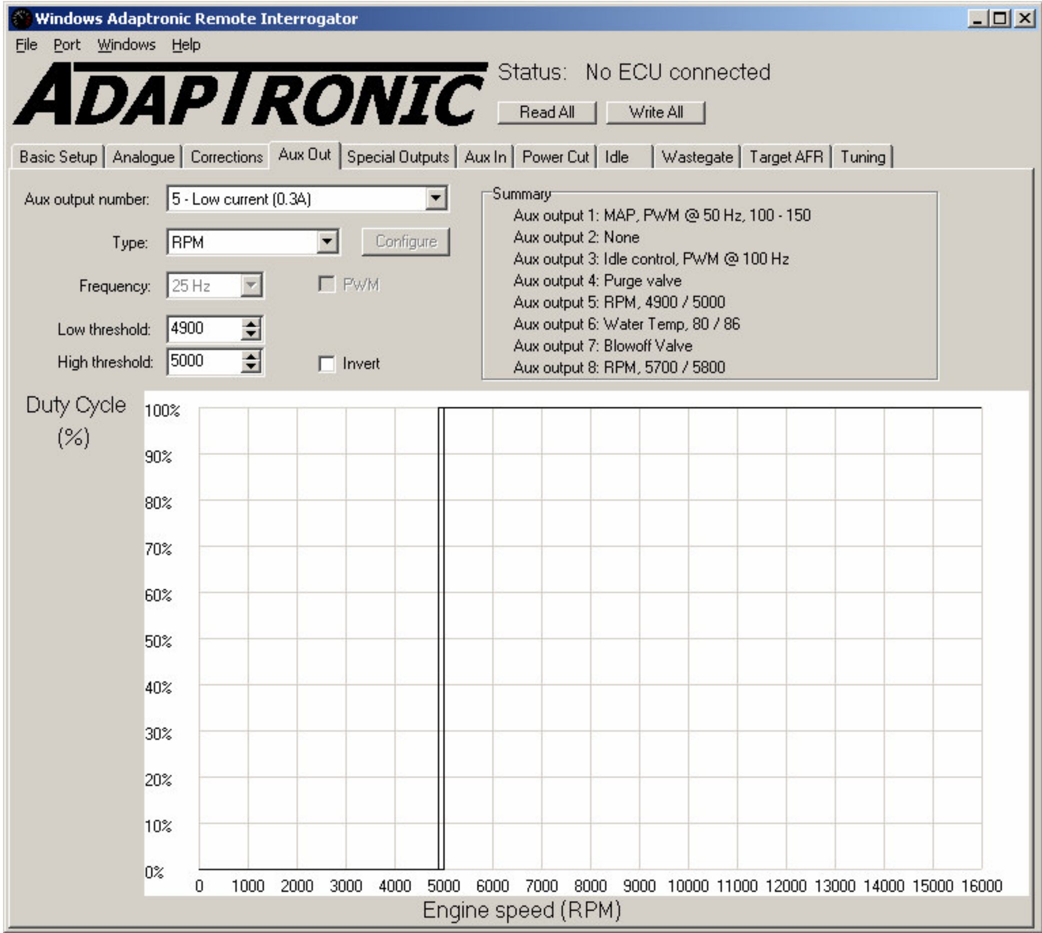

Figure 27: Shift Light Auxiliary Output Example

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):

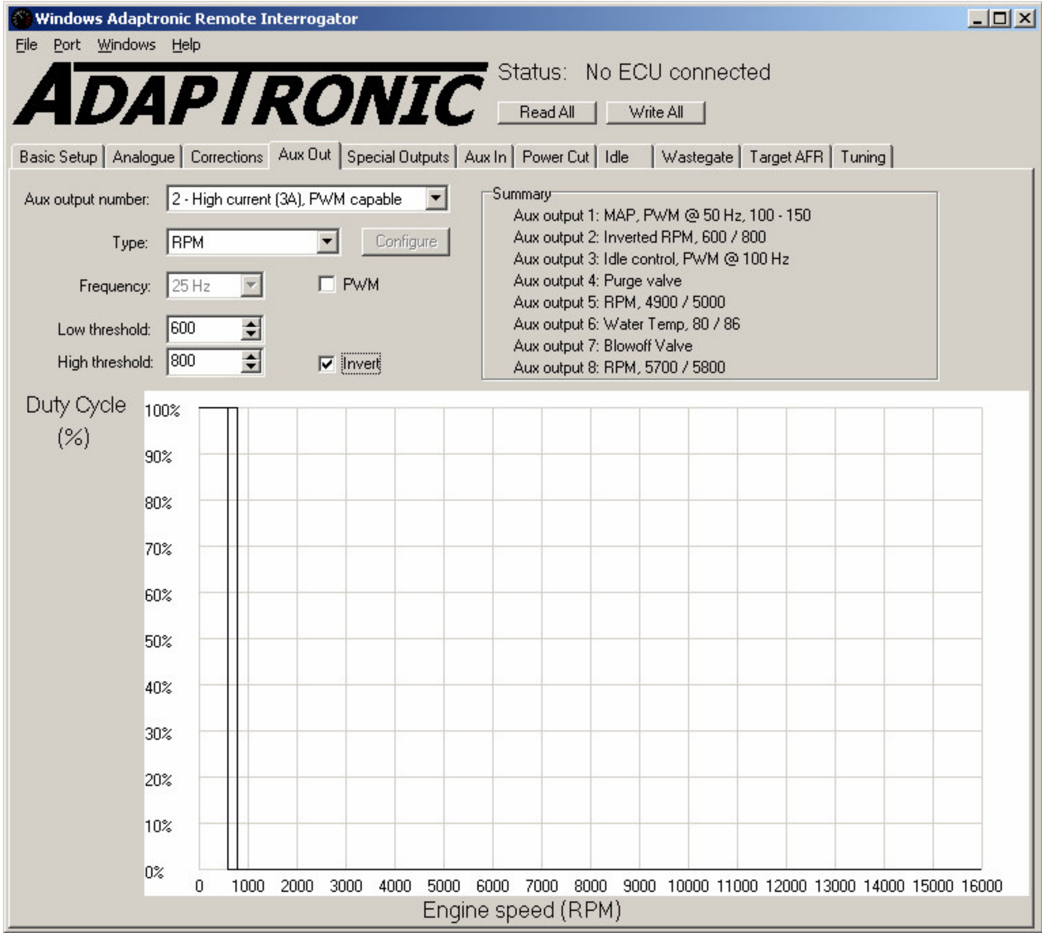

Figure 28: Stall Saver Auxiliary Output Example

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.

3.3. Auxiliary Inputs

These should be configured as required. Each input can be selected in terms of its function, and its 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.

3.4. Special Outputs

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

3.5. Fuel and 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.

To navigate in either map, the cursor keys will move the current cursor position (marked by a blue cell in the text map, and a blue square in the graphic map). Pressing "space" will move the cursor to the current position as indicated by the gauge window. 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.

Pressing "Page Up" or "Page Down" in any map will adjust the current cell up or down. The increment is 0.1ms for the fuel map, and 1° for the ignition map. Alternatively, one can type in a new value and press "Enter" to accept it. Clicking on a cell in the text map will move the cursor to that position.

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).

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.

3.6. Corrections

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

3.7. Target AFR

The desired AFR can be configured in this tabsheet. The values in the boxes are actually the AFR multiplied by 10. Unless you are using a linearised sensor such as an M&W unit, you would be best advised to set the entries all to 147, to tune for stoichiometry.

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.

4. Starting the Engine

4.0. 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 all 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 pulsewidth in the cranking table in the Control window. Try adjusting it upwards at first.

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.

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 that 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 disable the fuel cut all together by deselecting "Cut Fuel" and deselecting "Cut Ignition" in the Special Functions Window. Make sure also that the settings "Write when running normally" is not enabled, but that "Write when stopped" is enabled. If you want to switch off the engine, and you have been modifying the settings with the engine running, stall the engine (by putting the car into top gear and releasing the clutch - make sure your foot is on the brake during this exercise), wait for the fuel pump to stop, wait a few more seconds and then turn off the ignition.

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

4.1. 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 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:

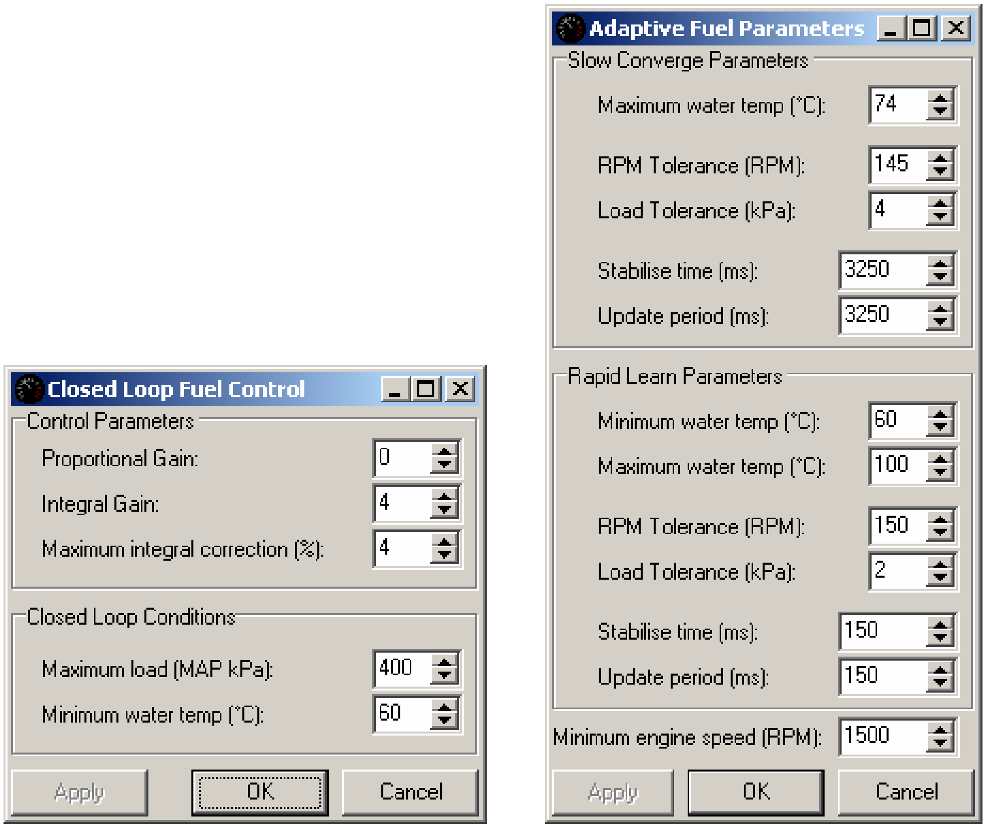

Figure 29: Rapid Learn Settings

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.

4.2. 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 $^{1}/_{3}$ 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).

4.3. 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 64/64.
- 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 MAP and RPM (and injector pulsewidth) at the same time.

Once you have a basis for the pulsewidth 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.

Note that until you have enabled deceleration fuel cut, you should still turn off the engine by stalling it and waiting a few seconds after the fuel pump has stopped. Once you have tuned the no-load conditions, it may be best to enable the deceleration fuel cut so that the settings are updated to EEPROM when you throttle-off.

During normal driving, closed loop mode only is recommended:

4.4. Ignition Tuning

The adaptive ignition tuning mode of the Adaptronic is not as mature technologically as the fuel tuning. Currently it works by advancing the ignition timing until it detects knock, when it retards the ignition timing in the map. There is a drawback to this method, which is that knock only occurs at wide throttle openings, and therefore most of the map can not be tuned in this manner. Therefore, 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.

5. 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), 8-point linearly interpolated calibration, range -127°C to 127°C
EGO input	0 - 1V factory narrowband, or Bosch "wideband" - input impedance 1MΩ, UEGO style analogue, M&W LSU4 and TechEdge 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

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 igniter)
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
Control Characteristics	
Map points	512 - every 500 RPM (0 - 15500 RPM) and 1/15th of maximum load (TPS or MAP)
Load determination	TPS or MAP
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