# Installation and Tuning Manual for Adaptronic Select ECU Range

# FIRMWARE VERSION: 10.000
# SOFTWARE VERSION: 10.000

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## COPYRIGHT NOTICE

## 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 intended for users setting up an Adaptronic Select ECU.
The Select ECU range includes a '440 Universal' model, and numerous 'Plug-In' models.
The 440 Universal model must be installed using a generic 440 Universal Select ECU flying loom, wired up to suit the factory wiring harness (or wired up from scratch). With the plug-in ECUs, some are standalone and completely replace the factory ECU (with minimal wiring, or no additional wiring at all), while some of the plug-in ECUs are to be fitted with the factory ECU retained aswell (again with minimal wiring, or no additional wiring at all).
The first part of this manual explains the Select ECU software and firmware, and how to setup and tune with these ECUs.
The last section of this manual (chapter 5) is only applicable to the 440 Universal Select ECU, and it explains the hardware of the ECU and how to wire it up (you should skip to that section first, unless you are using a plug-in 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. If a 440 Universal Select ECU is being fitted to an existing factory harness, you will need to source a wiring diagram for the vehicle.
2. If a 440 Universal Select ECU is being fitted (tapping into the factory wiring harness, or wiring from scratch), you will need to plan how all the outputs, inputs and triggering will be handled, then perform the wiring process.
3. Set the settings in the ECU in accordance with the input, output and triggering configuration (if you are using a plug-in ECU, which has a fixed pinout, there will usually be a base map that you can use to simplify this step).
4. Verify the operation of the sensors.
5. Verify the operation of the actuators.
6. Verify triggering.
7. Get the engine to run.
8. Tune the no-load conditions.
9. Set up idle control (if applicable).
10. Tune the loaded conditions (preferably on a dyno).
11. Set up other ancillary devices.

# 1. Installing Necessary Applications, Files and Drivers onto Laptop/PC

Adaptronic provides a single installation setup file (available on CD or as a free download from the Adaptronic website), which simplifies the process of installing all of the required files onto your computer. The first thing you need to do is obtain this installer file, and run it.

When you run the installer, it will automatically create a directory on the 'C:' drive of your computer, and in this directory it will place the tuning software ('WARI.exe'), the USB driver files, base maps, Plug-In ECU pinout tables, and a copy of this user manual.

Once you have completed that step, you can connect your Select ECU to your computer using the USB cable. The first time you do this, Windows will show the 'Found New Hardware Wizard', which allows you to install the drivers for the connected device. When this occurs, you will be asked if you want Windows to search for drivers automatically, and you should choose 'No, not this time'. This is shown below:



**Figure 1:** **New Hardware Wizard – step 1**

You should then click 'Next'.

On the next window, you should click 'Install from a specific location', as shown below:

**Figure 2:    New Hardware Wizard – step 2**

Despite the message in bold, you don't need to insert an installation CD if you have already run the installer as described earlier.

You should then click 'Next'.

On the next window, you should select 'Search for the best driver in these locations', and tick 'Include this location in the search'. See below:
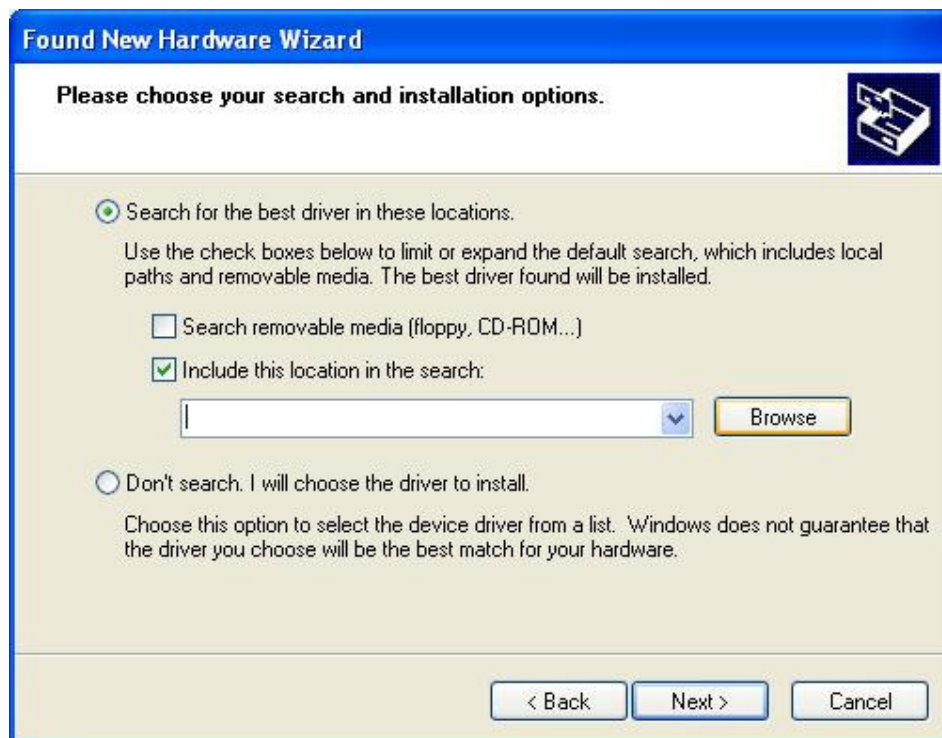


**Figure 3:    New Hardware Wizard – step 3**

You will then need to click 'Browse' and navigate to the directory for the Select ECU on your 'C:' drive, and choose the 'SelectDriver' folder. After this, you can click 'Next'.

At this point, if you see a warning you can click 'Continue Anyway'.
The USB drivers for your Select ECU will then be installed. Once this is completed you can click 'Finish'. From this point on, your Select ECU should be able to communicate with you laptop or PC using the tuning software, which will be described shortly.

# 2.    Initial configuration of the ECU

Note: If you are using a 440 Universal Select ECU, should have already wired up the ECU using the information in the last part of this manual (chapter 5), before returning to this first part of the manual!

## 2.0.    Basic Setup

When you ran the installer as described in section 1, a shortcut was created in the Windows start menu and on the desktop, allowing you to launch the Select ECU tuning software (called 'WARI.exe' – Windows Adaptronic Remote Interrogator). At this time you can run the WARI application and connect you Select ECU using the USB cable (if you haven't already).

The Select ECUs can communicate with the WARI tuning software even if there is no 12V ignition power to the ECU (this is possible due to the 5V power wire inside a USB cable).

Now, with WARI running and the ECU connected, you should verify that WARI can see the ECU. You should see a message such as 'ECU connected' or 'Reading Settings', rather than 'No ECU connected'.
The status should then progress from 'Reading Settings 0%' to 'Reading Settings 100%' as the settings are extracted from the ECU.

Once all of the settings have been read out of the ECU, if you have connected a Plug-In Select ECU with unsuitable settings in its memory, you may be presented with the following dialog box (but not in most cases):
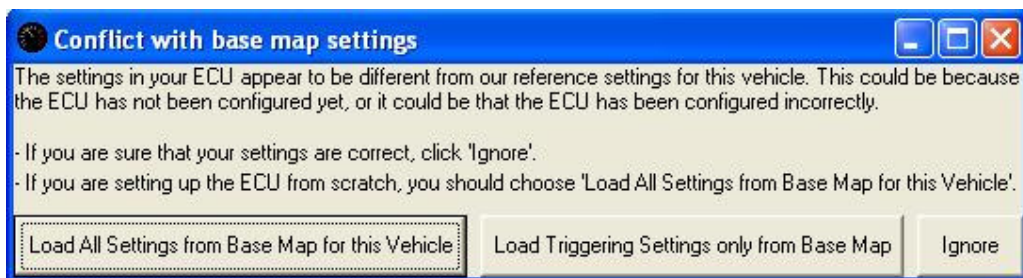


**Figure 4:     Warning of conflict with base map settings**

If this dialog box does appear, it means that WARI has spotted a potentially troublesome discrepancy when comparing the ECU settings to the base map for

corresponding Select ECU. In general this will only occur for tuners who work on many vehicles every day and utilise their own 'tweaked' versions of base maps, or start their own settings from scratch (not recommended for Plug-In ECUs). In this case, if you choose to load the base map settings, you will need to wait for the settings to be written into the ECU (as indicated by the ECU connection status, which will change from 'ECU Connected' to Writing Settings' or 'Updating Settings', with progress from 0% to 100%).

After this is done, your ECU is fully synchronised with the WARI tuning software, and what you see on the screen is a representation of the settings in the connected ECU.
Note: At any time, if the ECU connection status says anything other than '….. ECU Connected', this means that the settings in WARI and the settings in the ECU are NOT completely synchronised (this could be because you have no ECU connected at all, or it could be that settings are currently being written to the ECU or read from the ECU).

Now, before setting up the ECU it would be advisable to have a walk through some of the helpful extras in the software. At any time when there is 12V power to the ECU and a particular sensor is connected, you can see the present value from that sensor by selecting the menu option Windows -> 'Gauges', or by pressing F2. Also, by pressing F11 or selecting the menu item Windows -> 'ECU Data', you can view all of the current inputs, outputs and flags, another invaluable tool in diagnosing any problems with your ECU settings.

Next, the steps of configuring the ECU to run on your vehicle will be explained.

# 2.1. Triggering, Ignition Outputs, Injector Outputs

On the Triggering tabsheet, you will find settings which may need to be adjusted for the correct triggering, ignition and injection on your 440 Universal or Plug-in Select ECU.

See the images below, where the top image shows an example of what you would see if you had a 440 Universal Select ECU connected, and the bottom image shows what you would see if you had a Plug-In ECU connected:
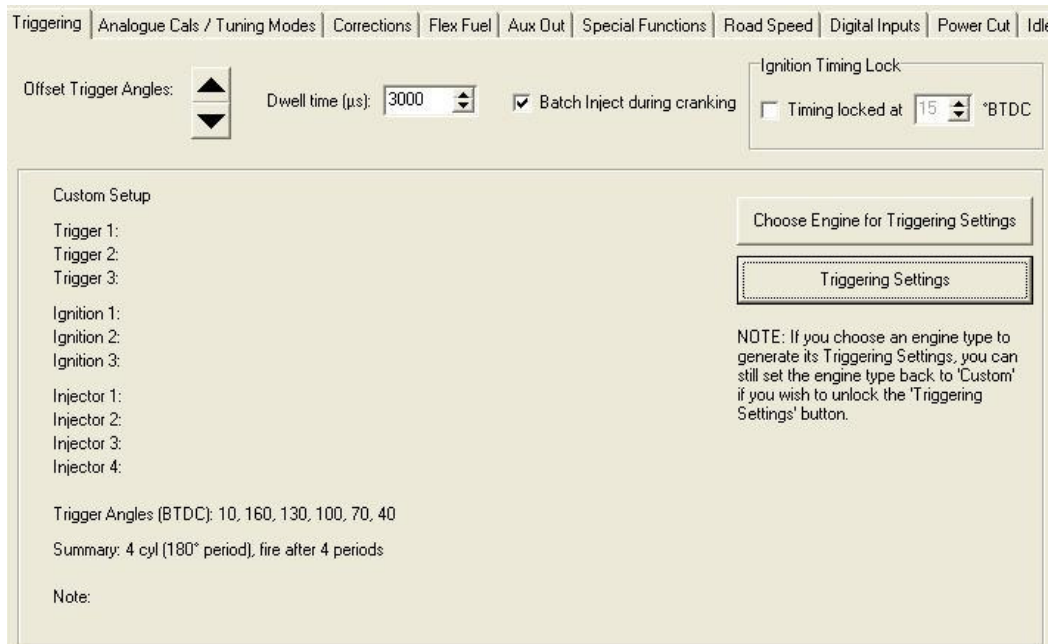


**Figure 5:** **Triggering tabsheet when using 440 Universal Select ECU**
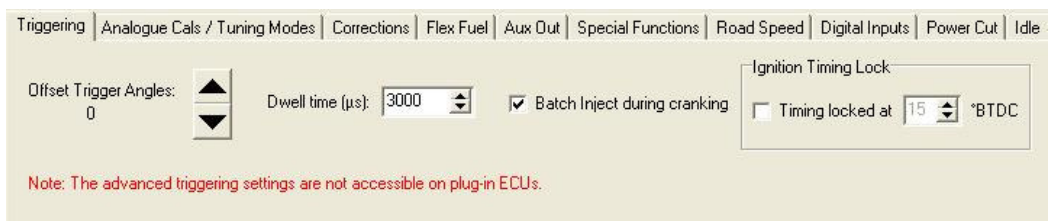


**Figure 6:** **Triggering tabsheet when using a Plug-In Select ECU**

If you have connected a 440 Universal Select ECU, you will have access to many more advanced triggering settings which are VITAL for the correct operation of the engine. These settings can be complicated, so if you have a Plug-In Select ECU these settings will already be done for you (this is why you can't change these settings if you have a Plug-In ECU).

If you have a 440 Universal Select ECU (for which you will need to specify the correct triggering settings), you should click the button labelled 'Choose Engine for Triggering Settings', and check if your engine is in the list. See below:

**Figure 7:** Choosing an engine for pre-defined triggering settings

If you choose an engine from the list, you will see something like this:
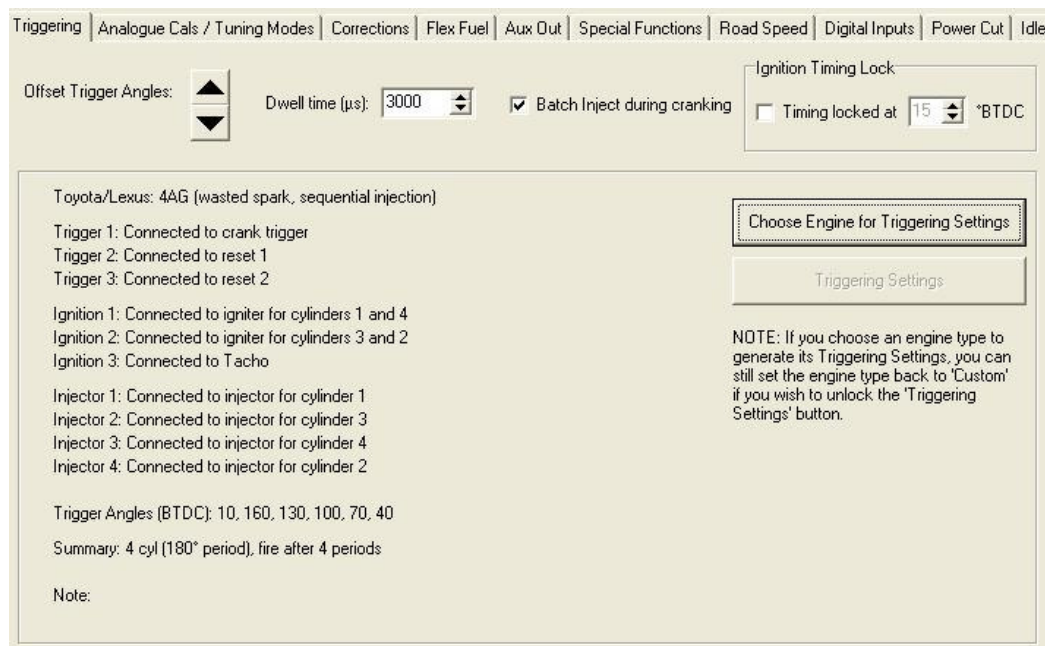


**Figure 8:** After choosing an engine for pre-defined triggering settings

Notice how the WARI software confirms the way that the crank/cam angle sensors should be connected, as well as the ignition and injection outputs.

If your engine isn't available in the list, that is not a problem, you will just need to set it to 'Custom' so you can set the triggering settings yourself. To set the triggering settings, click the button labelled 'Triggering Settings', and you will see something similar to the image below. Note that the settings shown below are for a 4 cylinder Toyota engine (with Toyota's typical 24+1+1 reluctor triggering), running wasted-spark ignition and sequential injection:
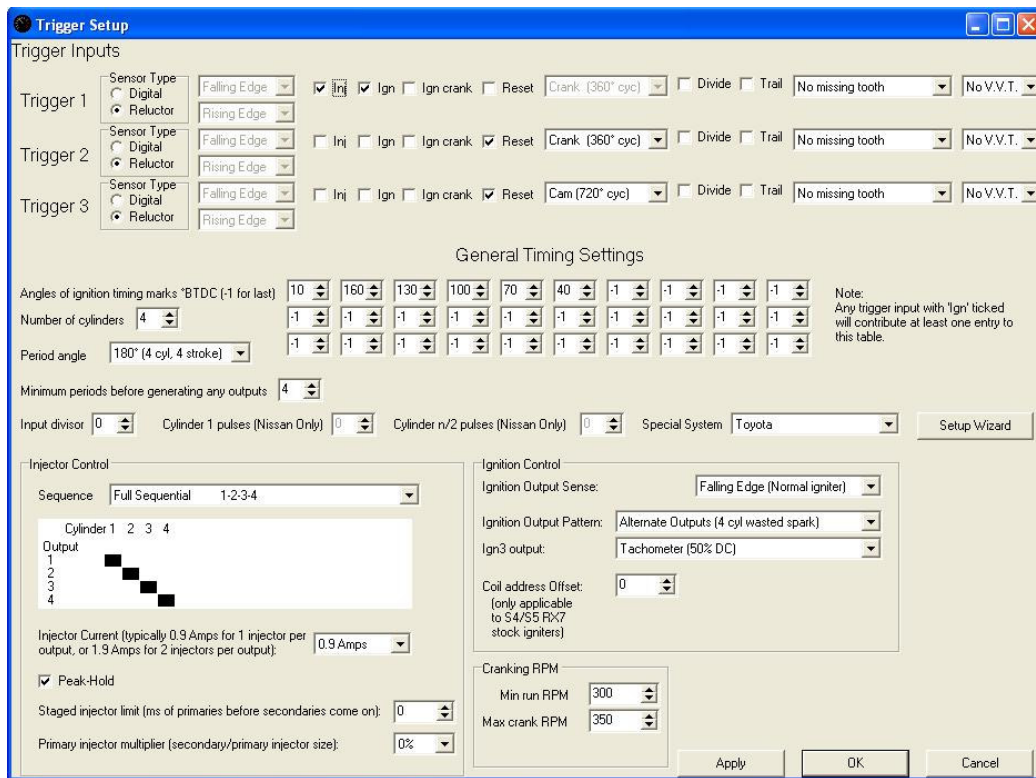
**Figure 9:** The Triggering Settings window

The various triggering settings will be explained next.

## 2.1.0. Ignition Outputs

Refer to the 'Ignition Control' panel on the Triggering Settings window.

There are four ignition outputs on the Select ECUs. Note that if you are using Ignition Output 4 then you won't be able to use Aux Output 1.

The 'Ignition Output Pattern' can be set up in one of the following ways:
- Simultaneously, as on an engine with a distributor. The third ignition output can then be configured as a tachometer function.
- Alternately, as on a 4 cylinder, wasted spark engine or a dual-distributor engine (eg Toyota 1UZFE). The third ignition output can then be configured as a tachometer function.
- In a cycle of three, as in a direct fire ignition on a three cylinder engine, or wasted spark on a six cylinder engine. In this mode, the tachometer output, if required, must be sourced from an auxiliary output, and the ign 3 output function set to ign 3.
- Leading/Trailing, as in on a two rotor Wankel engine with an addressing mode igniter. Currently in this mode the ECU can fire the leading/trailing spark plugs (ign 1/ign 2) via addressing (ign 3 set to coil address) with the factory addressing igniters or with a distributor.
- In a cycle of four, as in direct fire ignition on a four cylinder, or wasted spark on an eight cylinder engine, (ign 3 set to ign 3) and aux 1 set to ign 4.

- Wasted Leading 2 rotor, which allows Ign 1 to fire the leading plugs of a two-rotor Wankel engine in wasted spark mode, while Ign 2 and Ign 3 fire the trailing plugs in direct fire mode.
- Direct Fire 2 rotor, where Ign 1 and Ign 4 are the front and rear leading plugs, and Ign 2 and Ign 3 are the front and rear trailing plugs.

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 on the Triggering tabsheet) 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.

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

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

The dwell time is the time for which the coil is charged before firing. Typically values between 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 allowable is up to double the period, as each output fires only once every two periods. This is one reason why a wasted spark system (or coil-on-plug) is used on high revving engines rather than a conventional single coil/distributor system. If you have not already set the dwell time you should do so now (it may need to be adjusted later if you encounter spark breakdown).

## 2.1.1. Crank/Cam Angle Sensors – General

Refer to the top half of the Triggering Settings window.

Crank/Cam angle sensors are traditionally the most difficult of sensors to configure because of the multitude of different types available. Because of the flexibility of Adaptronic ECUs, they can be configured to a myriad of different sensors. This flexibility also makes the configuration process longer than that on a simpler system.

There are three trigger input channels on the ECU, called CAS 1, CAS 2 and CAS 3. Each of these can be configured as a reluctor (inductive) or a digital (hall-effect or optical) signal input. For digital trigger inputs, each channel can be configured to fire on the rising edge and/or the falling edge. **For reluctor inputs, you can only trigger off the falling edge**.

The ECU 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.

**Any unused trigger inputs should have all boxes deselected.**

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.

The Timing Lock feature (on the Triggering tabsheet) allows the ignition timing to be temporarily fixed while the engine is running, to verify the ignition timing (usually with a timing light).

Also on the Triggering tabsheet, you can use the arrows labelled 'Offset Trigger Angles' to shift the ignition timing so it lines up with the correct timing mark on the crank pulley. This is described in more detail later.

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, remember that the polarity DOES matter (incorrect**

**polarity of reluctor trigger sensors could cause poor trigger detection at low RPM, while still behaving correctly at higher RPM).**

You can now configure the ECU to suit the crank and/or cam angle sensors on your engine.

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 Select ECUs is calculated on a "per period" basis**. This is a throwback to the days of distributors, where a new ignition pattern would occur every period. Each period, a new ignition pulse is generated, and a new injection pulse is generated. The RPM is also measured between periods.

- The most highly accurate sensor (that is, the one with the most pulses per revolution) should be used to measure the ignition timing and to fire the injector. (Tick Inj and Ign) e.g. a multi tooth wheel (If it is has no missing teeth, then 'No missing tooth' should be selected, and whether Cam or Crank is selected makes no difference.)
- Using a multi-tooth wheel, the ECU can also reset its position within the period by detection of missing teeth or an additional reset pulse. In the case of a missing tooth system, a certain number of missing teeth should be selected for the ECU to detect. The "reset type" should also be selected. This will be 'Cam' if there is a single missing tooth per camshaft revolution, 'Crank' if there is a single tooth per crankshaft revolution, and 'Period' if there is a missing tooth for each ignition event.
- Any other input triggers should be used to stabilise the timing by resetting the count (tick 'Reset').

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

The 'minimum pulses before generating any outputs' should be set such that ECU will know exactly where the engine is up to before any outputs occur.

The 'Trail' tickbox is generally only used in combination with some special trigger modes (refer to the 'Special System' list on the Triggering Settings window).

The settings named 'cylinder 1 pulses' and 'cylinder n/2 pulses' allow the ECU to detect cylinder 1 and the opposing cylinder using the 'Trail' option (these settings are unused for many engines, but they are important for many Nissans and a few other engines). The number of ignition trigger pulses between the period reset and the trail event are counted for the purposes of generating a 'cam' or 'crank' reset condition.

The 'Divide' tickbox and the 'Input divisor' may need to be changed if the trigger sensor generates more than 30 pulses per period (there are a maximum of 30 entries in the timing mark table). The 'Input divisor' field determines the division ratio (for example, if it was set to 2, this means that the ECU would ignore every 2$^{nd}$ trigger pulse). If there are missing teeth on the trigger wheel in question, you should not tick 'Divide' on that channel, but instead set the Special System to 'Divide with missing teeth'.

The next step is to populate the table of timing mark angles, by working out the angles of the trigger pulses, in the order that they are received by the ECU as the engine rotates, starting with the first one after the reset pulse (or the missing teeth). These should then be calculated in terms of the angle BTDC of that period (this means that the entries in the timing mark table will be somewhere in the range of 0 to the period angle, eg. 0-180 for a 4 cylinder engine).

These angles should then be entered in the table, in order, with the value after the last pulse being -1. **The -1 is to indicate the end of the table, so any entry after the first -1 will be ignored.**

For example, if you had a 4 cylinder engine with a 12-1 trigger wheel on the crank (12 evenly-spaced teeth but with 1 missing, leaving 11), and the first tooth after the missing one occurred at 10 degrees BTDC, the entries in your timing table would be: 10, 160, 130, 100, 70, 40, -1

Notice how the numbers 'wrap around' at 180 degrees because it is a 4 cylinder engine, and the increment between each entry is 30 degrees (12 teeth * 30 degrees = 360 degrees of crank rotation).

*Resetting and Home Position:*

If there are inputs that provide only synchronisation information, they should have all boxes deselected, except for 'Reset'. If the setting is 'Cam (720°)', then the ECU will be reset to cylinder 1, and also reset to the start of the timing table, when the pulse occurs. If the setting is 'Crank (360°)', then the ECU will be reset to cylinder 1 or the third cylinder in the cycle on a 4-cylinder (usually cylinder 4), or cylinder 1 or the fourth cylinder in the cycle on a 6-cylinder (usually cylinder 6), or cylinder 1 or the fifth cylinder in the cycle on an 8-cylinder. This is because a sensor on a crankshaft can only give 360° worth of information, but can still be of use. If the setting is the 'Period' option, the current position will reset to the start of the angle table, however the current cylinder number will be unaffected. This is useful on sensors which do not provide any cylinder phasing information, such as the Suzuki G13B engine, or a sensor on a throttle-body injected engine, or a sensor inside a distributor where the number of teeth is equal to the number of cylinders.

Once you have set up the triggering, you should make sure all outputs are disconnected, crank the engine, and verify that the RPM indicated in the gauge window reads a steady and sensible value (usually around 150-250 RPM during cranking). If you have set up the ignition outputs (see the appropriate section), you should set the 'Crank timing' (on the 'Corrections' tabsheet) to a reasonable value (eg. 10° BTDC), crank the engine and with a timing light, verify that the ignition pulses occur at the appropriate angle.

As mentioned previously, there is a diagnosis mode that allows the ECU to temporarily fix/lock the ignition timing. By enabling the 'Timing lock' on the Triggering tabsheet, 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.

If you alter the Trigger offset (using the arrows labelled 'Offset Trigger Angles' on the Triggering tabsheet), the angles in the timing mark table will all be adjusted accordingly (this is similar to rotating a distributor to advance or retard the ignition timing).

If you wish to use VVT, you will need to set the cam trigger/s as VVT 1 and VVT 2 on the Triggering Settings window. For further information, see the VVT section in the ECU Reference section.

### 2.1.2. Injector Outputs

Refer to the Injector Control panel on the Triggering Settings window.

There are four independent injector drivers on the Select ECUs.
The Injection Sequence can be changed, and the list of available patterns is flexible enough to cover a myriad of different configurations. The table below shows which injector outputs 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, and the ECU will automatically maintain this current (regardless of whether the injectors are high impedance or low impedance). The injector current should typically be set at 0.9A (for one injector per output), although higher currents can be used if more injectors are installed (for example, 1.9A if 2 injectors are wired to a single output). 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, even with only one injector per output.

### 2.1.3. Specifying the Cranking Condition

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 ('running') operation. However when it goes below a certain speed, the ECU should switch back into cranking mode to ensure that it recovers. These two RPM points should be set in the 'Cranking RPM' panel on the Triggering Settings window.

## 2.2.    Configuring the Analogue Sensors

### 2.2.0.  Manifold Absolute Pressure (MAP)

The Select ECUs allow 'load sensing' by one of the following methods:

- An internal 4 bar MAP sensor inside every Select ECU
- An external MAP sensor (purchased separately, almost any brand can be used)
- Using the stock Mass Air Flow (MAF) meter (if applicable, and only if Adaptronic have characterized that particular type of MAF sensor).

Note that if your car was originally naturally aspirated with a MAF sensor, but has been converted to forced induction, then you must use a MAP sensor instead of the stock MAF sensor!

As shown below, you must select your load sensing option in WARI on the 'Analogue Calibrations' tabsheet:
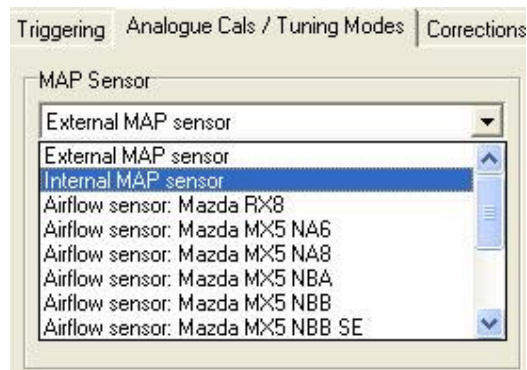


**Figure 10:    Choosing the load sensing option**

If you are using an external MAP sensor, the sensor must be calibrated. See the image below:
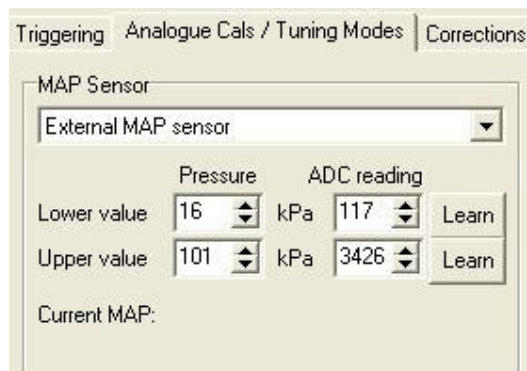


**Figure 11:    External MAP sensor calibration**

- Open the Analogue Calibrations 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.
- Apply this vacuum to the MAP sensor, and click the 'Learn' button (Note that 16kPa absolute pressure is the same as about 64 cm/Hg of vacuum).
- 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 have a way of applying 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'.

If you are using the internal MAP sensor inside the Select ECU, you may need to adjust the 'Internal MAP sensor offset', as shown below:



**Figure 12:    Internal MAP sensor offset**

You should see a reading of 100kPa at atmospheric pressure.


## 2.2.1.  Temperature Sensors


Refer to the 'Temp sensor calibration' panel as shown below:



**Figure 13:    Temperature sensor settings**

Each temperature sensor input on the Select ECUs (Water Temperature, Air Temperature, Aux Temperature) has its own calibration table. There is also a tickbox to specify whether the temperature inputs are 'biased' (pulled-up) inside the Select ECU (this will usually be ticked, except for some piggyback Select Plug-In ECUs which share temperature sensors with the factory ECU).
You may choose to enable a firmware-based filter (with a 1 second time constant) for the temperature readings, to make them more stable.

*Calibrating the 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, and populate the calibration table (see below):
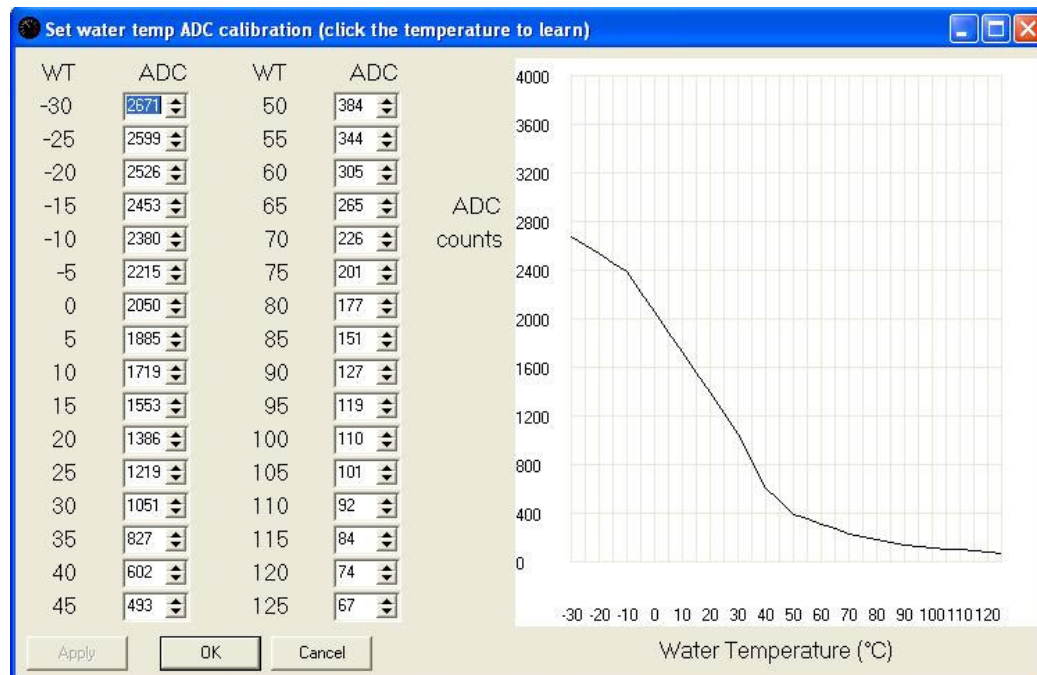


**Figure 14:  Temperature sensor calibration**

- It can be easiest to start at the hottest temperature by heating the sensor up to just above the maximum temperature (125°C). Stop heating the sensor.
- With a thermometer installed, monitor the temperature of the sensor.
- As the temperature falls through its operating range, 'learn' the ADC reading for each appropriate temperature by clicking on the temperature number (you will see the cursor changed to a pointing hand).
- Ensure that the sensor cools slowly so that the thermometer is reading the sensor temperature accurately. This may be facilitated by heating it gently, or immersing the sensor and thermometer in oil or water (not water at 125°).

- Once the sensor gets down to ambient temperature, repeat the process by freezing the sensor to its lowest reading, and allowing it to heat up to ambient, and learning the ADC readings as it reaches the appropriate temperatures.

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

ADC Value = $\frac{4095 \times ((4.878 * Resistance) / (4.878 + Resistance))}{6.6}$

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

### 2.2.2. Throttle Position Sensor (TPS)

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

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



**Figure 15:    TPS calibration**

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

- If you are using a TPS switch this will need to be set under the Aux in tab.

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

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

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

### 2.2.4. Units Selection

You may elect for some settings to be displayed in different 'units', for example temperatures in Degrees Fahrenheit or Degrees Celsius. See below:
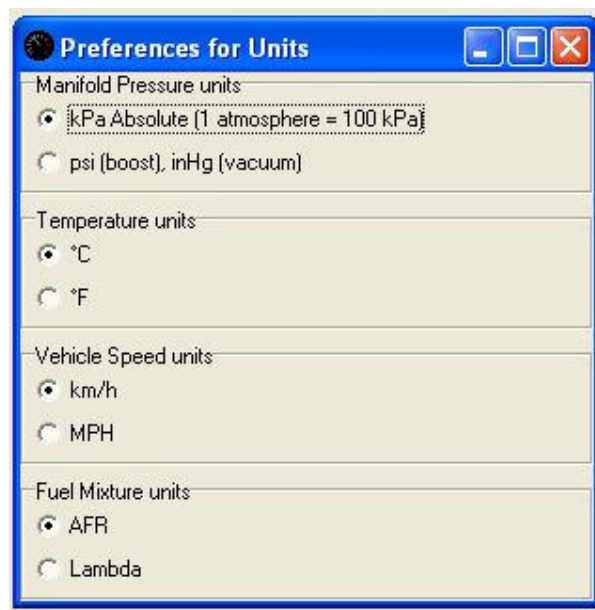


**Figure 16:    Preferences for Units**

The Units preferences are accessed from the 'Options' menu.

### 2.2.5. Knock Sensor

Note that there is a 3.5mm headphone jack on the Select ECUs, which allows you to listen to the signal coming from the knock sensor.
The knock sensor picks up detonation but also picks up a lot of engine noise.
This mechanical noise depends mainly on the engine speed, therefore to avoid the knock sensor interfering with normal engine operation you should set the background knock level to a level slightly above normal engine noise. This can be done by temporarily using very conservative ignition timing (so that real knock will not occur), then fill in the background knock level table throughout the rev range. The ECU will subtract the values in the background knock level table from the sensed knock level, so normal engine noise will be mostly cancelled out.

## 2.3.     Auxiliary Outputs

The easiest outputs to configure are general-purpose digital outputs. The first four (1-4, on the 6-pin plug) 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 aux outputs (5-8) are simple on/off, low current outputs, intended to drive relay coils or LED lights.

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, 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 below:
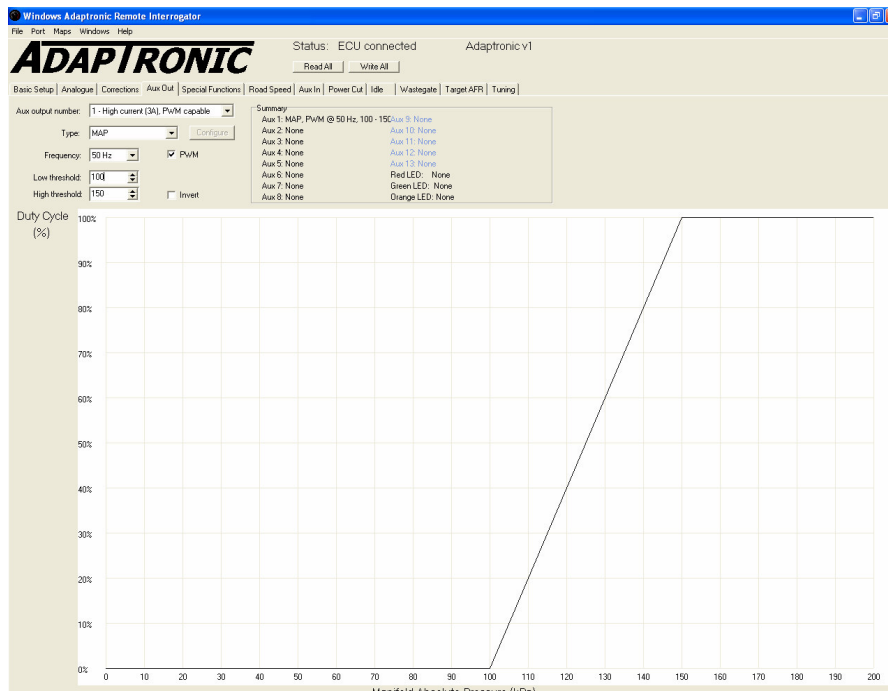
**Figure 17:    Water Injection Auxiliary Output Example**

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 below:
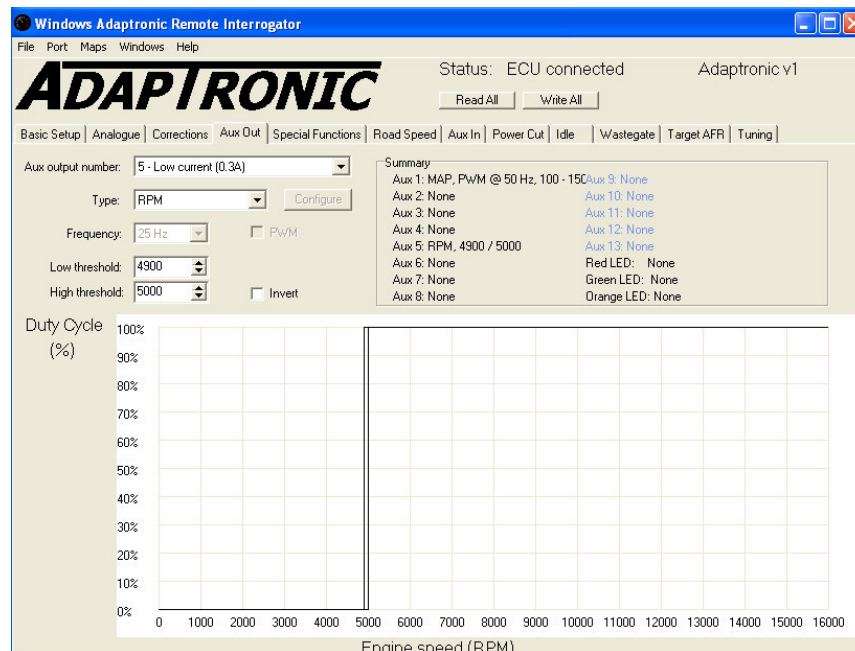


**Figure 18:    Shift Light Auxiliary Output Example**

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 shown below (note that in practice you would simply set up the idle speed control correctly, however this serves as an example):
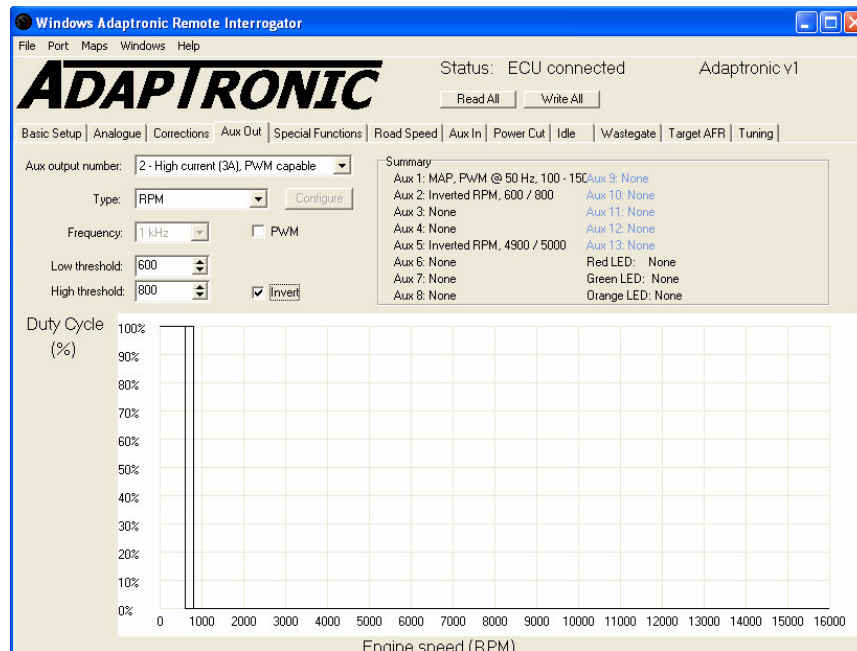


**Figure 19:    Stall Saver Auxiliary Output Example**

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

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

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

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

### 2.3.0.  'Logic Only' Outputs

The Aux Outputs can also be set to perform a logical 'AND' or a logical 'OR' function. When you set an output to one of these behaviours, you then need to specify two of the Logic-only 'Output Channels' which will be ANDed or ORed together to determine the on/off state of the output in question. For example, you might set Aux Output 2 to 'AND' type, and set the 'Output Channels' to 9 and 10, then set (Logic Only) outputs 9 and 10 to their own particular behaviour like any other aux output, and the end result will be that Aux Output 2 will turn on when Output 9 AND Output 10 are BOTH 'true'.
See the Digital Inputs section for other related information (if a logic-only output is active, the logic-only input of the same number will be considered active too).

## 2.4.      Special Functions

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

## 2.5.      Road Speed

There are four vehicle speed inputs on the Select ECUs, as follows:
- *MVSS 1* (Master Vehicle Speed Sensor 1 = default VSS signal from speedometer, or VSS input from powered right wheel)
- *MVSS 2* (Master Vehicle Speed Sensor 2 = VSS input from powered left wheel)
- *SVSS 1* (Slave Vehicle Speed Sensor 1 = VSS input from un-powered right wheel)
- *SVSS 2* (Slave Vehicle Speed Sensor 2 = VSS input from un-powered left wheel)

With 4x VSS inputs, this allows you to have separate master vehicle speed sensors on each driven wheel, and separate slave vehicle speed sensors on each un-driven wheel (this is only useful for traction control).
These wheelspeed signals can come from reluctor/inductive sensors (such as typical ABS sensors) or from hall-effect digital sensors.
The ECU measures the period between pulses and divides this into a number to arrive at a number proportional to road speed. If the ECU receives no pulses in a one second period, the speed for that input is set to zero.
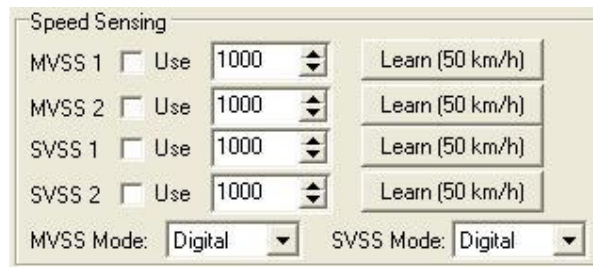
To calibrate the proportionality and achieve the VSS reading in km/h, either drive at 50km/hr and press the 'Learn' button (see below), or enter an arbitrary number and adjust it until the vehicle speed indicated at the ECU corresponds to the actual vehicle speed.
Note that the MVSS value on the gauge window will be the average of MVSS 1 and MVSS 2, and the SVSS value will be the average of SVSS 1 and SVSS 2.
The signal on a VSS input will be ignored unless the corresponding tickbox is checked on the Road Speed tabsheet. See below:
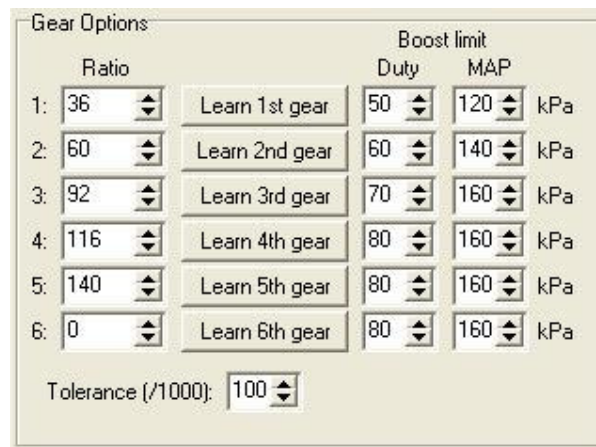
**Figure 20:    Vehicle Speed Sensor calibration**

## 2.5.0.  Gear Options

Under gear options, the user can set the ratio between rpm and road speed. To do this, enter the road speed that correlates to 1000rpm in the appropriate gear (note that this is not the actual gear ratio). See below:
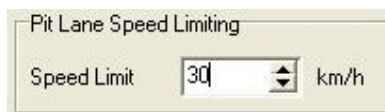


**Figure 21:    Gear Options**

Alternatively, you can click 'Learn' for each gear (you do not have to be at 1000 RPM to do this).

## 2.5.1.  Pit-Lane Speed Limiter



**Figure 22:    Pit Lane speed limiting**

Whenever a digital input (configured for pit lane speed limiting) is enabled, fuel will be cut whenever the vehicle speed exceeds the specified value (as in the above image).

### 2.5.2. Launch Control

This is set up in the panel shown below, from the Road Speed tabsheet in WARI.
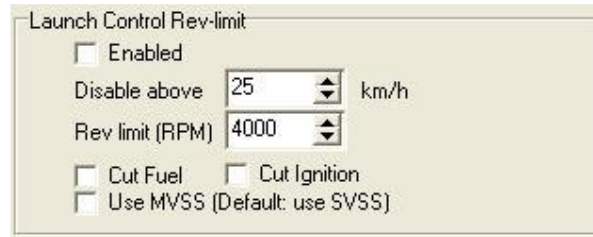


**Figure 23:    Launch Control panel**

This launch control feature is simply a secondary rev limiter. The 'Rev limit' setting defines the RPM that the launch control rev-limiter aims for.
When the RPM is within 200 RPM of the rev-limit, half of the cylinders will be killed. When the RPM exceeds the rev-limit, all of the cylinders will be killed. You can choose to cut fuel and/or ignition to kill the cylinders.
You can specify a road speed above which the launch control rev-limit will be de-activated.
If there is no slave-speed sensor installed, you can use a master-speed sensor to determine an approximate road speed. It is also possible to use launch control with no vehicle speed sensors fitted, but it would only work when the car is stationary (with the disable speed set to zero), and you would need a switch to disable it.
NOTE: To avoid conflict between the launch control and flat shift rev-limits, it is necessary to exceed a vehicle speed of 5 before any flat shifting can occur.

Note that there is an optional digital input type called 'Launch Control Enable', which gets logically OR-ed with the 'Enabled' tick box shown in the above image. If you wanted to use the digital input, you would normally disable the tick box so only the input will have an effect.
There is also a 'Launch Control Status' Aux Output type, intended for an LED indicator, which will be activated whenever the launch rev-limit is in effect.

### 2.5.3. Traction Control

This is set up in the panel shown below, from the Road Speed tabsheet in WARI.



**Figure 24:    Traction Control panel**

The purpose of traction control is to prevent excessive wheel slip during hard acceleration, and when exiting corners. This requires at least one master speed and one slave speed sensors to be installed, but it is preferable to have 4x VSS signals so the ECU can account for differences in wheel speed at the inside and outside wheels during a corner.
The wheel slip is controlled via ignition retardation and/or killing of half the cylinders, with a PID controller algorithm (refer to the idle control section for more information on PID control).

The traction control parameters will now be explained:

- 'Change-over road speed' - when the vehicle speed is below or above this value, different values can be applied for the 'Maximum Retard', 'Target Slip', 'Effort to cut timing by max retard' and 'Effort to kill half cylinders'. This allows the harshness of the system to be increased/decreased at higher speeds.

- 'Effort to cut timing by max retard' - as the PID controller effort approaches this value, the amount of ignition retard will be linearly increased up to the 'Maximum Retard' value, and then it will be clipped. If, for example, the 'Maximum Retard' was set to 20 degrees and the 'Effort to cut timing by max retard' was set to 100, a PID control effort of 50 would generate 10 degrees of ignition retard.

- 'Effort to kill half cylinders' - Once the PID controller effort reaches or exceeds this value, fuel or ignition will be cut in half of the cylinders. NOTE: if you only wanted to use ignition retard to control the slip, you would set the 'Effort to kill half

cylinders' to zero. Alternatively, if you only wanted to use cylinder-killing to control the slip, you would set the 'Effort to cut timing by max retard' or the 'Maximum Retard' to zero.

- Typically, one would specify moderate settings when below the 'Change-Over Road Speed' (to control launching wheel-slip), and then have a higher 'Maximum Retard' and/or lower values for 'Effort to cut timing by max retard' and 'Effort to kill half cylinders' when above the change-over speed (to control wheel-slip upon exiting corners etc). You may want to set the 'Effort to kill half cylinders' to zero when below the change-over speed, so cylinders will only be cut when slip occurs at higher speeds.

- The target slip can also be ramped down to the 'Target wheel slip at max turn', as the difference in slave vehicle speeds (on either side of the car) approaches the 'Slave-Speed difference at Max Turn'.

- If the 'Slip adjustment via POT on external input' tick box is enabled, the target slip will be taken from the External input (this only applies when above the "min road speed"), otherwise the value in "target slip" will be used. Typical target slip values would be between 10% and 20% in normal dry conditions, or between 5% and 10% in wet conditions, or around 5% in icy conditions.

- 'Allowable wheel slip error' - if, for example, this was set to 2%, the slip would be considered to be on target if it was anywhere between the target and the target + 2.

- 'Min engine speed' -> this RPM must be exceeded before traction control starts to do anything at all.

Note that there is an optional digital input called 'Traction Control Enable', which gets logically OR-ed with the 'Enabled' tick box shown in the above image. If you wanted to use the digital input, you would normally disable the tick box so only the input will have an effect.
There is also a 'Traction Control Status' Aux Output type, intended for an LED indicator, which will pulse on and off whenever the system is actively reducing slip, or it will remain on when below the slip target. If traction control is disabled, the traction control status output will be off.


## 2.6.    Digital Inputs

These should be configured as required. Each input can be selected in terms of its function, and can be set to 'active high' or 'active low'.

If multiple inputs are configured to the same function, either input will activate the same 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 'Digital Inputs' tabsheet.

### 2.6.0. 'Logic Only' Inputs

Each of the logic-only inputs corresponds to a logic-only output. For example, if auxiliary *input* 11 was set to 'enrich/retard', you could specify logic conditions on auxiliary *output* 11 that would cause an enrich/retard to occur. **The relevant logic-only input should be set to 'active high'**.
Refer to the Auxiliary Outputs section for more details.

## 2.7.      Power Cut, Idle, Wastegate

Refer the equivalent sections in the ECU operation section later in this manual.

## 2.8.      Target AFR

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

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

## 2.9.      Fuel Maps and Ignition Maps

The Select ECUs have two fuel maps and two ignition maps. The fuel and ignition maps can be activated and swapped between by pressing F5. Each of these is a two-dimensional array (although more commonly referred to as '3D'), 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 % Volumetric Efficiency, or the ignition angle in degrees BTDC (as described later in this manual).

See below, an example of an ignition map based on MAP (kPa):
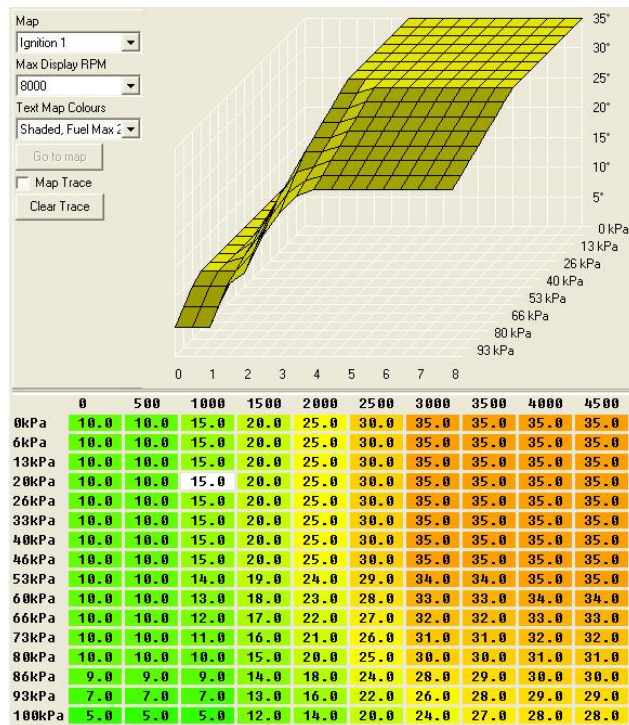
**Figure 25:    Example tuning map**

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

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

You can also copy and paste values using Ctrl+C and Ctrl+V, but this can only be done in a single instance of the WARI software application.

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

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

| | |
|---|---|
| Interpolate: | For a single column or single row selection, the values are linearly interpolated between the two endpoints For a rectangular selection, the four corners are used and the values interpolated between these |
| Select All: | Select entire map (for making overall changes) |
| Add/Subtract percentage: | Add or subtract a percentage value to the selected region. An offset can be added or subtracted using the PgUp/PgDn keys. |
| Mark as tuned: | Any cell can be marked as tuned or as untuned. This allows the tuner to record which cells have been tuned and which cells have not. Whether a cell is tuned or untuned also has significance for the adaptive tuning modes. |

# Starting the Engine

## 2.10. 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 150 - 250 RPM). Set up a timing light to verify the ignition timing during cranking; it should be as specified in the trigger/output window. If it is not, or the spark does not occur at a consistent angle, you have a triggering problem.

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

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 Triggering Settings window), and adjust the fuel pulse width in the cranking table on the Corrections tabsheet. Try adjusting it upwards at first. With too much fuel, the engine should start if the throttle is opened (unless you gradually foul the plugs).

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

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

that it idles higher 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 set the minimum coolant temperature for the overrun fuel cut to a very high value (eg 120 degrees).

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

## 2.11.    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:
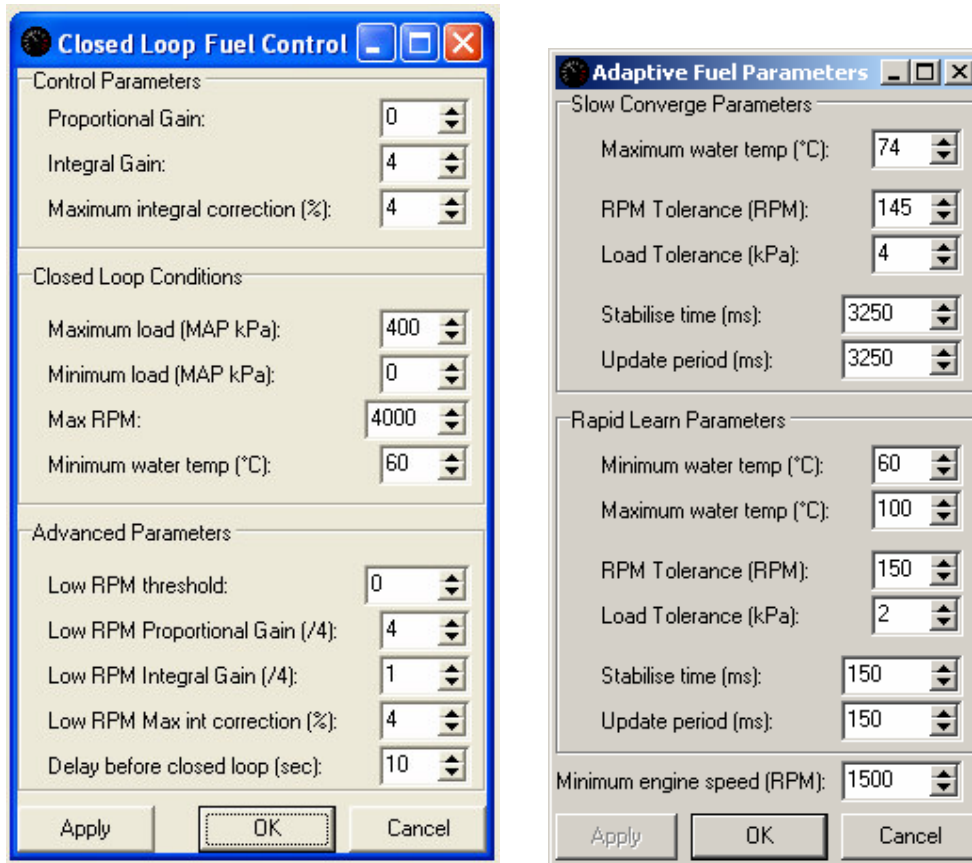


**Figure 26:    Rapid Learn Settings and Closed Loop Fuel Settings**

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.**

## 2.12. 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 ECU 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 Closed-Loop Fuel Control window. These are the 'proportional gain' and 'integral gain' terms:

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

For initial tuning, the recommended values are:

- Proportional gain: 2
- Integral gain: 4
- Maximum integral correction: 4% - 8%

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

- Proportional gain: 2
- Integral gain: 1
- Maximum integral correction: 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).

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

- Try using different gain values; if the map is changing too fast and oscillating back and forward, try smaller gain values and/or smaller maximum integral. If the map is not changing at all, try using higher gain values.
- Try using different tolerances. If the map is oscillating (that is, the ECU changes the values one way, then revisits the site and changes them back

again), it may help to reduce the tolerances. First try reducing the load tolerance, then the RPM tolerance. If the map is not changing at all, try increasing the tolerances. Try to avoid going above 96 for load or RPM; if the Load OK or RPM OK LEDs are not coming on, you will need to artificially place the engine under that condition (by adjusting the throttle, turning on electrical loads etc).

- Try using different timings. If the map is changing too quickly and oscillating, try using longer delays and intervals.
- You can help the ECU by adjusting the map values by hand to speed up the process. Humans are particularly good at spotting anomalies in the fuel map (especially a graphic map).

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

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

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

Here is one approach to do this:

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

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

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, etc. **NOTE: this will wear out the brakes**).

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

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

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

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

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

During normal driving, closed loop mode only is recommended:


## 2.14.    Ignition Tuning

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

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

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

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

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

# 3.    Software Guide

This section contains information on some of the features of the WARI tuning software.

## 3.0.    WARI (Windows Adaptronic Remote Interrogator)

### 3.0.0.  WARI Menus

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

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

Under the 'Windows' menu you can view the current 'Live Gauges' which are important for engine tuning and general diagnosis (shortcut F2).
There is also an 'ECU Data'' window (shortcut F11) which provides some extremely useful diagnostic information.

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

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

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

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

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

(xx.x) represents the timing of the leading plug and the second (yy.y) is the timing of the trailing plug.

**Inj: xx.x (yy.y/zz.z)**

The first value (xx.x) is the normal/primary injection duration, and the bracketed values (yy.y/zz.z) are the secondary injection durations (for staged injection).

**VVT 1 / VVT 2: xx.x (yy.y° zz%)**

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

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

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

### 3.0.1.  WARI Settings Management

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

WARI uses the following rules to synchronise the settings:

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

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

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

the ECU. Note: pressing 'OK' is equivalent to pressing Apply then closing the window.

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

### 3.0.2. ECU Data Window, and 'Calculation Trace'

The **ECU Data Window** can be accessed using the menu 'Windows -> ECU Data', or by pressing F11. It gives much useful diagnostic information to aid in setup, including all analogue voltages, numerous flags to show the state of the ECU, and more. Below is a screen shot:
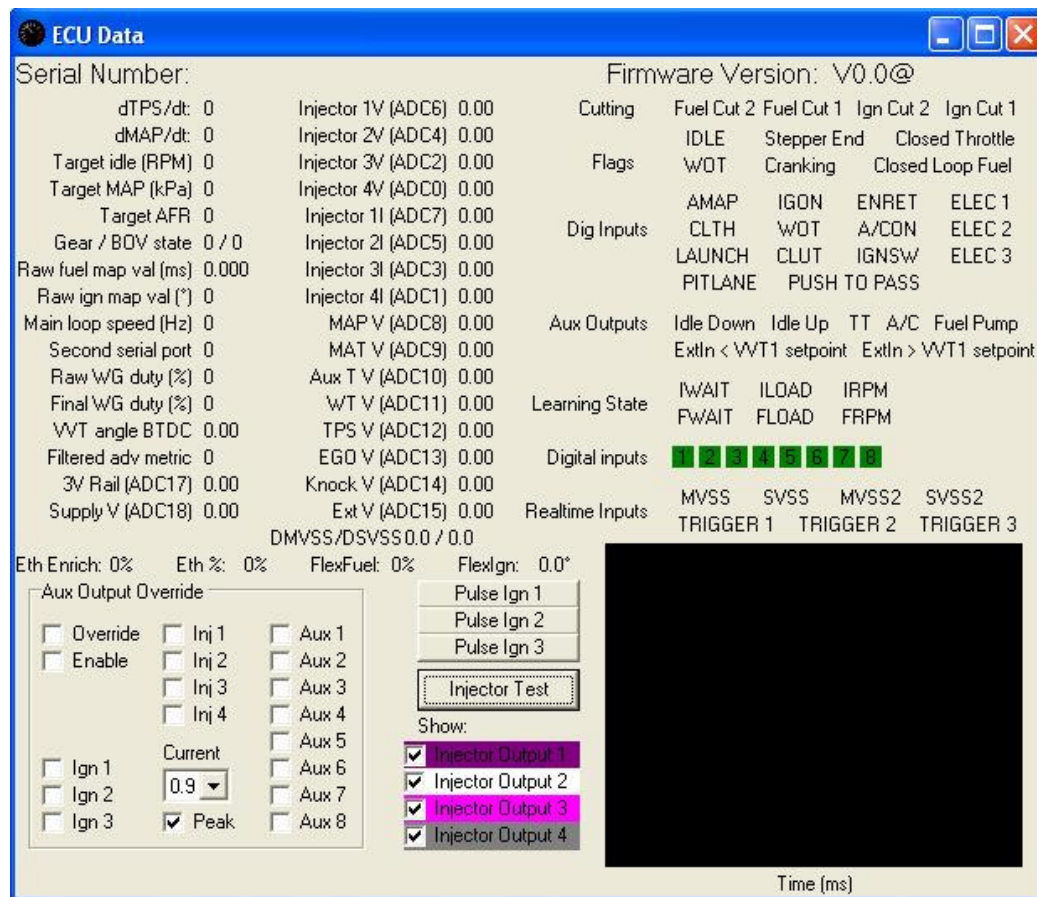


**Figure 27:    ECU Data window**

| Label | Meaning |
|---|---|
| Serial Number | Serial number of the ECU hardware itself. |
| Firmware Version | ECU Firmware version loaded into the ECU. |
| dTPS/dt | Rate of change of throttle position (how quickly throttle is being opened) |
| dMAP/dt | Rate of change of MAP |
| Target idle (RPM) | The target idle RPM (see idle function) |
| Target MAP (kPa) | The target MAP (see boost control function) |

| | |
|---|---|
| Target AFR | The target AFR. If the ECU is currently in open loop mode (due to a setting or a condition), this will not give a reading. |
| Gear / BOV State | The number before the slash is the detected gear number from correlation of RPM and vehicle speed. The number after is the blow-off valve control state. |
| Raw Fuel MapVal | Injector millisecond value (or %VE value) interpolated from the fuel map (s), before application of any trims. |
| Raw Ignition Map Val (degrees) | Ignition degree value interpolated from the ignition map (s), before application of any trims. |
| Main Loop Speed (Hz) | Speed of main loop calculation (varies with functions selected) |
| Second Serial Port | State of second serial port (values and their meanings not documented) |
| Raw WG Duty (%) | Raw wastegate control duty cycle interpolated from RPM dependent table |
| Final WG Duty (%) | Final wastegate control duty cycle after closed loop control changes. This is the same as on the Gauge window. |
| VVT Angle BTDC | VVT angle sensed. This is the same as on the Gauge Window. |
| Filtered Advance Metric | This is the same as on the Gauge Window (Adv). |
| 3V Rail | The measured value of the internal 3V rail within the ECU. Note that the maximum this can read is 3.00V. |
| Supply V | The supply voltage. This is the same as in the Gauge Window (Batt). |
| Injector 1-4 V | The voltage sensed at the injector pin on the ECU. This would normally read around 12V when the engine is not running. If this reads 0V, that indicates lack of 12V supply to the injectors. |
| Injector 1-4 I | The current sensed at the injector output. |
| MAP V - Ext V | The voltage measured at the analogue inputs of the ECU. |
| Cutting : Fuel Cut 1 / 2 | These show the status of the fuel cuts within the ECU. If one of these is active (green background), every second cylinder has fuel disabled. If both are active, the engine is in a complete fuel cut state. |
| Cutting : Ign Cut 1 / 2 | These behave the same as the Fuel Cut flags except that they correspond to the ignition cut status. |
| Flags : Idle | When this flag is enabled, the ECU is in closed loop idle state. |
| Flags : Stepper End | This flag is enabled once the ECU has fully opened the idle stepper motor at start-up. |
| Flags : Closed Throttle | This flag indicates that the throttle is closed, either due to an active digital input set as closed throttle or the TPS falling below the closed throttle threshold. |
| Flags : WOT | This flag behaves the same as Closed Throttle except for the Wide Open Throttle condition. |
| Flags : Cranking | This flag indicates that the ECU is in cranking mode. |
| Flags : Closed Loop Fuel | This flag indicates that the ECU is in closed loop fuel control mode. |
| Dig Inputs: | These flags indicate when various digital inputs are activated: AMAP (Alternate Map) IGON (Ignition On) ENRET (Enrich / Retard) CLTH (Closed Throttle) WOT (Wide Open Throttle) |

| | |
|---|---|
| | A/CON (Air conditioner request)<br>ELEC 1-3 (Electrical loads 1-3)<br>CLUT (Clutch / Neutral)<br>LAUNCH (Launch Control)<br>PITLANE (pit lane speed limiter enabled)<br>PUSH TO PASS ('push-to-pass' temporary boost increase enabled)<br>IGNSW (Ignition switch sensed by input battery voltage) |
| Dig Outputs | These flags indicate when special function digital outputs would be activated if an output were set to that function:<br>IDN (Idle Down, DC motor)<br>IUP (Idle Up, DC motor)<br>TT (Turbo Timer)<br>A/C (Air Conditioner)<br>FP (Fuel Pump)<br>ExtIn < VVT1 setpoint (the calibrated External/Spare Input value is less than the VVT 1 setpoint)<br>ExtIn > VVT1 setpoint (the calibrated External/Spare Input value is greater than the VVT 1 setpoint) |
| Learning State | These flags indicate when given conditions are met required for learning:<br>IWAIT (Ignition learning, waiting after changing cell)<br>ILOAD (Ignition learning, load is close enough to map point to learn)<br>IRPM (Ignition learning, RPM is close enough to map point to learn)<br>FWAIT (Fuel learning, waiting after changing cell)<br>FLOAD (Fuel learning, load is close enough to map point to learn)<br>FRPM (Fuel learning, RPM is close enough to map point to learn) |
| Digital inputs | Each of these 8 values corresponds to the 8 digital inputs. An active (green background) input indicates one pulled low. |
| Realtime inputs | Each of these inputs correspond to the realtime inputs:<br>MVSS (Master vehicle speed sensor)<br>SVSS (Slave vehicle speed sensor)<br>MVSS2 (Master vehicle speed sensor 2)<br>SVSS2 (Slave vehicle speed sensor 2)<br>TRIGGER 1 (Digital or reluctor input 1)<br>TRIGGER 2 (Digital or reluctor input 2)<br>TRIGGER 3 (Digital or reluctor input 3)<br><br>A background colour of green indicates that the input is high. A colour of red indicates that the input is low. A colour of yellow indicates that the input is changing (that is, it has been both high and low since the last time the screen was updated). If an input stays green or red the whole time, that indicates that the input is not being triggered. |
| Aux Output Override: Override | If this tickbox is selected, the normal ECU output driving the outputs (including auxiliary outputs, ignition and injector outputs) will be bypassed, allowing manual control of the outputs. |
| Aux Output Override: Enable | If this tickbox is selected, the outputs of the ECU are enabled. If not, the outputs are disabled, as though the ECU were being re-flashed. |
| Aux Output Override: Inj 1-4 | These tickboxes allow the operator to have manual control over the injector outputs of the ECU. |

| | |
|---|---|
| Aux Output Override: Current | This combo box allows the operator to control the current set for the injector outputs in override mode. |
| Aux Output Override: Peak | This tickbox allows the operator to have manual control over the peak-hold or constant current state of the injector outputs in override mode. |
| Aux Output Override: Aux 1-8 | These tickboxes allow the operator to have manual control over the auxiliary outputs of the ECU. |
| Injector Test / Pulse Ign X | Pressing this button will perform an injector test by exercising each injector output in turn and monitoring the injector voltage and current. The current is set to that specified in the aux output override pane. The resulting waveforms are graphed in the black area. Each injector trace can be enabled or disabled by the tickboxes underneath the Injector Test button.<br>There is also a similar feature for the ignition outputs. If you press the 'Pulse Ign N' button, the 'Nth' ignition output will be pulsed for the dwell time specified on the Triggering tabsheet. |

The **Calculation Trace Window** is another useful diagnostic feature, and it can be reached using the menu 'Help -> Calculation Trace'. This is also a very useful diagnostic tool, which incorporates a flow diagram to allow you to see where many different calculated values originate from. For example, if you see an unexpected fuel trim value, you can use the calculation trace to determine where it is coming from and what is contributing to it.

## 3.1. Firmware Flashing Utility

**Note: Firmware upgrades can only be performed when the engine is not running. Reprogramming firmware should not be done lightly.**

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

To upgrade the firmware of an Adaptronic ECU, you will need to run the Flashing Utility (from the 'Firmware' menu). See below:



**Figure 28:    Firmware Flashing Utility**

The utility will then attempt to reset the ECU automatically, which may take a few seconds. The software should then display a boot/hardware version string and ECU serial number. **The Flashing Utility will not be able to successfully flash any new firmware until you see the message saying that the ECU is connected, followed by the serial number**.

Next the firmware file should be loaded. The latest version can be downloaded from the website, and there will also be a firmware file in the same directory as the WARI application on the 'C:' drive of your laptop or PC. It will be in the form of an encrypted 'adf' file.
The 'Load' button should be clicked, and the firmware file should be loaded. Once the file has been loaded, the ECU can be programmed by clicking the 'Program' button. After this completes, the programming should be verified by clicking the 'Verify' button. If there were no errors, the programming operation was successful. Click 'Done' so the ECU can resume normal operation. If the Flashing Utility window disappears before you click 'Done', simply open the utility again from the main menu and then you will be able to click the 'Done' button.

## 3.2.    Hardware Specifications

Note that some of the input/output functionality is 'fixed' in the Plug-In Select ECUs.

| Sensor Interfaces | |
|---|---|
| Crank/cam angle sensor type | 3 programmable inputs, reluctor or digital, min 0.8V peak voltage for reluctor detection, max 15000 RPM (may be affected by the ignition output setup) |
| Manifold absolute pressure input | 0 - 5V, 20kΩ input impedance, 2-point linear calibration (the ECU's internal MAP sensor may be used instead of an external MAP sensor) |
| Air, water and aux temp inputs | 4k7 pull-up (requires separate thermistor connected to ground), filtered using 100nF capacitor to 0V, 32-point linearly interpolated calibration, range -30°C to 125°C |
| EGO input | 0 - 1V factory narrowband, or Bosch 'wideband' - input impedance 10MΩ, UEGO style analogue, M&W LSU4, TechEdge and Innovative LC-1 serial interface |
| Knock input | High impedance, filtered input |
| Throttle position input | 20kΩ input impedance, 0-5V (5V supplied by ECU), 2-point calibration |
| Digital inputs | 8 inputs, each configurable as active-high or active-low, internally pull-up |
| Actuator Interfaces | |
| Number of injector drivers | 4 (suitable for high or low impedance injectors) |
| 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 | 4 |
| Ignition output type | Open-collector with 470Ω pull-up and 100Ω series resistor (allows direct connection to OEM transistor or separate ignitor) |
| Number of auxiliary outputs | 8 (4 high-current, 4 low-current) |
| High current outputs | Max current 7A (or 3A inductive), 3 of these PWM capable, PWM frequency selectable (25Hz - 2kHz) |
| Low current outputs | Max current 200mA - suitable to drive relay coils, or LEDs with series resistors |

# 4.    ECU Operation

## 4.0.    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

## 4.1.    Reading Inputs

### 4.1.0. Temperature Inputs

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

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.

### 4.1.1. 0-5V Inputs (TPS, MAP and External/Spare 0-5V)

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

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

| | |
|---|---|
| **0% ADC reading** | 327 |
| **100% ADC reading** | 2609 |

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, 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.

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

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

### 4.1.2.0. 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 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 their wideband probe of choice and then disconnect the wideband probe without changing any wiring.

### 4.1.2.1. Oxygen sensor input: None

The AFR is set to 'invalid'.

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

The AFR is set to 'invalid' by default. When the sensor consistently provides a voltage greater than a set minimum, 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 1:    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.

## 4.1.2.3.   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 2:    Calibration table used by the ECU in UEGO 0-3V mode**

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

## 4.1.2.4.   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 3:    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.

## 4.1.2.5.   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 4:** **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.

## 4.1.2.6.    Oxygen sensor input: UEGO 0-5V on External input

This mode assumes that following calibration:

| | **Voltage** | **AFR Reading** |
|---|---|---|
| **Lower value** | 0.0 | 10.0 |
| **Upper value** | 5.0 | 20.0 |

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

This mode can be used in conjunction with a 0-5V linearised wideband oxygen sensor. 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.

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

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

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

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

## 4.1.2.9.    Second Serial Port: Innovative Motorsports LC-1/LM-1

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

### 4.1.2.10.  Second Serial Port: FJO

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

### 4.1.2.11.  Second Serial Port: TechEdge 2J1

The TechEdge 2J1 works in much the same way as the TechEdge 2C0, with the exception that the configuration of the 2J1 requires very different values. The values that we use are 77 and 218.

### 4.1.3.      Knock Sensor Input

The Knock sensor input is first buffered, then fed into a filter/amplifier.
The output of the 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).

### 4.1.4.      Digital Inputs

There are eight digital inputs, which can be setup under the tab Digital Inputs.
Each input can be selected as active high or active low. The default is active low, as generally switches are connected to 0V on one side, and the ECU on the other side.

Each input also needs its function to be selected. If multiple inputs are selected as the one function, they are logically OR-ed together.
The following table gives an example of this behaviour:

|  | 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 6:**      **Example of OR-logic on electrical load inputs**

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

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

The possible auxiliary input types are as follows:

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

- Enrich/Retard Switch: Used as a trigger to a fixed fuel enrichment and ignition retard (for example when using nitrous oxide)
- Ignition switch: Used as a trigger to cut power to injectors and ignition output if the ECU has permanent power.
- Turbo Timeout cancel: Used as a trigger to abort the turbo timeout.
- Alternate fuel ignition map: Used as a trigger to select the alternate fuel and ignition map, e.g. a power/economy switch, for different fuels, or for different tunes e.g. circuit vs drag racing.
- Traction control enable: This input gets logically OR-ed with the traction control 'Enabled' tick box under the Road Speed tab.
- Launch control enable: This input gets logically OR-ed with the launch control 'Enabled' tick box under the Road Speed tab.

### 4.1.5. 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.

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 earlier in this manual.

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

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

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

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

### 4.1.6. Vehicle Speed Sensing

There are four vehicle speed sensor (VSS) inputs. You may just use MVSS 1 if your vehicle has a reed switch or Hall Effect switch (from the speedometer or gearbox) that shorts to ground, generating a pulse train as the wheel rotates. You only need to use multiple VSS inputs if you plan on running traction control.

The ECU measures the period between pulses, this is then divided into the number given by the user to arrive at a number proportional to road speed.
If the ECU receives no pulses in a one second period, the speed for that input is set to zero.

## 4.2.  Calculations, Control Policies and Special Behaviour

### 4.2.0.  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. You may need to periodically refer to this section while reading other parts of this manual.

### 4.2.1.    Tuning Modes

There are several different tuning modes that the ECU can use for the fuel and ignition maps. Refer to the 'Tuning Modes' tabsheet in WARI, as shown below:
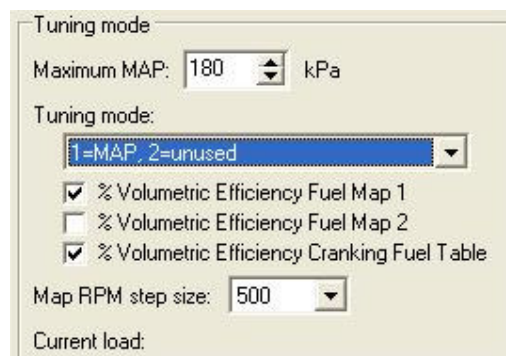


**Figure 29:    Tuning Mode panel**

The various tuning modes will now be described.

**Volumetric Efficiency (VE) tuning will be explained after this.**

### 4.2.1.0.    1 = MAP, 2 = unused

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

### 4.2.1.1.    1 = MAP (default), 2 = TPS (fallback)

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

### 4.2.1.2.    1 = MAP (fallback), 2 = TPS (default)

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

### 4.2.1.3.    1 = MAP, 2 = TPS, max (MAP, TPS)

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

### 4.2.1.4.    1 = MAP, 2 = TPS, avg (MAP, TPS)

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

### 4.2.1.5.    1 = MAP, 2 = TPS, min (MAP, TPS)

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

### 4.2.1.6.    1 = MAP, 2 = TPS, MAP + TPS

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

### 4.2.1.7.   1 = unused, 2 = TPS

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

### 4.2.1.8.   1 = MAP, 2 = TPS, use MAP if TPS = 0

In this mode, fuel and ignition map 1 are used in conjunction with the MAP sensor, if the engine is in the closed throttle state (a digital input of type 'closed throttle' is active, or the TPS reading is less than the closed throttle threshold). Otherwise, the second map is used in conjunction with the TPS. This can be useful if you want a separate map for idle only.

### 4.2.1.9.   1 = MAP, 2 = MAP, use Digital Input to select #2

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

### 4.2.1.10.  1 = TPS, 2 = TPS, use Digital Input to select #2

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

### 4.2.1.11.  1 = MAP, 2 = TPS, use Digital Input to select #2

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

### 4.2.1.12.  1 = MAP, 2 = TPS, MAP x TPS

This is the same as '1 = MAP, 2 = TPS, max (MAP, TPS)' in that both MAP and TPS are used in conjunction with both fuel and ignition maps, however instead of the greater of the two values being used, the product of the two is used. This tuning mode can be very useful when tuning an engine with Individual Throttle Bodies.

### 4.2.1.13.  1 = MAP, 2 = MAP, Pri = 1, Sec = 1x2,  Ign = 1

In this mode, both fuel maps are based on MAP. The duration for the primary injectors will be the sum of fuel map 1, trims, and the primary dead time correction. The duration for the secondary injectors will be obtained by adding the trims to the value in fuel map 1, multiplying the result by fuel map 2, then adding the secondary dead time correction. Ignition map 1 will be used normally for ignition timing in this mode.

## 4.2.2. Fuel Calculation, including Volumetric Efficiency (VE)

Refer to the 'Tuning mode' panel on the 'Tuning Modes' tabsheet in WARI, as shown below:
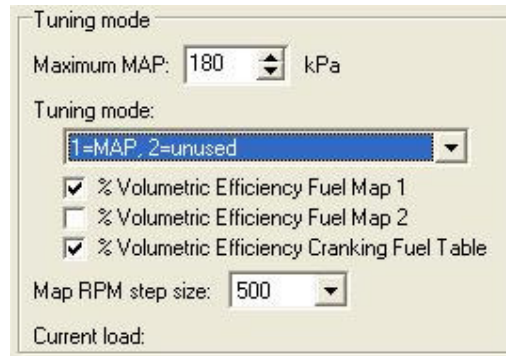


**Figure 30:    Tuning modes and Volumetric Efficiency options**

There are tickboxes to determine if Volumetric Efficiency (VE) tuning will be used for fuel map 1 and/or fuel map 2, and the cranking fuel table. In VE mode, the values in the corresponding fuel maps will be percentages of volumetric efficiency. Otherwise, the values in the fuel maps will be milliseconds of fuel to inject.

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 (or %VE) from the table. If batch fire during cranking is selected then it will continue to fire in batch mode until the cranking flag is dropped.

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

Otherwise, if the engine is not in cranking mode, the fuel pulse width (or %VE) is looked up from the fuel map based on RPM and load.

**How the Volumetric Efficiency (VE) calculation works:**

With the VE tuning mode, you must also specify an engine capacity and injector size (on the same tabsheet as the tickboxes for enabling VE tuning), and of course you must tune the VE map itself.
In VE mode, the ECU performs further calculations to determine how many milliseconds of injector pulse width are needed, based on MAP, engine capacity, injector size, number of cylinders, target AFR, and of course the Volumetric Efficiency.
In other words, **in VE mode, the value obtained from the fuel map is just one part of a theoretical calculation of injector pulse width, rather than being the pulse width itself**.

You basically need to tune the VE map instead of a milliseconds map, and when you increase or decrease the VE values it will still have a direct effect on the injector pulse width. The reason why VE tuning is so nice is because you can just enter something like 80% VE in every cell initially, and usually the car will run fairly well straight away!

In closed-loop fuel mode, the target AFR will still be used in the usual way (as well as being part of the VE calculation). All trims, including the closed-loop correction, still behave as normal (and are added after the theoretical milliseconds calculation in VE mode).

You can get an equally good result with millisecond tuning compared to VE tuning, but the difference is that it's usually quicker to tune VE because the theoretical millisecond calculation in VE mode gives a better 'starting map'.

***So, the fuel pulse width has now been obtained from the cranking fuel table or fuel map, incorporating VE where applicable, what happens next?***

The calculated "fuel trim" value (in %) is applied on top of the value obtained from the fuel map (after the Volumetric Efficiency calculation where applicable), and this final figure is what gets 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.

### 4.2.3. Staged Injection

The preferred method of operating staged injection is to use volumetric efficiency mode, and set the secondary injector size to a non-zero value. This will automatically engage the staged injection calculation, whereby injector outputs 1 and 3 are used for primary injectors, and 2 and 4 are used for secondary injectors. The amount of fuel to be delivered through the primary injectors is calculated by the VE tuning mode described above, and when this exceeds the available injection time (calculated from the engine RPM), the remainder of the fuel delivery is performed by the secondary injectors. This means that there is only a single fuel map to adjust, and there are no calculations to perform to determine under what conditions the secondary injectors must engage.

### 4.2.4. Ignition Calculation

When in cranking mode, the ignition figure is taken from the Crank Timing (° BTDC) (on the Corrections tabsheet). Note that the ignition angle in the gauges will read this value when cranking. Also note that the timing lock option (on the Triggering tabsheet) does not apply when the engine is in cranking mode.

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

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

- Knock sensing retard
- Traction Control retard
- Transient throttle ignition advance
- Idle PD control ignition trim

If the timing lock is enabled (see Triggering tabsheet), the calculated ignition angle is replaced with the timing lock value.

NOTE: Being in Volumetric Efficiency mode will NOT have any affect on the ignition angle calculation!

### 4.2.5.  Rotary Spark Split

Refer to the image below, which shows the Spark Split table on the 'Corrections' tabsheet:



**Figure 31:    Spark split table**

If the ignition output pattern is set to a rotary mode, the normal ignition timing value corresponds to the timing of the leading plug. The spark split, defined as a function of load and RPM in the Basic Setup tabsheet, is subtracted from the leading plug ignition angle to arrive at the trailing plug advance angle.

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

### 4.2.6.      Fuel Trim Calculation, and Transient Throttle

#### 4.2.6.0.     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.

### 4.2.6.1.    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.

### 4.2.6.2.    Inj 3/4 trim (MAP MAP mode only)

When in the 14th tuning mode (see above), this trim value will be applied to injectors 3 and 4. On a two rotor Wankel engine, this is equivalent to trimming the rear rotor.

### 4.2.6.3.    Water Temperature

The water temperature is measured. If no water temperature value is available, a value of 27° is assumed. This is interpolated in the both the low and high MAP coolant enrichment tables to give two separate calculated values, these two values are then interpolated to the correct current MAP value (see Corrections tabsheet), which then contributes to the final trim value. If no MAP values are set then only the basic low MAP coolant enrichment is used.

### 4.2.6.4.    Air Temperature

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

### 4.2.6.5.    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

### 4.2.6.6.    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.

### 4.2.6.7.    Transient Throttle / MAP prediction

*With 'MAP prediction' enabled (recommended!):*

When the throttle is moved quickly, the MAP sensor may not respond fast enough, and this can cause a 'lean spot' or hesitation. This is why MAP prediction was introduced. In MAP prediction mode, there is a table of predicted MAP values against RPM and TPS, as shown below:

**Figure 32:    Predicted MAP table**

You will need to perform data-logs and/or monitor the values on the F2 Gauge window to determine what MAP values occur at different RPM/TPS points, in steady-state. During transient throttle events (or if the MAP sensor fails), the ECU will use the values in this table to come up with a 'predicted' MAP value. When the throttle is blipped at a significant rate (beyond hard-coded thresholds), the Predicted MAP value will be used for the duration specified by the 'Transition Time (ms)', and then the sensed MAP value will be used again (provided that the MAP sensor is working). Note that the 'MAP' value on the F2 Gauge window will be the value obtained by combining the Predicted and Sensed MAP values as described above, because this is the MAP value that is actually used by the ECU.
See also the 'Asynchronous Accelerator Pump' section for more details.
Note: If the MAP sensor reading becomes invalid (eg. due to a sensor failure), and MAP prediction is enabled, the ECU will also use the MAP prediction table for the steady-state MAP reading until the sensor error is rectified.

*With 'MAP prediction' disabled (not recommended, unless you don't have a potentiometer type TPS):*

Refer to the image below (this panel is on the Corrections tabsheet in WARI), and note that the 'Asynch Accel. Pump' in this image is explained separately in the 'Asynchronous Accelerator Pump section.



**Figure 33:    Classic transient throttle settings**

In this case, 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 ('TPS-based Enrich' and 'MAP-based Enrich', 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 ('Enrich Duration'), and can be seen by the trim value changing as the throttle is quickly applied.

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

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

### 4.2.6.8.     Digital Input Enrich/Retard

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

### 4.2.6.9.     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.

### 4.2.6.10.     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.

### 4.2.7.  Ignition Trim Calculation

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

### 4.2.7.0.     Master Trim

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

### 4.2.7.1.     Water Temperature

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

### 4.2.7.2. Air Temperature

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

### 4.2.7.3. Digital Input Enrich/Retard

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

### 4.2.7.4. Closed Loop Ignition Adjustments

The ignition trim value calculated by the feedback loop is added to the ignition trim depending on the mode (closed, rapid learn or slow converge).

### 4.2.7.5. Ignition Adjustments for Closed Loop Idle Control

Refer to the Idle Control section for more information.

### 4.2.7.6. Traction Control ignition retard

Refer to the Traction Control section for more information.

## 4.2.8. 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 (on all injectors) 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.

*With 'MAP prediction' enabled (recommended!):*

Refer to the image below (this panel is on the Corrections tabsheet in WARI):
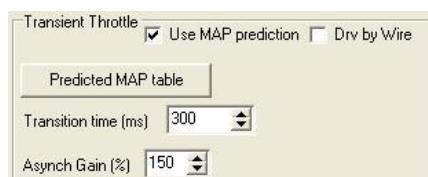


**Figure 34:    Transient Throttle using Predicted MAP**

In MAP prediction mode, the change in calculated injector duration is continuously monitored. When the throttle is moved quickly, the calculated injector duration will also change quickly. When this occurs, the difference in injector duration (scaled by the 'Asynch Gain (%)') will be injected instantaneously and asynchronously, for the duration specified by the 'Transition Time (ms)'
.

*With 'MAP prediction' disabled (not recommended, but compulsory if you don't have a potentiometer type TPS):*

Refer to the small sub-panel on the right in the image below (this is on the Corrections tabsheet in WARI):
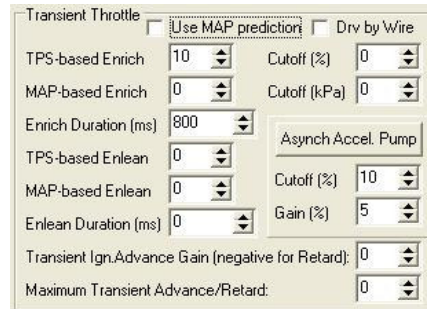


**Figure 35:    Asynch Accelerator Pump using classic settings**

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

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

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

The cut-off of the asynchronous pump refers to the peak TPS percentage that will allow the asynchronous pulse, i.e. any change starting above this point will not result in an asynchronous pulse. If the cut-off value is set to 0, then any positive change in the TPS value will result in an asynchronous pulse (provided the gain conditions are also met).

The gain of the asynchronous pump refers to the change in TPS value that is required to inject the squirt duration in the asynchronous table (so a larger gain in this case will actually lead to shorter asynchronous pulses). If the gain is set to 0, then it is assumed the gain has not been setup and is taken to be 30.

### 4.2.9.  Closed Loop Fuel Control

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

1.  The engine must be running mode (not stationary);
2.  The engine must not be in any fuel or ignition cut mode;
3.  The engine must not be at WOT (if WOT enrichment/open loop is enabled);
4.  The ECU must be in either Closed Loop, Rapid Learning or Slow Converge modes for fuel control;

5. The water temperature must be above the minimum closed loop operation temperature (if there is no water temperature available, open loop mode is forced);
6. The RPM must be below the max rpm value;
7. There must be a valid AFR reading from an oxygen sensor input or the second serial port;
8. The load value (TPS or MAP) must be below the maximum load for closed loop operation;
9. The target AFR must fall within the range of reading of the currently active oxygen sensor (including the serial sensors);
10. The engine must have been running for the 'Delay before closed loop' duration.

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

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

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

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

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

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

### 4.2.10. Adaptive Fuel Control

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

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

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

In adaptive mode, the ECU starts a timer every time the engine changes 'cells' (ie, the closest RPM and load point in the fuel and ignition maps). This timer allows the engine to stabilise, so that the ECU is not performing corrections to transient events. This timer elapses after the 'Stabilise time' has occurred (this figure can be set differently for Rapid Learning and Slow Converge modes). During this time, the Learn Wait flag will be set, so one aid to tuning is to connect a light to an auxiliary output, and configure it to be a "Learning wait" type output.

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

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

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

### 4.2.11. Closed Loop Ignition

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

### 4.2.12. Adaptive Ignition

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

increase. This RPM shift is referred to as the 'Advance Metric', and will have a positive value if the torque will be increased by advancing the ignition.

By default, the ignition dithering will only take place if the conditions for adaptive ignition are met (that is, minimum/maximum engine speed and minimum/maximum coolant temperature). When the ignition dithering is not in effect, the Advance Metric will read zero. Under the 'Always sense torque' tickbox is enabled in the Adaptive Ignition parameters, the dithering will always be active and the Advance Metric will always be calculated. This is disabled by default as it has a poor effect on idle smoothness.

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

- The knock threshold determines the level of knock allowed before the ignition will be retarded.
- The minimum and maximum rpm values set the conditions for entry into the adaptive ignition loop.
- Always sense torque will dither the ignition regardless of the conditions, when it is off dithering will only occur when in adaptive ignition mode.
- Update other parts of map will check that all loads and rpm's higher are equal or more advanced, all loads and rpm's lower are equal or more retarded, if not they will be changed.
The adaptive ignition system is noisy, to remove some of this noise, there is a filtering option which uses the number set to determine the percentage that comes from the sample taken, while the remaining percentage comes from the previous value. The lower and higher thresholds set the minimum and maximum values that the adaptive ignition can change the map, the stabilise time sets the time that the ecu needs to be held at a set rpm and load for the adaptive ignition to occur.

### 4.2.13.Flex Fuel control

The Select ECU range allows corrections to be made to suit Flex Fuel systems. This requires a suitable Fuel Composition sensor to be fitted.

Note: If you are running a Flex Fuel system, you **must** use Volumetric Efficiency tuning, and you **must** set up WARI to display lambda rather than AFR, or the numbers won't make sense. Refer to the section about Units Preferences.

The Flex Fuel tabsheet in WARI looks like this:
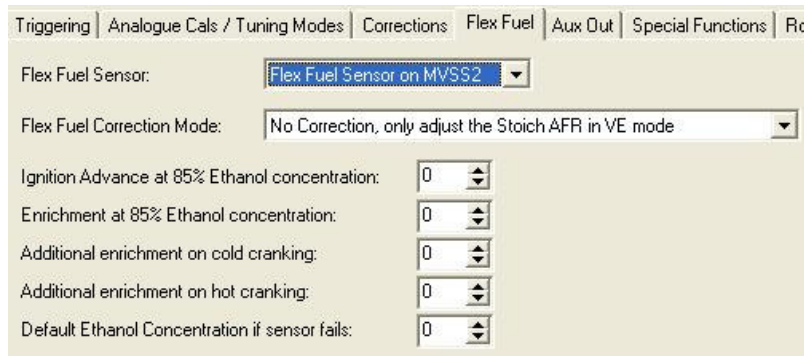
**Figure 36:    Flex Fuel tabsheet**

The Fuel Composition sensor should generate a signal with variable duty cycle and variable frequency, to represent the composition of the fuel. The sensor should be connected to one of the last three VSS inputs (MVSS 2, SVSS 1, or SVSS 2), and the chosen VSS input must be configured as digital, not reluctor.

The sensor will normally vary its signal as follows:
-    50 Hz = 0% Ethanol Concentration
-    150 Hz = 100% Ethanol Concentration
-    0 Hz or > 160 Hz = Sensor Error

On the 'ECU Data' window (F11), there are live values displayed for the Ethanol Concentration ('Eth %'), and the 'base' enrichment to achieve current Stoichiometric AFR ('Eth Enrich'). Note that the stoichiometric AFR will be 14.7:1 for 0% Ethanol, and 9.0:1 for 100% Ethanol.

You can choose between two methods of Flex Fuel compensation. The options are:
1) No Correction, only adjust the stoichiometric AFR in VE mode
2) Fixed enrichment and advance (interpolated by ethanol content)

Option 1:
This simply changes the target AFR based on the target lambda specified by the user, and the stoichiometric AFR derived from the ethanol concentration. This means that with the same target lambda, the ECU will deliver more fuel to compensate for an increase in ethanol concentration.

Option 2:
This will do the same as option 1, except that there are additional corrections that you can set up.
When cranking, the ECU will interpolate between the 'Additional enrichment on cold cranking' (20 degrees coolant temp) and the 'Additional enrichment on hot cranking' (60 degrees coolant temp) to arrive at an enrichment amount for 85% ethanol, and that value will be scaled by the actual ethanol concentration. The Flex Fuel settings will make no changes to the ignition timing when cranking.
When the engine is running, the 'Enrichment at 85% ethanol concentration' will be scaled by the actual concentration to come up with an additional enrichment, and the same will occur with the 'Ignition advance at 85% ethanol concentration' to come up with an additional trim to the ignition timing.

## 4.3. Power Cut

The power cut is a feature which allows power production of the engine to be cut. This can be done by cutting fuel, 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 (if launch control is enabled, a vehicle speed of 5 must also be exceeded for a flat shift power cut to occur);
6. Bringing the engine speed above the launch control 'rev limit', with launch control enabled (a soft rev-limit will occur automatically within 200RPM of the actual launch control rev limit);
7. Bringing the MAP above the 'Instant Overboost power cut' value;
8. Bringing the MAP above the '1 sec Overboost power cut' value for 1 second;
9. Bringing the vehicle speed above the 'Pit Lane speed limit', with a corresponding digital input activated;
10. Holding the WOT condition while cranking (if the feature is enabled, and 'Don't cut but reduce fuel pulse width' is disabled);
11. 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);
12. 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 the closed throttle threshold, or a digital input configured as a Closed Throttle input being active);
3. The water temperature must be above the 'Minimum water temperature' (if there is no water temperature available, this test is skipped);
4. The air conditioner output must be disabled, if the 'Not when A/C is on' option is selected;
5. There must be no input configured as a clutch/neutral input which is active, if the 'Only when in gear' option is selected;

6. These conditions must be met for the 'Time Delay' before the fuel cut occurs.

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

## 4.4. Special Functions

### 4.4.0. Fuel Pump Control

The fuel pump is activated for the 'prime time' (see the Special Outputs tabsheet) when the ECU is first powered up, and for 'trigger timeout' after each trigger pulse. This means that the fuel pump will run whenever there is an RPM reading, and stop running after the 'trigger timeout' elapses 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.

### 4.4.1. Air Conditioner

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

1. An input set as an air conditioner input is active (for at least 800ms);
2. The engine speed is above the 'Min RPM' value (on the Special Outputs tabsheet);
3. The engine is not at wide-open 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.

### 4.4.2. Purge Valve

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

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

### 4.4.3.  PRCV Control

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

### 4.4.4.  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'.

### 4.4.4.0.     Digital Input Enrich/Retard

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

### 4.4.5.  Turbo Timer Control

#### 4.4.5.0.    Turbo Timer 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.

#### 4.4.5.1.    Turbo Timer, 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.

#### 4.4.5.2.    Turbo Timer, 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 37:    Series Mode turbo timer configuration**

### 4.4.5.3.    Turbo Timer 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.

### 4.4.6.    Variable Valve Timing

Variable Valve Timing (VVT) technology is a technique whereby the valve timing can be varied with relation to the crankshaft angle. This can either be implemented as an open loop, or a closed loop system. In the former, a variable duty cycle is output as a function of engine speed only. In the latter, the angle of the camshaft with respect to the crank shaft is continuously sensed and the actuator output changed to achieve a target angle.

The Select ECUs have two VVT channels. They each have their own target VVT angles, but they share the same control parameters, and both must either be open loop or closed loop. If a separate RPM-based open loop function is required in conjunction with closed loop VVT, this can be effected by using the wastegate control output in open loop mode.

**Figure 38:    Variable Valve Timing control panel**

### 4.4.6.0.    Open Loop VVT

Open loop VVT mode is selected by setting all P, I and D values equal to zero. The VVT angles, as a function of RPM, then become the duty cycle that is output directly to the VVT outputs.

All VVT outputs will be set to zero duty cycle when the engine is stationary.

### 4.4.6.1.    Closed Loop VVT

There are four components of the closed loop VVT control algorithm in the Select ECUs. These are as follows:

1. Setpoint and gain calculation
2. Current angle detection
3. Control policy
4. Actuation

### 4.4.6.2.     VVT Setpoint and Gain Calculation

This table of setpoints as a function of engine speed is accessed by clicking the 'Target Angles' button within the VVT pane in the Special Outputs tabsheet. You may choose to utilise one of the fuel or ignition maps instead (using the drop-down lists on the VVT panel), but this adds more time to the VVT tuning process with little benefit usually.

The setpoint is an angle, in degrees. This is a function of engine speed, and has set points every 500 RPM (unless you choose to utilise one of the fuel or ignition maps). It is calculated in degrees before top dead centre; hence higher values indicate a more advanced camshaft. A value of zero is supposed to indicate the camshaft in its 'neutral' position, with no control effort applied.

The controller is a PID controller, which allows for different gains at different RPM. The points where the gains can be set are 1000, 3000, 5000 and 7000 RPM. Between these points, the gain values are interpolated. Below 1000 RPM, the 1000 RPM values are taken, and above 7000 RPM, the 7000 RPM values are used.
The reason for having multiple gains is because the oil pressure (and therefore the responsiveness of the VVT solenoid) will change with RPM.

### 4.4.6.3.     VVT Current Angle Detection

The angle is detected by calculating the time difference between the index pulse on the camshaft with respect to the crankshaft position. The crankshaft position is determined in the usual manner by use of a trigger event angle table and a crankshaft position sensor. Usually the home position will be marked on the crank angle sensor by means of a missing tooth.

The camshaft angle for VVT channel 1 or 2 is detected by selecting the 'VVT 1' or 'VVT 2' option in the 'Triggering Settings' window for the input connected to the camshaft sensor. Note that this angle must be in a constant position with respect to top dead centre, for a given camshaft to crankshaft angle.

This is offset by the 'Reference' position for each channel. This reference position is the nominal position of the timing pulse of the camshaft, with respect to the crankshaft, in the camshaft's 'home' position (that is, with no control effort applied to the solenoid).

The procedure of adjustment for these values is as follows:

1. Disable the VVT outputs (set the Aux Output type for each output to 'None')
2. Ensure that the triggering timing mark table is correct and that the correct triggers for VVT 1 and/or VVT 2 are selected
3. Start the engine and allow it to idle with both camshafts in their 'natural' positions
4. Ensure that the base ignition timing is set correctly (by using the timing lock feature or otherwise)
5. Zero the 'Reference' value in the appropriate VVT panel for this VVT channel

6. Read the VVT 1 position from the gauges window (the first number).
7. Enter this value (to the nearest integer) into the 'Reference' value in the VVT appropriate panel for this VVT channel
8. The VVT 1 position should now be between -0.5 and +0.5
9. Perform steps 5-8 for the second VVT channel, if desired

### 4.4.6.4.    VVT Control Policy

The control loop is a PID controller. This section will not explain how to set up the gains of a PID controller.

The error term is calculated by taking the current VVT angle (which is offset from the home position, as described above) and subtracting the angle setpoint (which is interpolated from the table).

The PID gains are calculated by interpolating the PID gain table against the engine speed, as described earlier.

From the error, the error history and the PID gains, a control effort output is determined. This is a duty cycle.

The integrator within the PID controller will progress no further under the following conditions:

1. The error is positive, and the output value for that channel is at the minimum of its range
2. The error is negative, and the output value for that channel is at the maximum of its range

This is to reduce the potential problem of 'integrator wind-up'.

The gain can be varied as a function of engine speed for the reason that as oil pressure varies with engine speed and the dynamics of the system change, the gain that is required to achieve acceptable response at low engine speeds causes instability at higher engine speeds.

### 4.4.6.5.    VVT Actuation

This control effort value is then added to the 'default' duty cycle to arrive at the output duty cycle. This is clipped within the range of the minimum and maximum duty cycle percentages before being applied to the relevant output.

The base/default duty cycle value should be determined experimentally by finding at what duty cycle the valve starts to open. This offset allows the controller to respond quickly without having to build up the integrator over a long period of time.

The maximum and minimum values should be kept within a range so that the time for the integrator to come out of saturation is minimised. For example, if the valve at 60% duty cycle is completely shut off, there is no benefit to the controller to be able to

apply a value lower than this. Allowing the controller to apply a lower value will only require a longer time period for the valve to come back into its 'active' range once the control loop comes out of saturation.

### 4.4.6.6. Gauge Meanings for VVT

The gauge window allows the operator to see the current VVT parameters to gauge the performance and optimise the control parameters.
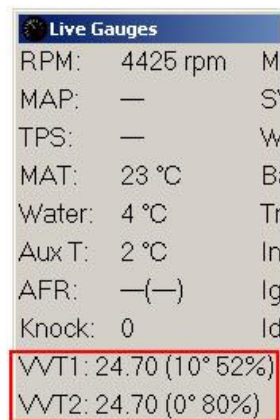


**Figure 39:    VVT live gauges**

In this example, the timing sensed by each camshaft is 24.70°, advanced from the reference position. The setpoint of VVT1 is 10°. Hence the camshaft is further advanced than it should be. The 52% figure indicates the duty cycle applied to the VVT 1 solenoid.

The setpoint of VVT2 is 0°, indicating again that the cam is too far advanced with respect to the setpoint. The ECU will be attempting to drive that output at a higher duty cycle. It is currently at 80%, which would be the limit set in the parameters.

### 4.4.7. Metering Oil Control

Series 5 – 8 Mazda RX7 engines used an electrical metering oil pump which controls the oil delivery to the combustion chamber. Series 1-4 Mazda RX7 used a mechanical metering oil pump and the RX8 used a different electrical oil metering pump with which the ECU is not compatible.

The series 5 to series 8 MOP consist of a 6 wire stepper motor, and a 3-wire feedback position potentiometer. The feedback position is wired as a 0-5V input, similar to a TPS. The wiper of this potentiometer must be connected to the EXT input on the ECU.

Being a stepper motor, it requires 4 auxiliary outputs from the ECU, however two of these are merely logical inversions of the first two. The first two aux output types are selected by selecting MOP1 or MOP2. These must connect to two separate windings on the stepper motor. The inverse of each must connect to the other end of the appropriate winding.

This is done in hardware on the FD Series 6/7 RX7 plug-in ECU.

Then, the Ext In calibration can be adjusted for the oil position calibration for the sensor. These values, for the Select ECUs, are:

| Engine series | Lower reading (ADC) | Upper reading (ADC) |
|---|---|---|
| Series 5 (FC) | 474 | 2610 |
| Series 6/7 (FD) | 474 | 2610 |

The position of the oil metering pump then is a table of RPM vs MAP.

The tables below show the factory positions of the MOP settings:

Oil Metering Position (Rotaries) — Position is 0 - 100

| | 1000 | 3000 | 5000 | 7000 |
|---|---|---|---|---|
| MAP = 0 kPa | 4 | 5 | 5 | 6 |
| MAP = 50 kPa | 4 | 5 | 5 | 6 |
| MAP = 100 kPa | 4 | 20 | 35 | 40 |
| MAP = 150 kPa | 4 | 50 | 60 | 90 |
| MAP = 200 kPa | 4 | 80 | 90 | 100 |

Oil Metering Position (Rotaries) — Position is 0 - 100

| | 1000 | 3000 | 5000 | 7000 |
|---|---|---|---|---|
| MAP = 0 kPa | 8 | 8 | 8 | 8 |
| MAP = 62 kPa | 8 | 15 | 15 | 15 |
| MAP = 125 kPa | 8 | 30 | 40 | 40 |
| MAP = 187 kPa | 50 | 60 | 80 | 80 |
| MAP = 250 kPa | 80 | 80 | 90 | 95 |

**Figure 40:    MOP factory position for Series 5 (left) and Series 6 (right)**

## 4.5.    Generic Auxiliary 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.

## 4.6.    Idle Control

### 4.6.0.0.    Introduction

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

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

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

### 4.6.0.1. Cranking Condition

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

### 4.6.0.2. Open Loop Idle Effort

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

The open loop value is calculated from the following settings:

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

The easiest way to set these up is to disable closed loop control (by setting all of the gains to zero in the closed-loop idle panel), 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.

### 4.6.0.3. Performing Closed Loop Idle Speed Control

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

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

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

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

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

The target idle speed is governed by the following settings:

1. Target idle speed when engine is hot and cold, as a function of water temperature (if there is no valid water temperature value, the cold target idle speed is assumed);
2. An extra speed can be added for the case of electrical loads (this would normally be about 100 RPM);
3. An extra speed can be added for the case of A/C being on
4. An extra speed can be added for the case of a low battery supply.
5.

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

Once the target idle speed has been determined and the ECU has determined that it should make an effort to control idle speed, the idle speed controller is activated. It is a basic PID controller.
The 'I' (integral) component affects the behaviour of the idle control valve (solenoid or stepper motor) to obtain the correct 'steady-state' idle speed.
The idle control system can put the 'P' (proportional) and 'D' (differential) components into effect by adjusting the idle control valve, or by adjusting the ignition timing for more rapid corrections. The P, I, and D components behave as follows:

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.

Note that if you choose to use ignition timing for the PD part of the PID controller, you should try to make the main ignition map as flat as possible around the idle speed region of the map.

One way to configure the PID gain 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 actual idle control; they should really only be used to stop an engine from stalling. These will react immediately, unlike the closed loop control algorithm

### 4.6.0.6. Driving the Idle Valve

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

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

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

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

**Table 7: 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, but some motors will skip steps if the step period is too fast.

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.

## 4.7. Wastegate (Boost Control)

### 4.7.0.0. Introduction

The conventional mechanical arrangement on a turbocharged engine with electronic boost control is to have a pressure feed from the compressor outlet go to the servo diaphragm via a T-piece and an electric solenoid bleed valve. Opening the valve allows some air to bleed off, reducing the pressure seen by the servo diaphragm. Closing the valve allows the full pressure to be seen by the servo diaphragm, and the standard wastegate pressure will be maintained.

As with fuel control, ignition control and idle speed control, a combination of feed-forward and feedback is used.

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

### 4.7.0.1. Open Loop Wastegate Control

The open loop system is quite simple. Within the Wastegate tabsheet, there is a set duty cycle (as a percentage) for each 500 RPM from 0 to 7500 RPM. The ECU will interpolate these values, based on the current RPM, to arrive at a duty cycle which is fed to the wastegate output.
To force only open-loop control, the P, I and D gains in the Control pane must be set to zero.

### 4.7.0.2. Closed Loop Wastegate Control

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

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

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

### 4.7.0.3. Push-To-Pass

This feature allows you to set up a 'Push-To-Pass' digital input, and whenever that input is enabled you will get a temporary increase in boost. The settings for this feature can be found on the 'Special Functions' tabsheet, as shown below:
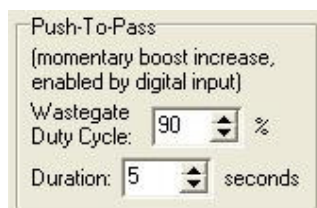


**Figure 41: Push-To-Pass settings**

The push-to-pass wastegate duty cycle will override all other wastegate duty cycle calculations for the specified push-to-pass duration (when the input is enabled).

## 4.8. Driving Outputs

### 4.8.0. Ignition Outputs

There are four dedicated ignition outputs. These can be configured to fire simultaneously (as on an engine with a distributor) or alternately (as on a 4 cylinder, wasted spark engine), leading/trailing as in a rotary. In some modes, the third ignition output can be configured as a tachometer function. They can also be configured to fire in a cycle of three, which is suitable for direct fire ignition on a three cylinder engine, wasted spark on a six cylinder engine, or leading trailing with addressing on rotary

with addressing igniters. In this mode, a tachometer output must be sourced from an auxiliary output. Ignition Output 1 will fire first after the reset pulse from the crank/cam trigger.
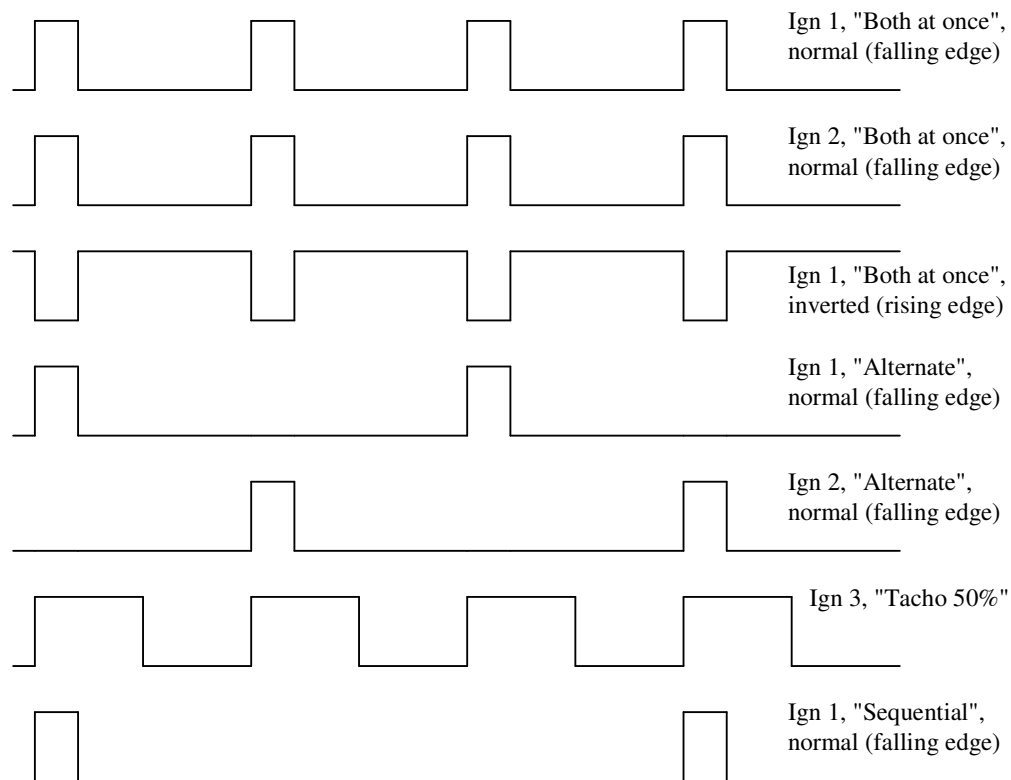
The ignition outputs can also be configured to fire in a cycle of four, suitable for direct-fire four cylinders or waster-spark eight cylinders. In this situation, ign 3 has to be set to Ign 3, and Aux Output 1 must be set to Ign 4.

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

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

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

The following diagram shows some typical waveforms:



|  | Ign 1, "Both at once", normal (falling edge) |
|  | Ign 2, "Both at once", normal (falling edge) |
|  | Ign 1, "Both at once", inverted (rising edge) |
|  | Ign 1, "Alternate", normal (falling edge) |
|  | Ign 2, "Alternate", normal (falling edge) |
|  | Ign 3, "Tacho 50%" |
|  | Ign 1, "Sequential", normal (falling edge) |

**Figure 42:   Ignition Waveforms in Different Modes**

### 4.8.1.  Injection Outputs

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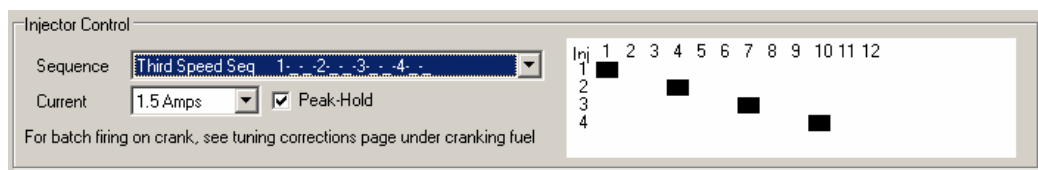


**Figure 43:   Injector Firing Pattern Example**

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

The current needed for most injectors is about 0.9 Amps. To achieve this, there are a number of selections which the user can make based on how their injectors are wired up. Normally one would select an injector current of 0.9 Amps for one injector per output, or 1.9 Amps for two injectors paired together on each output. The other injector current choices are not used often.

When tuning in milliseconds mode (instead of VE mode), the staged injector limit sets the limit of the primary injector in terms of ms of the secondary injectors, the primary injector multiplier sets the percentage increase in size of the injector, and this is all used to calculate the actual injector on time for each injector when using staged injection.

When using staged injection, you should only use the alternate full speed or batch injection sequences.

The preferred method for tuning staged injection mode is VE tuning and covered earlier in this document.

If you are running a 2-rotor Wankel engine with staged injection, the injector outputs should be wired as follows:

- Injector output 1 = Front (1) primary injector
- Injector output 2 = Front (1) secondary injector
- Injector output 3 = Rear (2) primary injector
- Injector output 4 = Rear (2) secondary injector

## 4.8.2. Auxiliary Outputs

Each output is driven low to activate it. There is no internal pull-up or high side driver, so these outputs can only sink current. If an output needs to be configured as a 0-12V signal (for example, to feed into a tachometer or another piece of equipment), a separate pull-up resistor of an appropriate value must be placed.
Not all auxiliary outputs are created equal, for this reason you must choose the correct channel for the correct output type.

# 5.    Wiring the Adaptronic

## 5.0.    Introduction

Note: This section of the manual only applies to the 440 Universal Select ECU, which needs to be wired up using a flying loom.

|If you have a Plug-In Select ECU, there are pinout tables available for each Plug-In ECU model, which should provide sufficient information on how those ECUs operate using the applicable factory ECU plug and harness (these pinouts can be accessed from the menu 'Help -> Open Pinout for this ECU').

The pinout for the 440 Universal Select is shown below, along with a typical wiring diagram:

View from loom side of plug:
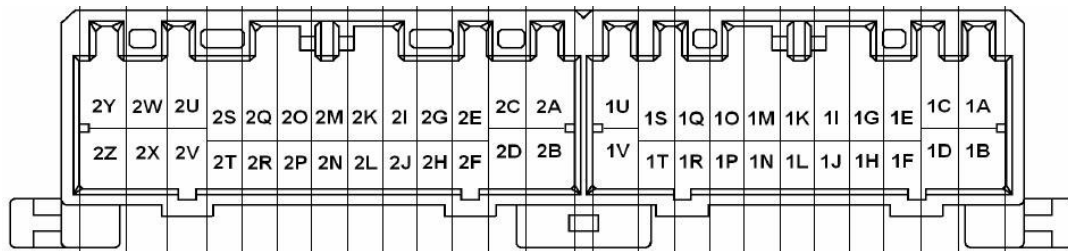


| Pin Number | Function | Comments |
|---|---|---|
| 1A | Constant 12V | Straight from battery via fuse |
| 1B | +12V Ignition | From ignition switch |
| 1C | Ext In | External/Spare 0-5V analogue input |
| 1D | Aux Output 2 | Approximately 3 Amps capable, and PWM capable |
| 1E | Aux Output 6 | Low-current only (eg. relay coils), NOT PWM capable |
| 1F | Ignition output 3 | External igniter required (DON'T connect directly to coil) |
| 1G | Ignition output 1 | External igniter required (DON'T connect directly to coil) |
| 1H | Ignition output 2 | External igniter required (DON'T connect directly to coil) |
| 1I | SVSS1 | Slave vehicle speed sensor 1 |
| 1J | Aux Output 3 | Approximately 3 Amps capable, and PWM capable |
| 1K | SVSS2 | Slave vehicle speed sensor 2 |
| 1L | Aux Output 7 | Low-current only (eg. relay coils), NOT PWM capable |
| 1M | MVSS1 | Master vehicle speed sensor 1 |
| 1N | Digital Input 7 | 12V tolerant inputs, can be switched high or low |
| 1O | Digital Input 3 | 12V tolerant inputs, can be switched high or low |
| 1P | Digital Input 1 | 12V tolerant inputs, can be switched high or low |
| 1Q | Digital Input 2 | 12V tolerant inputs, can be switched high or low |
| 1R | Aux Output 8 | Low-current only (eg. relay coils), NOT PWM capable |
| 1S | Digital Input 4 | 12V tolerant inputs, can be switched high or low |
| 1T | Ignition output 4 | External igniter required (DON'T connect directly to coil) |

| 1U | Digital Input 5 | 12V tolerant inputs, can be switched high or low |
|---|---|---|
| 1V | Digital Input 6 | 12V tolerant inputs, can be switched high or low |
| 2A | Power Ground | High-current ground (connect to chassis, or battery negative terminal, or engine). DON'T connect to sensors. |
| 2B | Power Ground | High-current ground (connect to chassis, or battery negative terminal, or engine). DON'T connect to sensors. |
| 2C | Sensor Ground | DON'T connect to chassis or power ground |
| 2D | Sensor Ground | DON'T connect to chassis or power ground |
| 2E | CAS 1 input | For crank or cam angle sensors, reluctor or digital |
| 2F | CAS 3 input | For crank or cam angle sensors, reluctor or digital |
| 2G | CAS 2 input | For crank or cam angle sensors, reluctor or digital |
| 2H | Aux T | Spare Auxiliary Temperature input |
| 2I | None | No Connection |
| 2J | Knock | Knock sensor signal |
| 2K | +5V output | 5V supply for sensors (eg. MAP, TPS etc) |
| 2L | Digital Input 8 | 12V tolerant inputs, can be switched high or low |
| 2M | TPS signal input | Throttle Position Sensor signal |
| 2N | O2/EGO signal input | Oxygen sensor signal |
| 2O | MAP sensor signal input | Manifold Absolute Pressure sensor signal |
| 2P | MAT | Manifold Air Temperature signal |
| 2Q | ECT | Engine Coolant Temperature signal |
| 2R | MVSS2 | Master vehicle speed sensor 2 |
| 2S | None | No Connection |
| 2T | Aux Output 5 | Low-current only (eg. relay coils), NOT PWM capable |
| 2U | Injector Output 1 | Up to 1.9 Amps, handles high or low impedance injectors |
| 2V | Injector Output 4 | Up to 1.9 Amps, handles high or low impedance injectors |
| 2W | Aux Output 1 | Approximately 3 Amps capable, and PWM capable |
| 2X | Aux Output 4 | Approximately 3 Amps capable, NOT PWM capable |
| 2Y | Injector Output 2 | Up to 1.9 Amps, handles high or low impedance injectors |
| 2Z | Injector Output 3 | Up to 1.9 Amps, handles high or low impedance injectors |
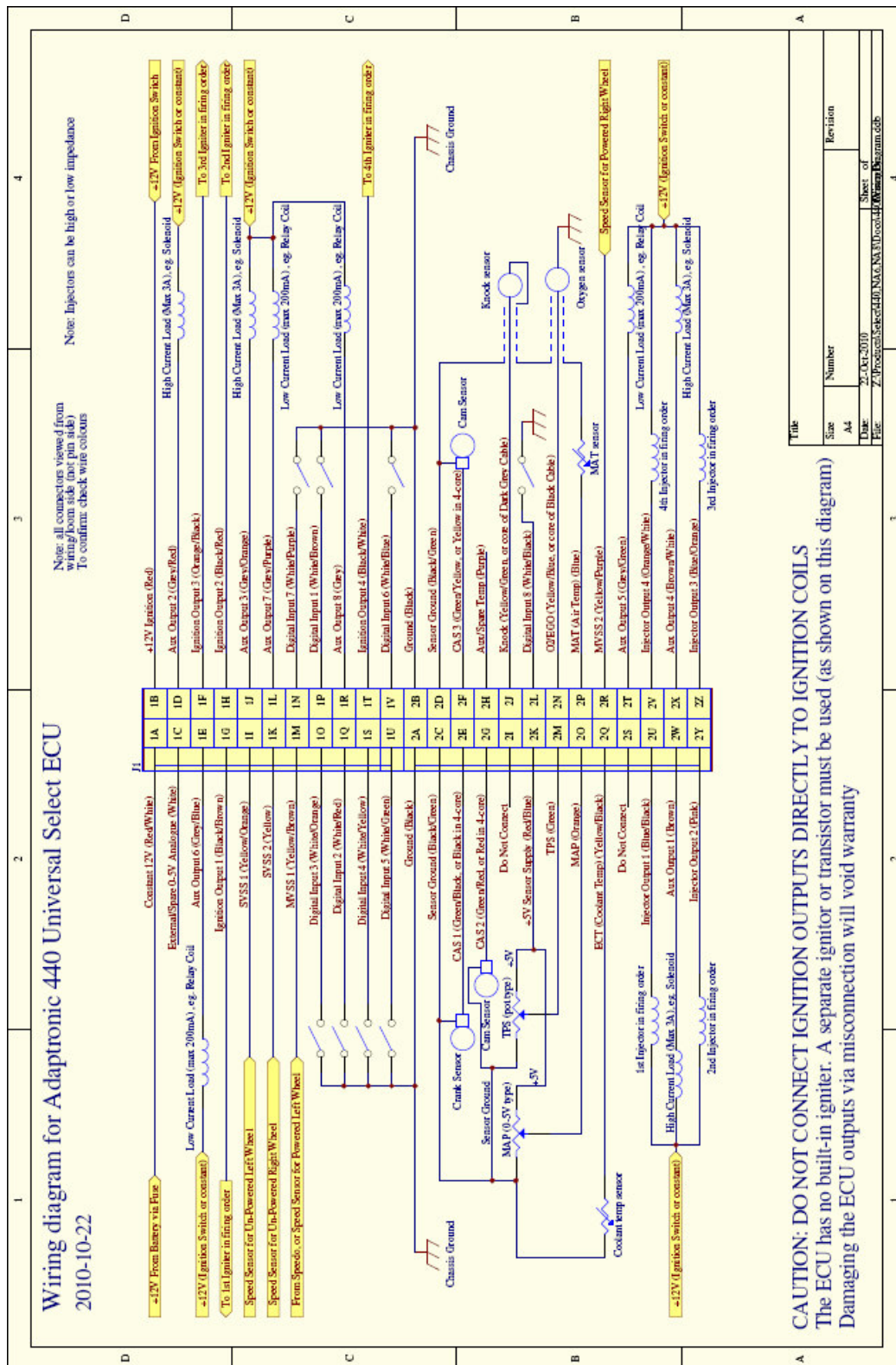
Figure 44: 440 Universal Select ECU Wiring Diagram

The 440 Universal Select has the following connectors and ports:

- One 22-way dual-row connector, which accepts the plug for the first of the two bundles in the 440 Universal Select flying loom;
- One 26-way dual-row connector, which accepts the plug for the second of the two bundles in the 440 Universal Select flying loom;
- Two 2.5mm jacks, one for serial data in from peripheral devices (such as wideband oxygen sensors), and the other for serial data out to external dashboards or data-loggers;
- One 3.5mm headphone jack for listening to knock.

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 below 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.

## 5.1.    Temperature Sensors

There are three temperature sensor inputs - Engine Coolant Temperature on Pin 2Q, Manifold Air Temperature on Pin 2P, and Aux/Spare Temperature on Pin 2H.
These sensors are to be connected as a thermistor (a resistor whose resistance varies with temperature) between sensor ground and the sensor input.

- 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 input is strictly optional, and currently it is only used for displaying an extra temperature reading in the live gauges.

## 5.2.    Throttle Position Sensor (TPS, pin 2M)

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 has a 5V supply output wire which can be used to power the TPS. The TPS is traditionally wired so that full throttle gives the highest voltage on the signal wire, and closed throttle gives the lowest voltage.

## 5.3.    Manifold Absolute Pressure (MAP) sensor (Pin 2O)

The 440 Universal Select ECU has an internal 4 bar MAP sensor, but you may choose to install an external MAP sensor if you wish. 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 sensor 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).

## 5.4.    Crank/Cam Angle Sensors (CAS pins 2E, 2F, 2G)

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 CAS inputs on the ECU. If the sensor is grounded at the engine block, do not ground this to the sensor ground wire too.

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 below:
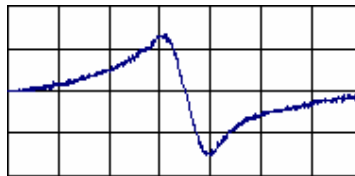


**Figure 45:    Reluctor Waveform (correct)**

- For reluctor sensors, there will usually be two wires, where the positive side should go to the appropriate CAS input on the ECU, and the negative side should go to sensor ground.
- 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:
   o pin 1 to pin 2 is 170Ω
   o pin 1 to pin 3 is 170Ω
   o pin 1 to pin 4 is 170Ω
   o pin 2 to pin 3 is 340Ω
   o pin 2 to pin 4 is 340Ω
   o 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 NOT as shown below. 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 below).
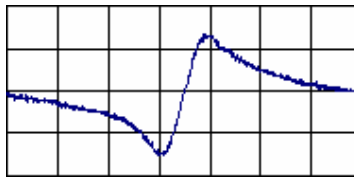
**Figure 46:    Reluctor Waveform (inverted, incorrect)**

## 5.5.    Vehicle Speed Sensors (VSS)

The 440 Universal Select ECUs have four VSS inputs, which can be connected to digital (hall-effect) or reluctor/inductive pickups (such as many standard ABS sensors).
The first VSS input (MVSS 1, pin 1M) is used for idle speed control on vehicles which have no neutral switch, however the VSS values can also be logged by the PC. The other three VSS inputs (pins 2R, 1I and 1K) are not required unless you plan on running traction control.

## 5.6.    Digital Inputs

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 they 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 to turn it on) 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'.**

## 5.7.    Power to the ECU

There is one Ignition Switch +12V input on the ECU. This should be connected so that it comes on only with the ignition. Only a small amount of current flows through this wire, as it is only required to power up the electronics in the ECU.
There are two 'Power Ground' wires, which should be connected to the engine block, or chassis, or battery negative terminal. If you are tapping in to the factory ECU loom, there will be wires that are already grounded in this fashion somewhere on the vehicle.

## 5.8. Injector Wiring

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 heat-sink temperature (under the bolts on the ECU lid) 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:

| ECU Pin | Cylinder |
|---|---|
| 2U – Injector Output 1 | 1 |
| 2Y – Injector Output 2 | 3 |
| 2Z – Injector Output 3 | 4 |
| 2V – Injector Output 4 | 2 |

## 5.9. Auxiliary Outputs

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 and 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, VVT, 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 (with series resistors). 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 relay coils.
- 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.

## 5.10. Knock Sensor (Pin 2J)

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. If you are using a long loom, the knock sensor should be connected via shielded cable because of the low signal levels.

## 5.11. EGO Sensor (Pin 2N)

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
- Insulate any loose strands of the braid, by shrinking a piece of heat-shrink over the end of the sheath
- 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.
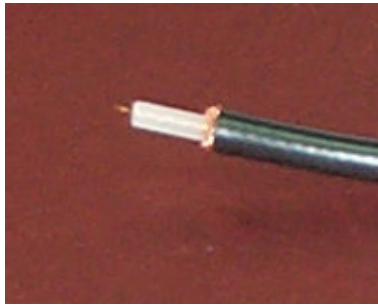
**Figure 47:    Stripped back sheath and cut braid**
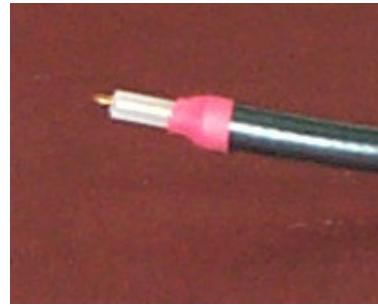


**Figure 48:    Stripped back sheath and insulated braid**

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.
- Shrink a length of heatshrink around the braid, to insulate it from other conductors.
- Shrink a length of heatshrink over the join, to insulate any exposed braid.
- 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 49:    Stripped back sheath and twisted braid**
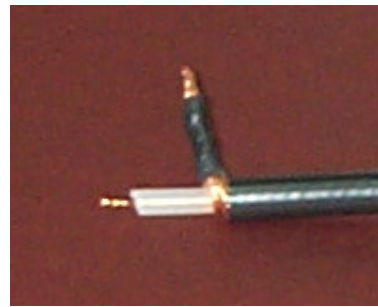


**Figure 50:    Heatshrink over braid**
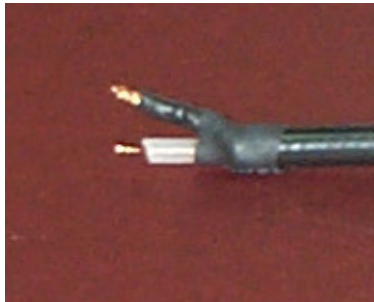


**Figure 51:    Heatshrink over join**

## 5.12.    Connecting a Wideband Oxygen Sensor

There are three methods to connect a wideband oxygen sensor:

- Into the normal oxygen sensor input (pin 2N).
- Into the 'External' analogue input (pin 1C). This input is 5V tolerant and is suitable for most linearised oxygen sensors.
- Into the secondary serial port of the ECU (2.5mm 'Serial In' jack). This is the most preferable option.

The secondary serial port is one of the 2.5mm jacks (Serial In).
The Innovate devices have a 2.5mm jack of their own, so they can be connected straight through with the corresponding cable. However, most other types of wideband oxygen sensor controllers have a 'DB9' 9-pin serial port, which means that you may need to use a gender-changer and/or adaptor cable to be able to connect into the 2.5mm Serial In jack on the Adaptronic Select ECUs.

The following serial protocols are currently supported through this serial port:

- M&W UEGO LSU4
- Innovative Motorsports LC1 / LM1 (and/or TC-4 EGT unit)
- TechEdge WBO2 serial frame format 2
- TechEdge 2J1
- FJO Gen II
- AEM UEGO

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

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

## 5.13.    Other Options for Secondary Serial Port – 'ELM 327 @ 38400 baud'

There are off-the-shelf devices available which contain an ELM327 chip, which is basically an 'OBD to RS232 Interpreter'. This device is designed to allow communications between an OBD connector and an RS232 connection.
If one of these devices is connected to the secondary serial port of the ECU, and set to 'ELM327 @ 38400 baud', the ECU will periodically send a command every 11 seconds to clear any fault codes stored in the factory ECU, often *before* they can cause the fault light to illuminate on the dashboard. This is useful for 'piggyback' installations whereby the factory ECU needs to be retained to control certain things on the vehicle, such as an automatic transmission. There is also a similar secondary serial port mode which only clears the fault codes once at startup (this is required in some cases if the vehicle's OBD/CAN bus doesn't like to be 'hogged' continually).

## 5.14.    Innovate TC-4 Thermocouple interface device on Second Serial Port

The secondary serial port can also be used to receive data from an Innovate TC-4 thermocouple interface device. Currently, this simply allows the four EGT values from the TC-4 device to be displayed on the gauge window, and they can also be logged.

**An Innovate LC-1 wideband oxygen sensor can be chained in series with a TC-4 device. If you wish to do so, the TC-4 must be placed at the ECU end of the chain.**