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Currently there are a few sweet options for hardware, all have the same brain, but with different baseboards.

Where to get firmware

FOME firmware releases are located here. You can download a release and install to the ECU with the console, or another way is to use TunerStudio (TS).

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Guide to tuning the ETB and VVT PIDs

Write something here about the ETB setup and the VVT PIDs

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So, you've just got yourself a shiny new BMM MX5 Miata ECU for your NA or NB, nice! If you're wondering how to install and get it running, you've come to the right place. This guide …

FOME Overview

What is FOME

Fome is an open-source project to create a whole vehicle open ecosystem that is able to work with modern vehicles with a view to safety, reliability, and sustainability. Fome is born out of existing open-source projects and intends to build upon those in a way to meets automotive standards and provides the best possible experience for users and contributors.

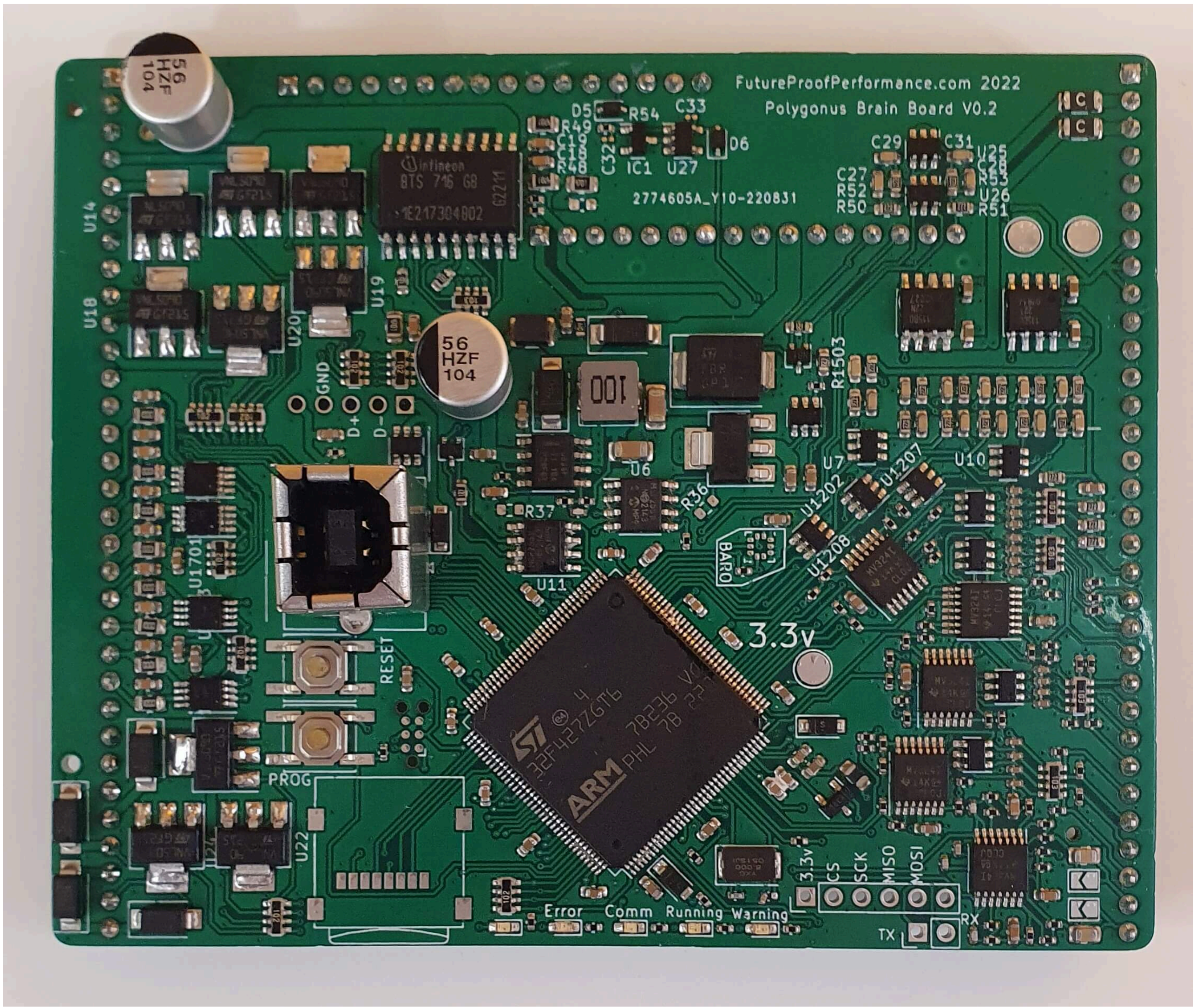
Which FOME hardware to pick

Currently there are a few sweet options for hardware, all have the same brain, but with different baseboards.

BRAIN

Polygonus 🧠

This is where the real action happens. Designed to be consistent across different base board applications to simplify design, ensure repeatability, and reduce cost. The Polygonus (said Puh-LIG-on-us) Brain is on all FOME ECUs.



BASEBOARDS

BMW

For the M50TU and M60 engines (and harnesses), this plug and play FOME ECU will allow you to use your turn signals (cringe jokes). No but really, E36 Chassis is hot right now. Street/Drag/Drift you name it. Everyone who had an S-Chassis now wants an E36. Hell you could use this in other chassis too.

Miata

You love big hair, short shorts, and tops off 24/7 (and stereotypes too). Luckily FOME has you in mind with a wide arrangement of options fot the Mazda Miata Platform.

BeerMoneyMotorsports in sexy *billet* cases. NA,NB, 1.6, 1.8, VVT, turbo, ITBs, etc. You name, it, and its covered.

Harley

Whether you're cruising the highways, crushing that 1/4 mile, or just want more power, the

Harley FOME ECU (designed for 2021+ bikes) is an excellent choice. NMSTEC has them available ready to go, also in a very nice *billet* case.

Coming Soon

Universal

Sometimes you don't know what car your engine is going in, or you want to do a swap. Regardless, a universal option is always good to have. It uses the common and reliable VAG (not that VAG, but Volkswagen Audi Group) plugs with a nice 120 pins. This means 8 cylinders of sequential fueling (up to 12 batch), plenty of inputs and outputs. (20 lowside, 4 highside, CANBUS, SD Card) It should be able to handle 95% of projects out there.

Honda

VTEC baby

Where to get firmware

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Tuner Studio Setup

Make sure that you have downloaded the latest version of TunerStudio (TS) from here. Although the base version of the software is free, it is strongly recommended to buy a license for the additional features including auto-tuning and the ability to customize the default dashboard.

Begin the setup by plugging the ECU into the laptop and opening TS. Create a new project and click *detect* under firmware. Select the COM port corresponding to the FOME ECU in the device list. If the COM port cannot be found or the firmware cannot be automatically detected, click *Other/Browse* and load the .ini file for the ECU which can either be downloaded or found within the ZIP file on the USB device which appears when the ECU is plugged into the computer.

Note

As per the FOME Statement, we want to make clear that FOME is currently a fork of rusEFI, and that present boards are BOTH rusEFI and FOME compatible. As time goes on, and more changes are made, this compatibility may change.

Flashing the firmware

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Power cycle ECU

Any change that you make to the tune or ecu should be followed by a power cycle of the ecu. The only exception to this is for tuning tables (VE Timing etc.)

Always have a main relay

The main relay is an essential component of the FOME ECU system. It is responsible for delivering power to the ECU when the key is turned on. Without the main relay, the ECU would not receive any power and would not be able to function properly.

Why use a main relay?

Using a main relay has several benefits. First, it helps to protect the ECU from power surges and voltage spikes that can occur when the engine is starting. Second, it allows for a more secure and stable connection between the ECU and the power source, which can help to prevent electrical interference and noise.

It's important to note that the wiring of the main relay may vary depending on the specific ECU and vehicle configuration. Always refer to the manufacturer's instructions and wiring diagrams when installing the main relay to ensure proper installation and operation.

Why do I have XYZ error?

Check error code and compare to this list (grab list out of firmware)

Table Axis

Make sure these are always numerically ascending (i.e. 1, 2 ,3 not 1, 1, 3, or 1, 3, 2.)

If you have these going from a large number to a small, stuff is not going to work.

How to pick a fuel method

Use this to explain the pros and cons of each of the methods and which is more suitable for certain builds

Guide to tuning the ETB and VVT PIDs

Write something here about the ETB setup and the VVT PIDs

Miata MX5 Quick Start Guide

So, you've just got yourself a shiny new BMM MX5 Miata ECU for your NA or NB, nice! If you're wondering how to install and get it running, you've come to the right place. This guide will cover how to install the ECU to the car with a Bosch LSU 4.9 wideband oxygen sensor and a mass air pressure (MAP) line. Installation of additional sensors or peripherals is covered in the advanced guides.

> ***NOTE:*** Before commencing the ECU installation, it is recommended to jack up the car or drive it onto ramps in the case when the oxygen sensor location is under the vehicle.

Required Tools and Components

- BMM Miata ECU
- BMM wideband adapter harness
- BMM options port pigtail
- Genuine Bosch LSU 4.9 oxygen sensor
- 3 metres of silicone vacuum hose 5/32" or 4mm internal diameter
- 4mm straight barb joiner
- 22mm wrench or 22mm oxygen sensor socket
- Timing light
- USB cable (included with ECU)
- Windows, Mac or Linux laptop with an installed copy of EFI Analytics TunerStudio

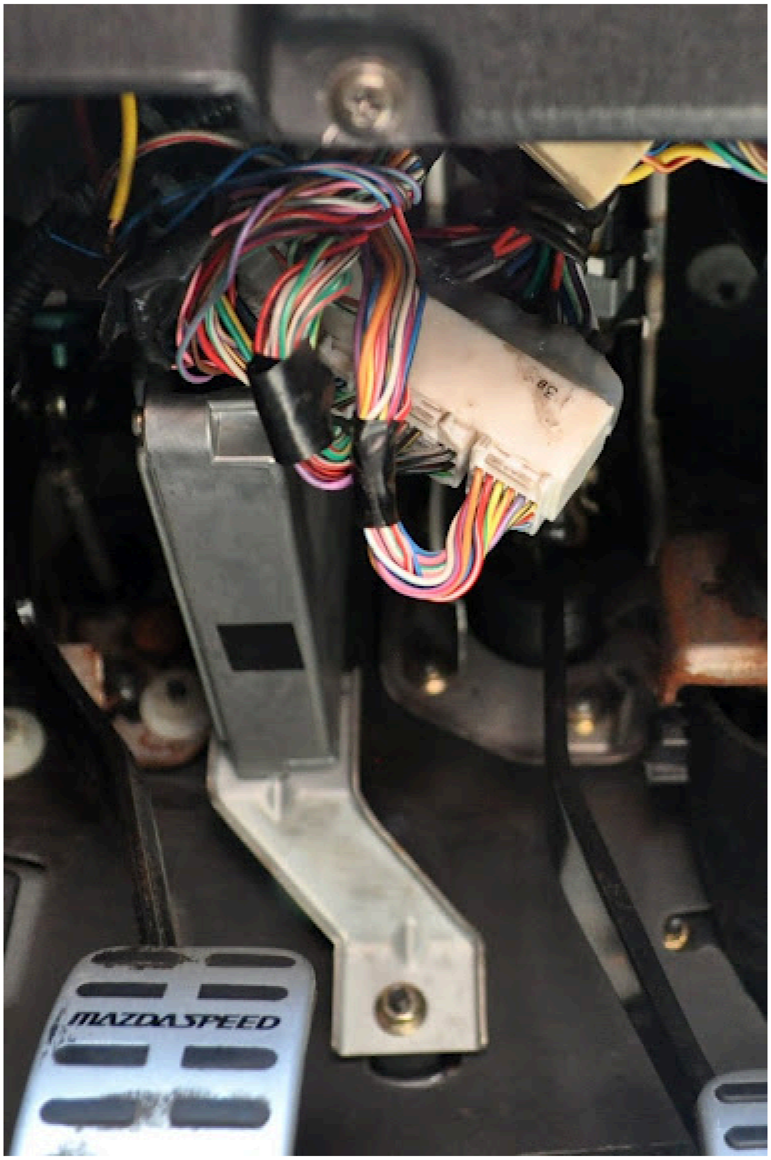
- Spanner and socket set

Removing Original ECU

The stock ECU location for a Miata will be in one of three spots depending on the driving side and year:

Left Hand Drive NB

The ECU can be found above the pedals, next to the steering column.



90-93 Left Hand Drive NA and Right Hand Drive NA/NB

The ECU can be found under the carpet in the passenger side footwell. To access this, the carpet needs to be unhooked from the vertical trim piece on the edge closest to the passenger door. Removing this trim piece can also simplify access. The ECU kick plate will also need to be removed after taking off the five 10mm nuts and bolts holding it in place.

94-97 Right Hand Drive NA

The ECU can be found behind the passenger's seat, under the carpet. Move the seat forwards all the way. Next, the passenger door sill needs to be removed with a philips head screwdriver so that the carpet towards the back of the seat can be pulled back to reveal the ECU.

Once the ECU has been located on your Miata, disconnect the car battery then remove all electrical plugs to the ECU. Un-bolt any remaining ECU mounting brackets from the car with a 10mm socket and the ECU should now be free from the car. The last step is to use a philips head to remove the factory ECU mounting brackets from the stock ECU case for these will be needed to mount the BMM ECU.

Connecting Wideband Oxygen Sensor

> ***NOTE:*** It is imperative that you use a genuine Bosch LSU 4.9 sensor rather than a cloned product. A fake LSU 4.9 will not provide accurate readings and can cause a lot of headaches down the track. The best way of avoiding a fake sensor is to buy directly from a reputable supplier of vehicle parts rather than generic large online re-

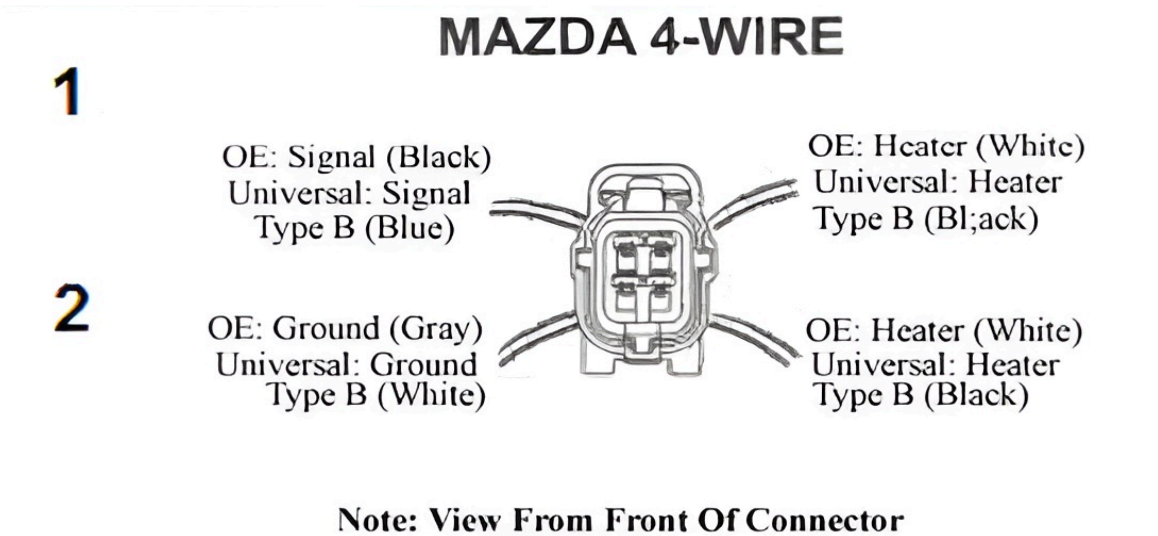
> sellers. Typical part numbers for this Bosch sensor include: 17025, 17212, 17123 and 17217. The notable difference between these part numbers is the cable length so it is recommended to measure what length you need ahead of time.

Find the factory oxygen sensor on the exhaust and unplug it from the wiring harness. In the case that the car has multiple oxygen sensors, the one to remove is the closest sensor to the engine block before any catalytic converters. Next, unscrew the sensor and replace it with a Bosch LSU 4.9 wide-band sensor. Connect the sensor to the BMM wideband adapter harness. The trailing end of the harness will need to be fed through the firewall into the cabin. The easiest way of doing this, as shown in the image below, is to cut a hole in the nearest firewall bung to the stock ECU location, and feed the cable through that. Cable tie the wiring away from any hot areas of the engine bay. Inside the cabin, connect the wideband adaptor harness plug to the options port pigtail and plug it into the ECU.

Using an External Wideband Controller

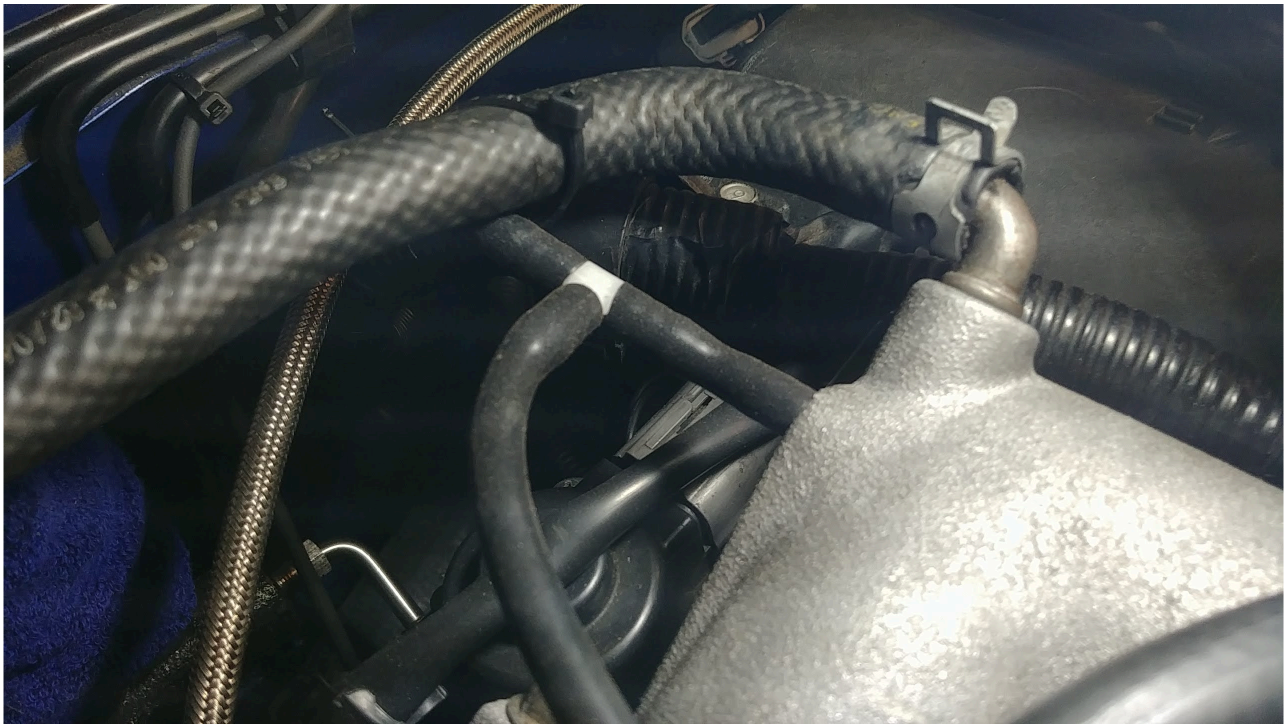
In the case you wish to use an external wideband controller such as an *AEM X-Series*

Wideband UEGO AFR Sensor Controller Gauge, the wideband sensor should be plugged into the wideband controller instead of directly into the ECU. The best way to wire in the controller is directly to the old narrow band oxygen sensor plug on the car based off the diagram below. In this diagram, pin 1 goes to the controller analogue output, pin 2 to the signal ground, pin 3 to the controller 12V input and pin 4 to the other controller ground (if applicable). Make sure to double check the voltages on the pins before connecting the controller to them. The external controller also requires additional setup in Tuner Studio which will be covered later.

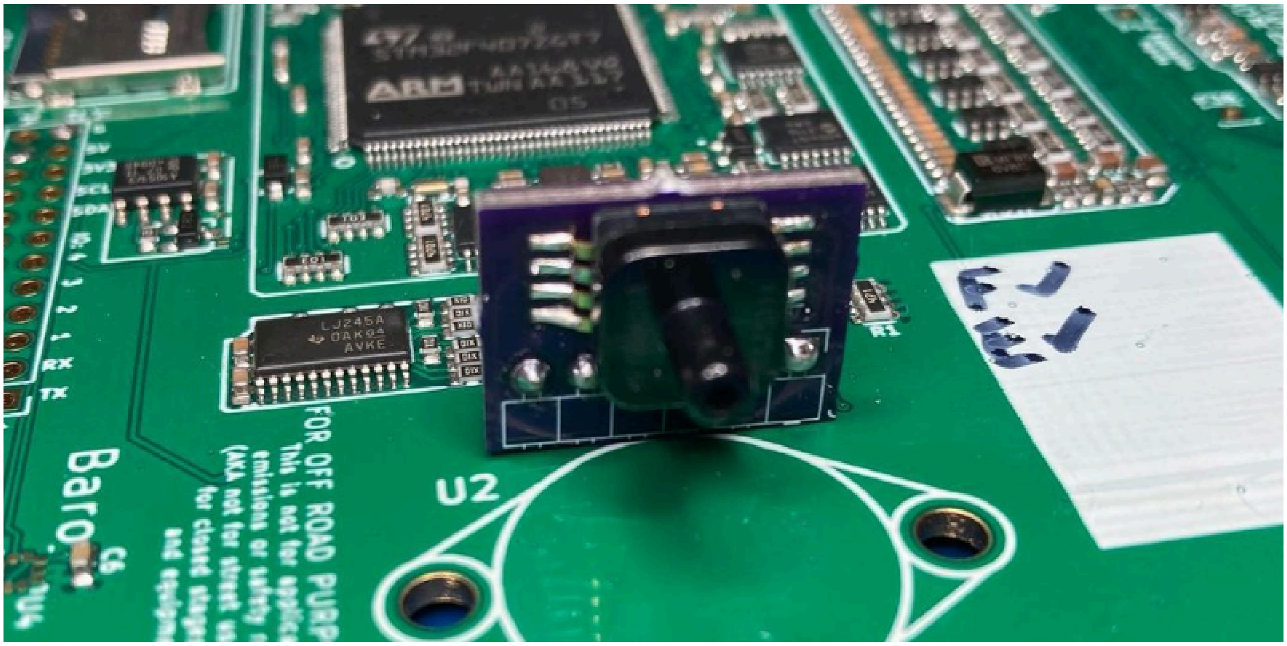


Connecting MAP Line

Look around the intake manifold for any spare vacuum ports that lie after the throttle body and connect the vacuum line. If there are no spare ports, pick one and attach the vacuum line to it using a tee piece. It is recommended but not required to cable tie the vacuum line to the tee. In the image below, there was a free vacuum port on the back of the intake manifold which has been tee'ed off into the MAP line and the blow off valve line (only applicable on turbo charged vehicles).



Like the oxygen sensor, feed the line through the bung in the firewall to the ECU. If you have a 4mm barb joiner, connect the vacuum line to the vacuum line protruding from the BMM ECU case. If you do not have a barb joiner, open up the BMM ECU case with a philips head and feed the vacuum line through the case. Mock up the position of the case in the car before cutting the vacuum line to length. Pull the vacuum line onto the MAP sensor on the ECU (the sensor with the nipple on it pictured below) and optionally fasten it with a small cable tie. The ECU can now be put back into its case.

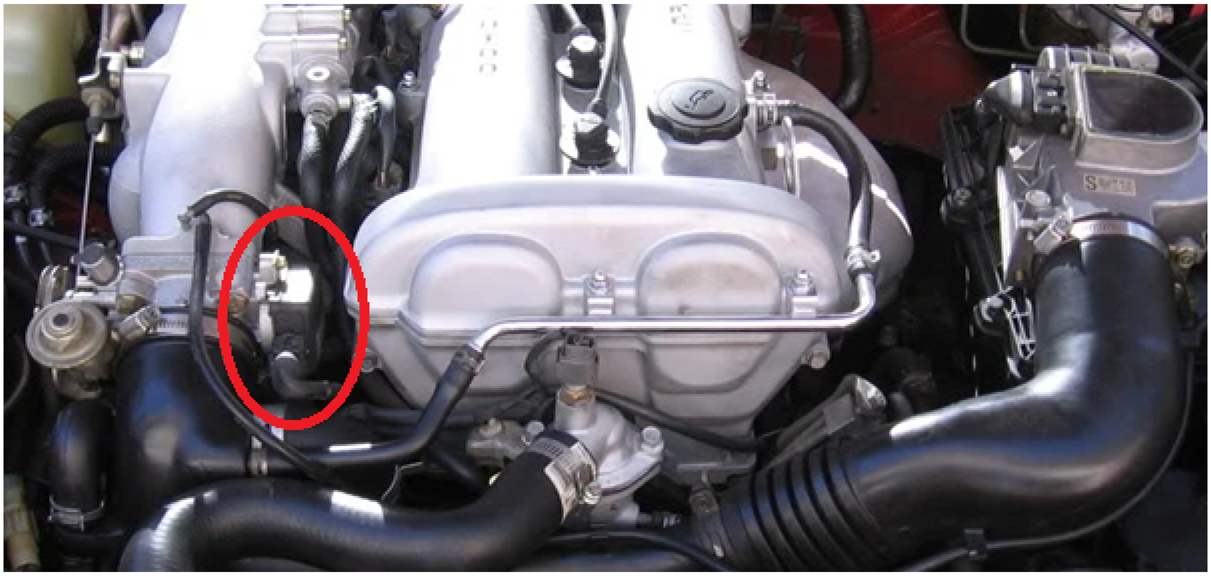


Using the MAP line combined with an intake air temperature (IAT) sensor, the BMM ECU can run the car using what is known as speed-density air metering. This means that you can unplug the mass air flow (MAF) sensor or the air flow meter (AFM) for the NA 1.6L vehicles. Removing these sensors and replacing them with a pod filter directly to the intake can even result in a fractional power increase from the reduction in intake restriction.

Additional Steps for NA6 Vehicles

The NA6 1.6L vehicles which use an AFM instead of a MAF require a few additional modifications to run with a BMM ECU. A manual NA6 do not have a variable throttle position sensor (TPS) like the automatic NA6, later model NAs and all NBs. An NA6 also needs an external intake air temperature (IAT) sensor wired in as the AFM which has one inside is typically removed. They also require a jumper for the ECU to control the fuel pump which was previously the job of the air flow meter.

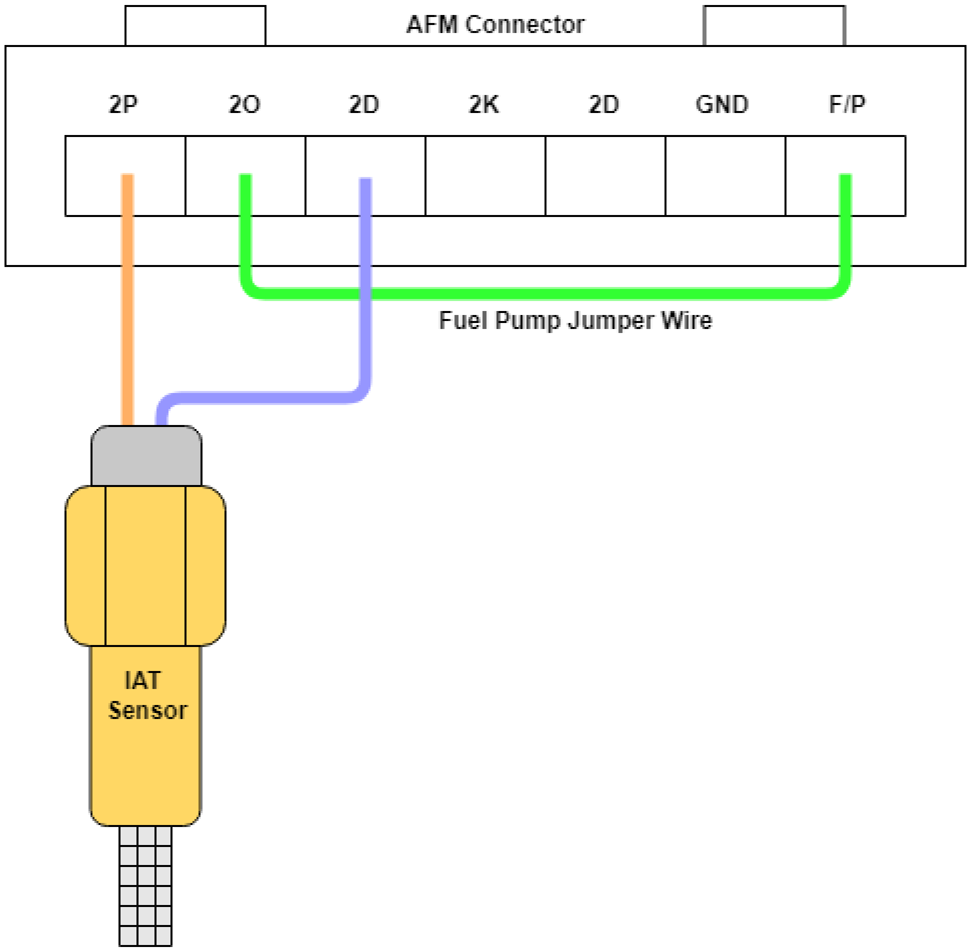
The first step is to disconnect the factory TPS sensor. **This is very important or it will cause a short circuit later.**. The TPS sensor location is shown in the image below.



The BMM ECUs for this vehicle include a KIA TPS and adapter. The KIA TPS will plug straight to the OEM TPS plug without any additional wiring. If using another variable TPS that requires re-wiring, the NA6 TPS connector pinout is as follows:

Function	Cable Colour
Signal	Green/White
Ground	Black/Green
5V Reference	Red

The next step is to wire up the IAT sensor and to add a jumper wire to the AFM connector as per the wiring diagram below. Any IAT sensor with two wires can be used although a GM IAT sensor is recommended as FOME already has a configuration for it. As the IAT is a resistance-based sensor, the orientation of the wires does not matter.



Connecting the ECU

Now that the MAP line and wideband are connected to the ECU, the remaining wiring harness plugs from the OEM wiring loom can be plugged into the ECU. Take the factory ECU mounts and attach them to the BMM ECU case. The ECU can now be re-installed into the factory location. The car battery can now be re-connected.

Tuner Studio Setup

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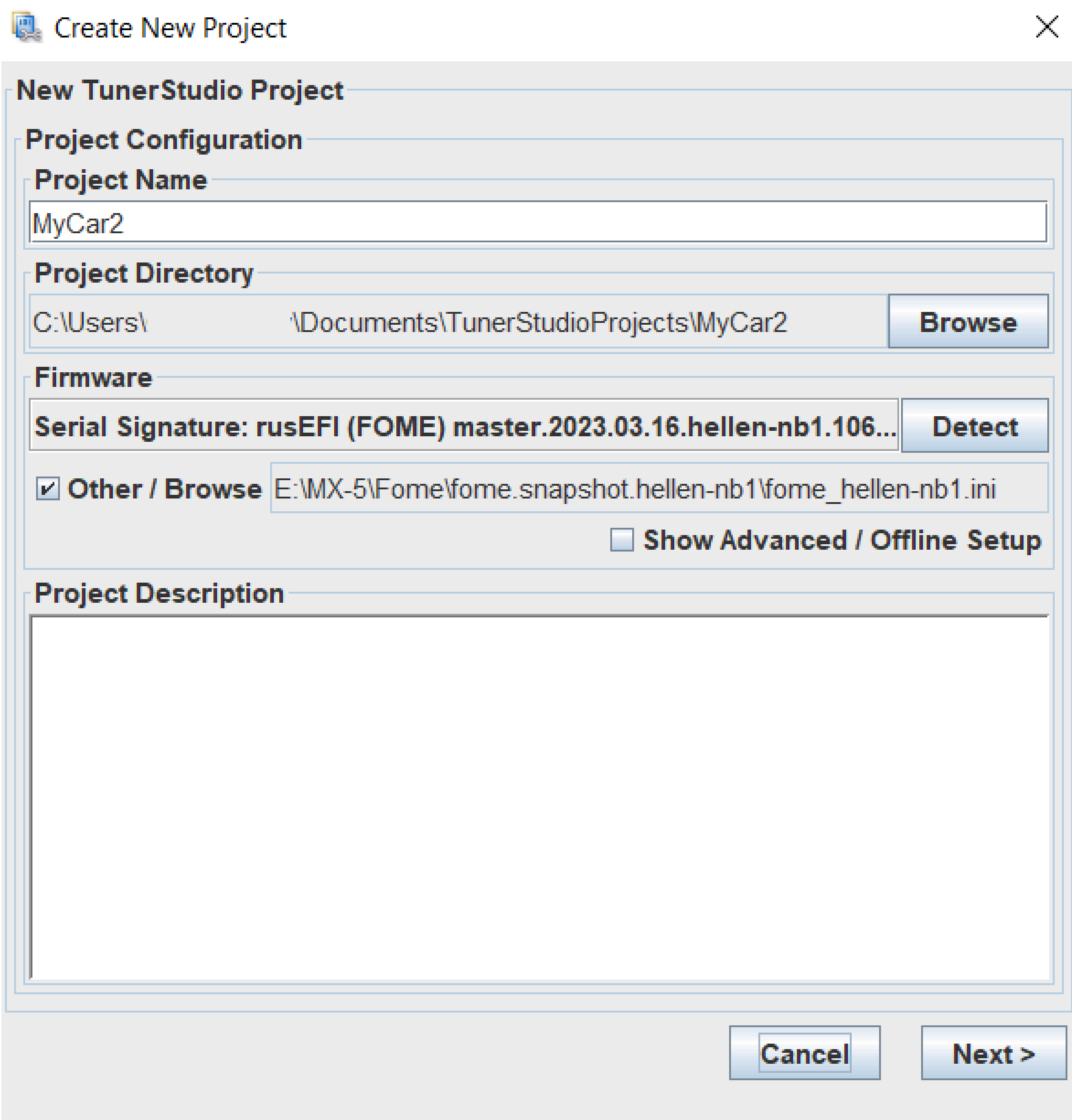
Although the base version of the software is free, it is strongly recommended to buy a license for the additional features including auto-tuning and the ability to customize the default dashboard.

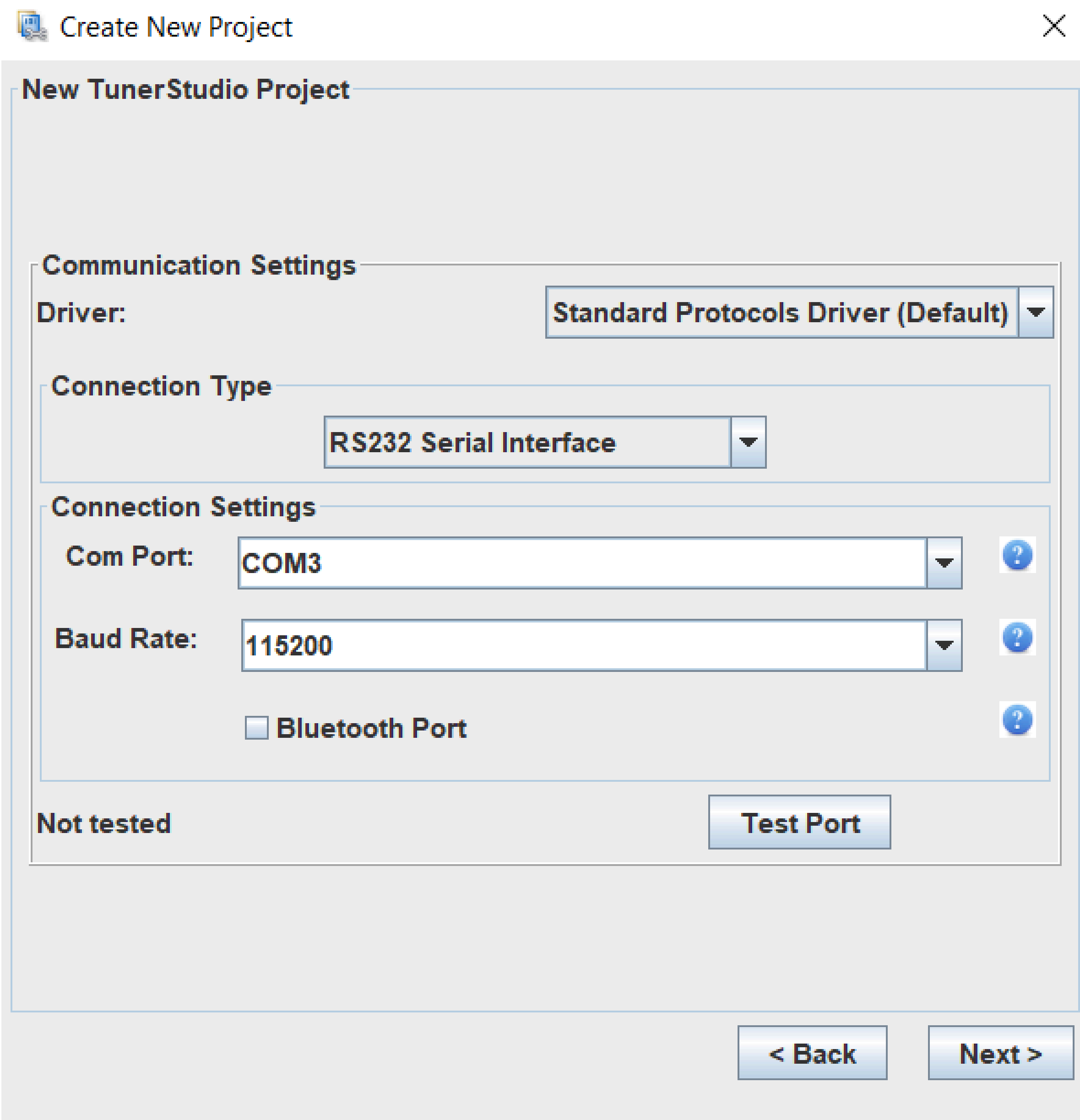
Begin the setup by plugging the ECU into the laptop and opening TS. Create a new project and click *detect* under firmware. Select the COM port corresponding to the FOME ECU in the device list. If the COM port cannot be found or the firmware cannot be automatically detected, click *Other/Browse* and load the .ini file for the ECU which can either be downloaded or found within the ZIP file on the USB device which appears when the ECU is plugged into the computer.



In the next dialog choose between lambda or air fuel ratio (AFR) as your display units. lambda is recommended as it is easier to comprehend and tune with. For example, the ideal or stoichiometric AFR for regular petrol is 14.7 (14.7 parts air to 1 part fuel) which corresponds with a lambda of 1. Lambda represents the percentage of air in the combustion chamber compared to the amount needed for ideal or stoichiometric combustion to occur. If a car is running 10% lean, the AFR would be 16.17 and lambda would be 1.1. If the car is 10% rich, AFR would be 13.36 and lambda would be 0.9.

Looking at lambda, it is instantly obvious what percentage rich or lean the engine is running but with AFR, it requires more effort. **The only time AFR should be selected here is if you are using an external wideband controller**.

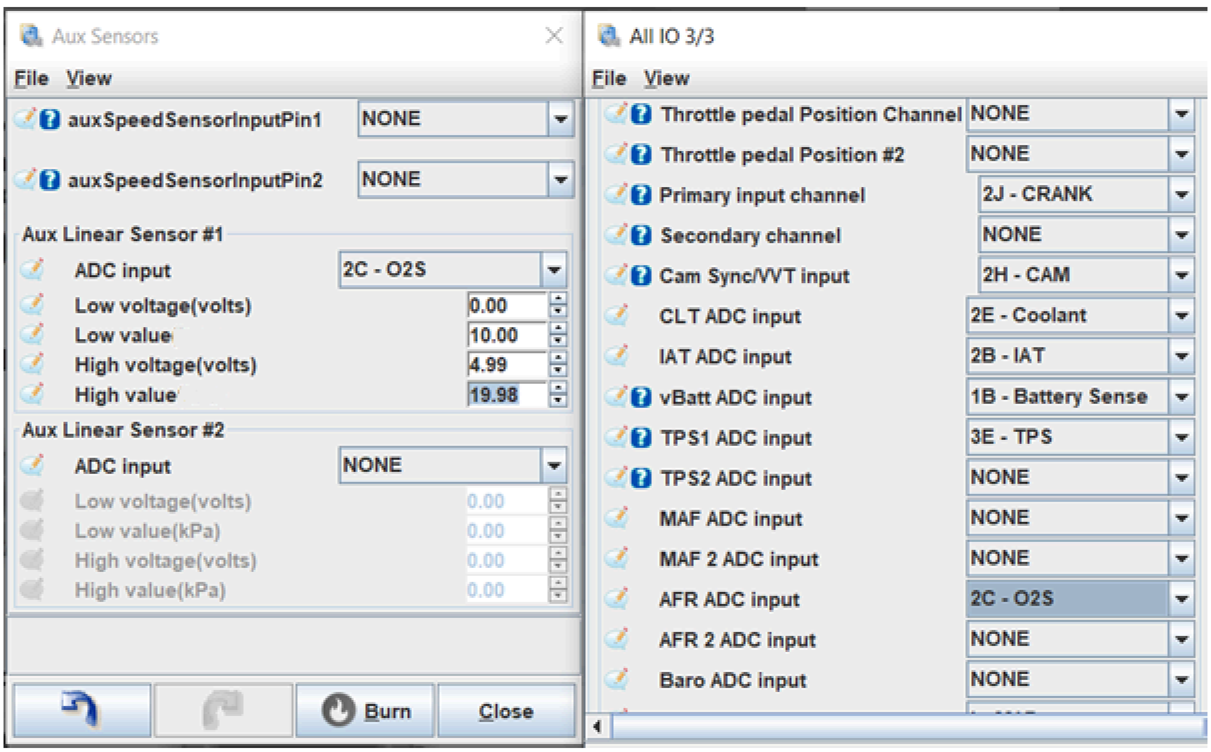
In the third dialog box, configure it as shown in the image below but select the com port which corresponds to your ECU. If unsure, go to the device manager on your computer and it should list the COM port number next to the name of the ECU. Click *Test Port* and if successful, move to the next dialog.



In the final dialog box, select the default gauge layout (you can change this later as you wish) and click *finish*. The last step before cranking the engine is to click the *Ignition* button to open the ignition settings and change the timing mode from *dynamic* to *fixed* and the fixed timing setting to 10 degrees. This will lock the engine to operate at 10 degrees of timing so that you can set the base timing.

Additional Tuner Studio Steps for an External Wideband Controller

To set up the external wideband controller there are several additional steps in Tuner Studio. First, your display units should be set to AFR for this as already stated. If you forgot to do this earlier, press *CTRL + P* to open the vehicle properties. Now, open the *Aux Sensors* dialog under *Sensors* and the *Full Pinout 3/3* dialog under *Controllers*. As per the diagram below, set the *AFR ADC Input* and *ADC Input* to the pin corresponding with *O2S* (pin 2C for the example). for the values in the *Aux Linear Sensor #1* box you need to reference the manual of your wideband controller for what voltages correspond to its AFR outputs. In the example below, 0V corresponds to an AFR of 10.0 and 4.99V corresponds to an AFR of 19.98. Once these are set, click *Burn*.



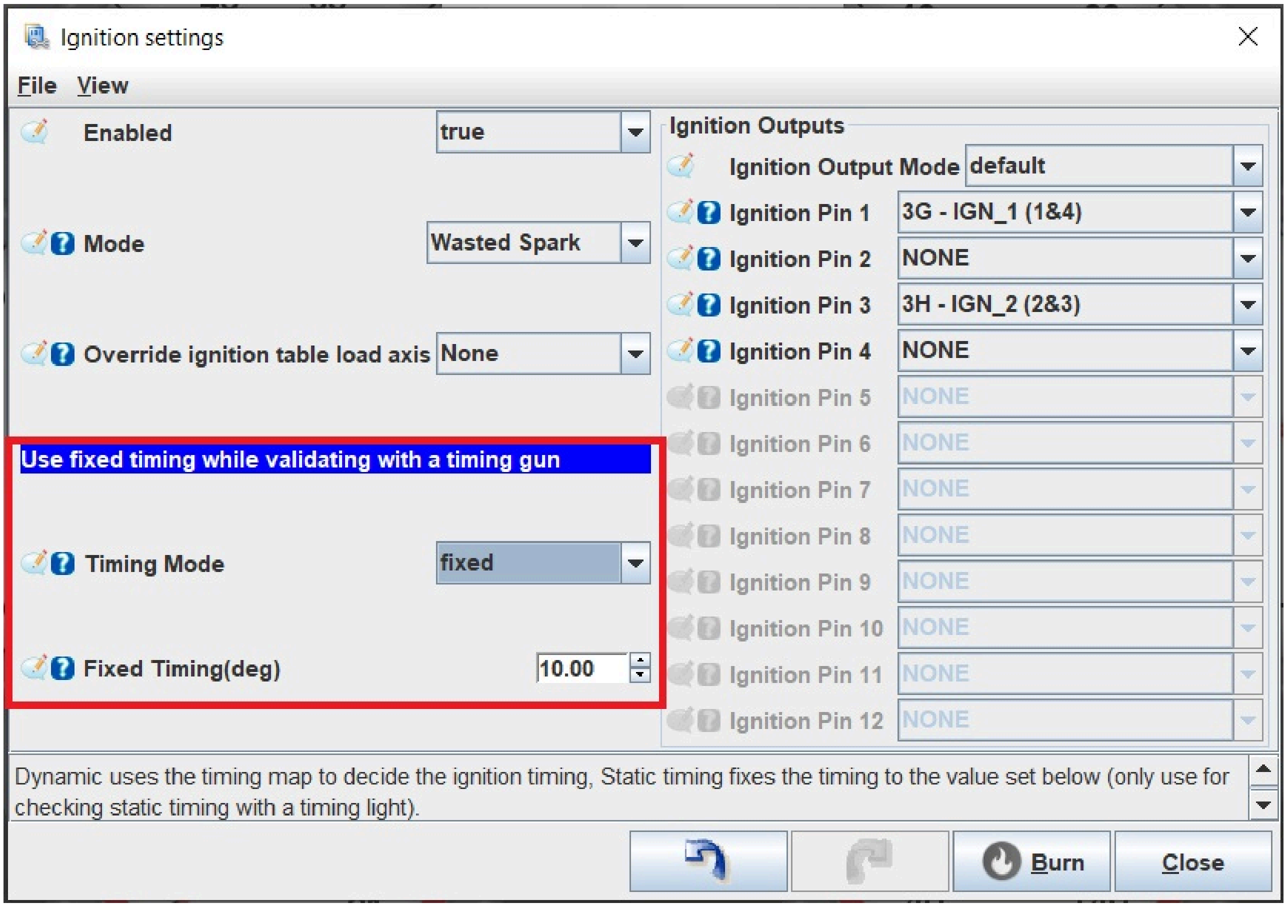
After completing all of the setup steps, you can go ahead and turn the car key two clicks to *ON* and listed for the fuel pump priming. Once the fuel pump has primed, go ahead and start the engine. Let it run for a few seconds and turn it off again. **Do not drive the vehicle yet, there are still several steps to complete before the car is ready for a drive**.

Set Base Timing

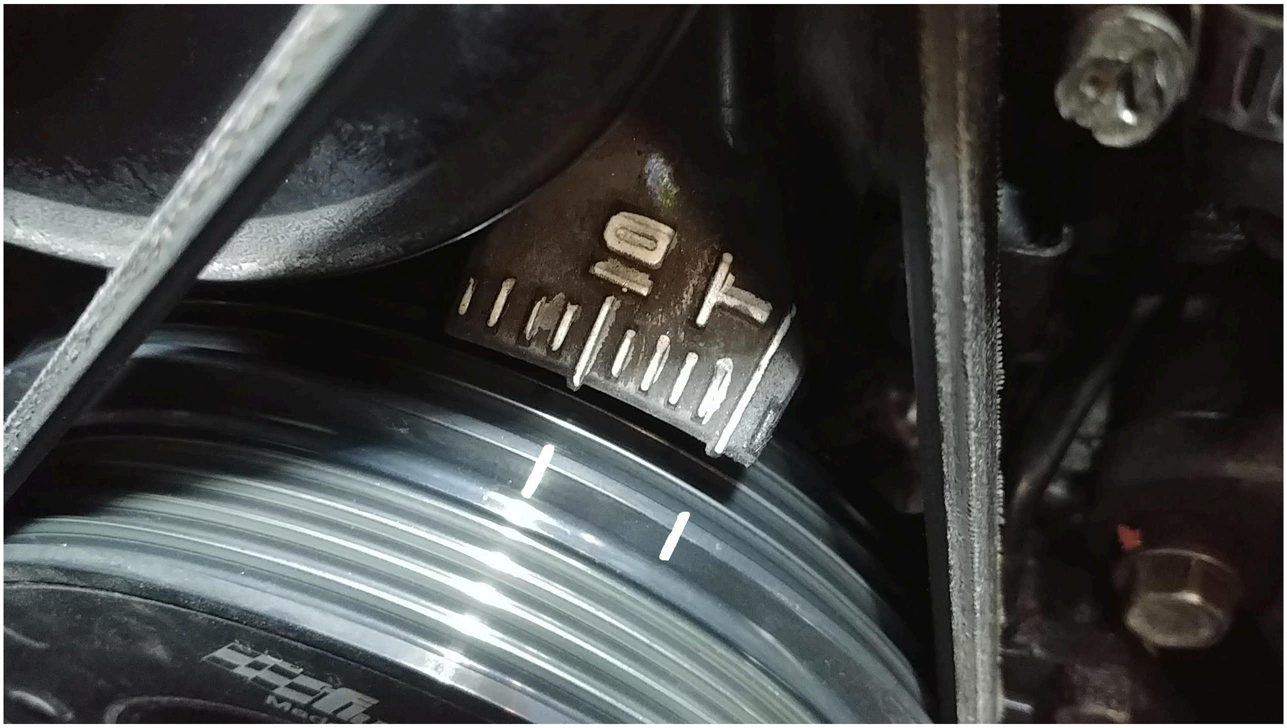
The car should start on the base map although once it is running, the base timing needs to be set up. This syncs the timing between the ECU and the car so that they are both reading the same values. Typically. the base timing will be a few degrees out from the base map as it varies slightly from car to car.

To set the base timing, connect the timing light power to a spare 12V battery and the inductive clamp onto the cylinder 1 spark plug lead (the closest spark plug to the front of the engine bay). Ensure that the arrow on the inductive clamp is pointing along the wire towards the spark plug, not towards the coil pack.

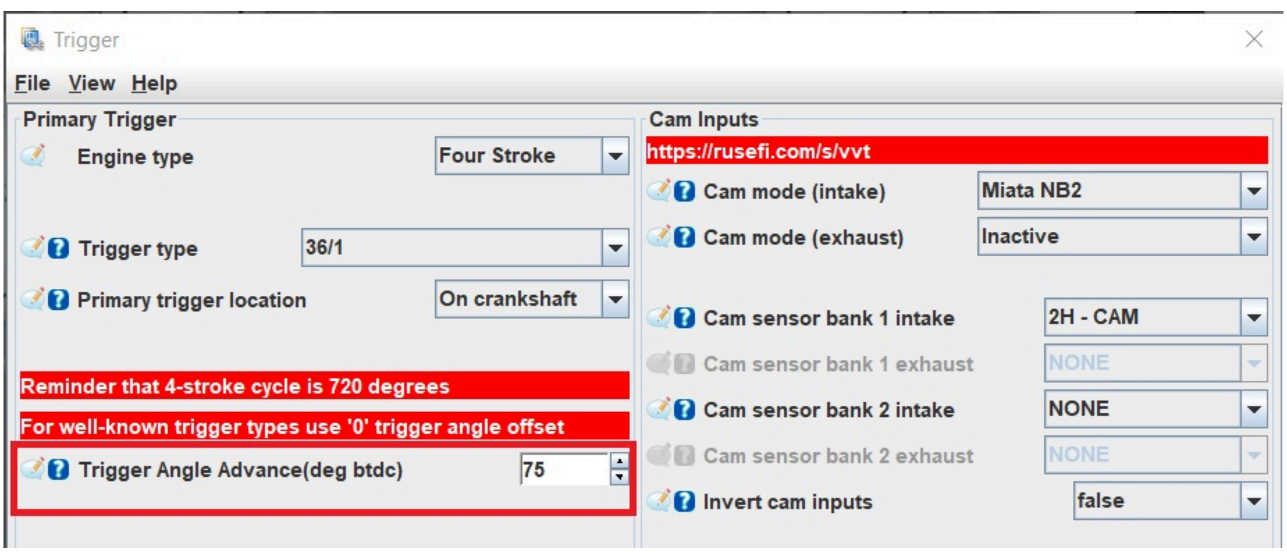
In TS, under *Ignition* > *Ignition Settings*, set the timing mode to *fixed* and *10* degrees then burn the configuration.



Now start the car and hold the timing gun trigger, shining the light onto the bottom harmonic damper pulley on the front of the engine. This pulley has two timing marks on it and a labelled cover above it. When the timing is spot on, these marks on the rotating pulley will line up with the *10* and *T* marks on the cover as shown below.



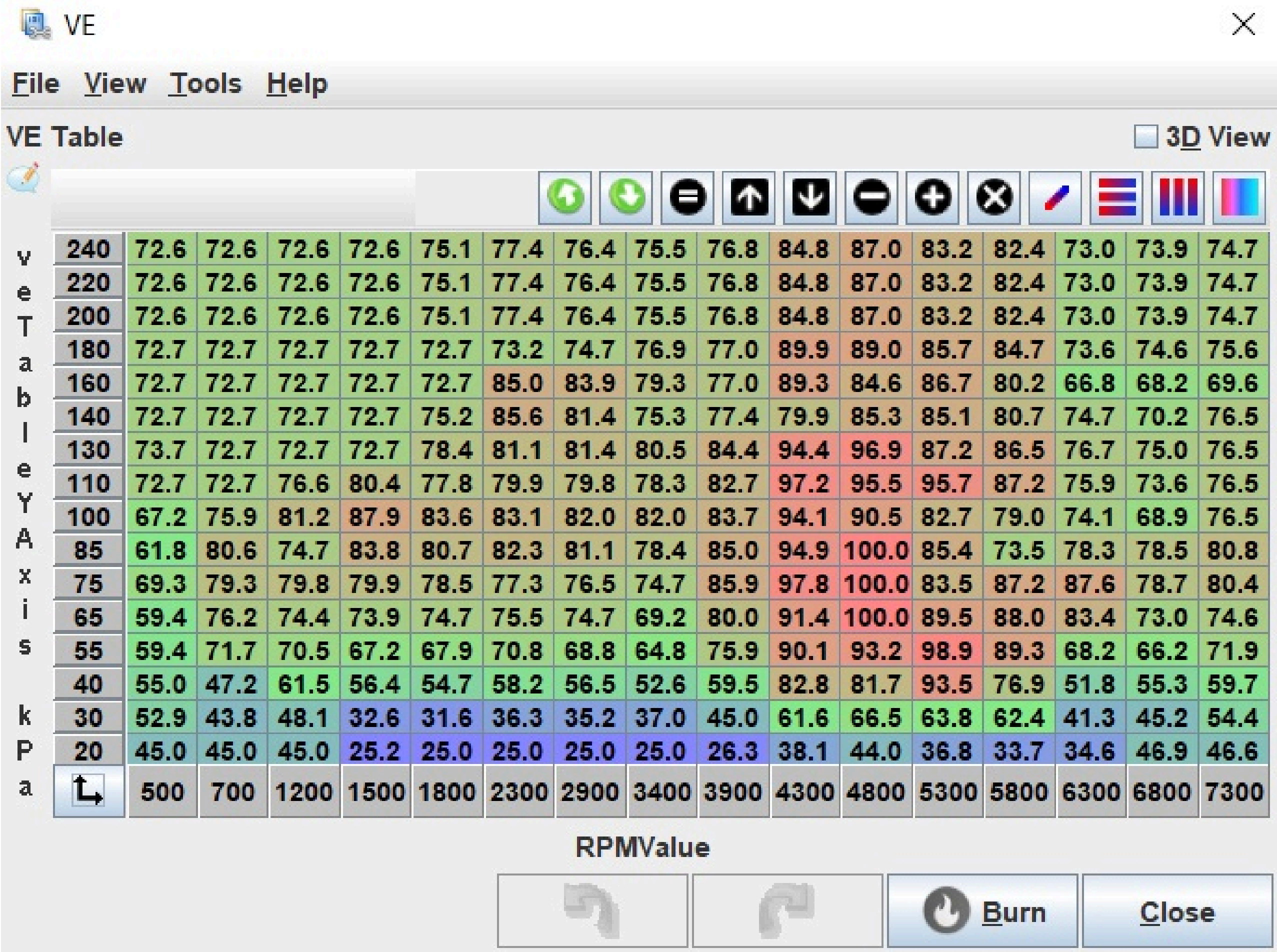
If your timing marks do not line up like in the image above, you will need to change the base timing. Count how many marks the timing is off by and turn the car engine off. In TS, go to *Base Engine* > *Trigger* and increase/decrease the *Trigger Advance Angle* by the amount of marks the timing was off by then burn the configuration. Repeat this process until the timing marks line up then change the timing mode back from *fixed* to *dynamic*.



First Drive and Tuning the VE Table

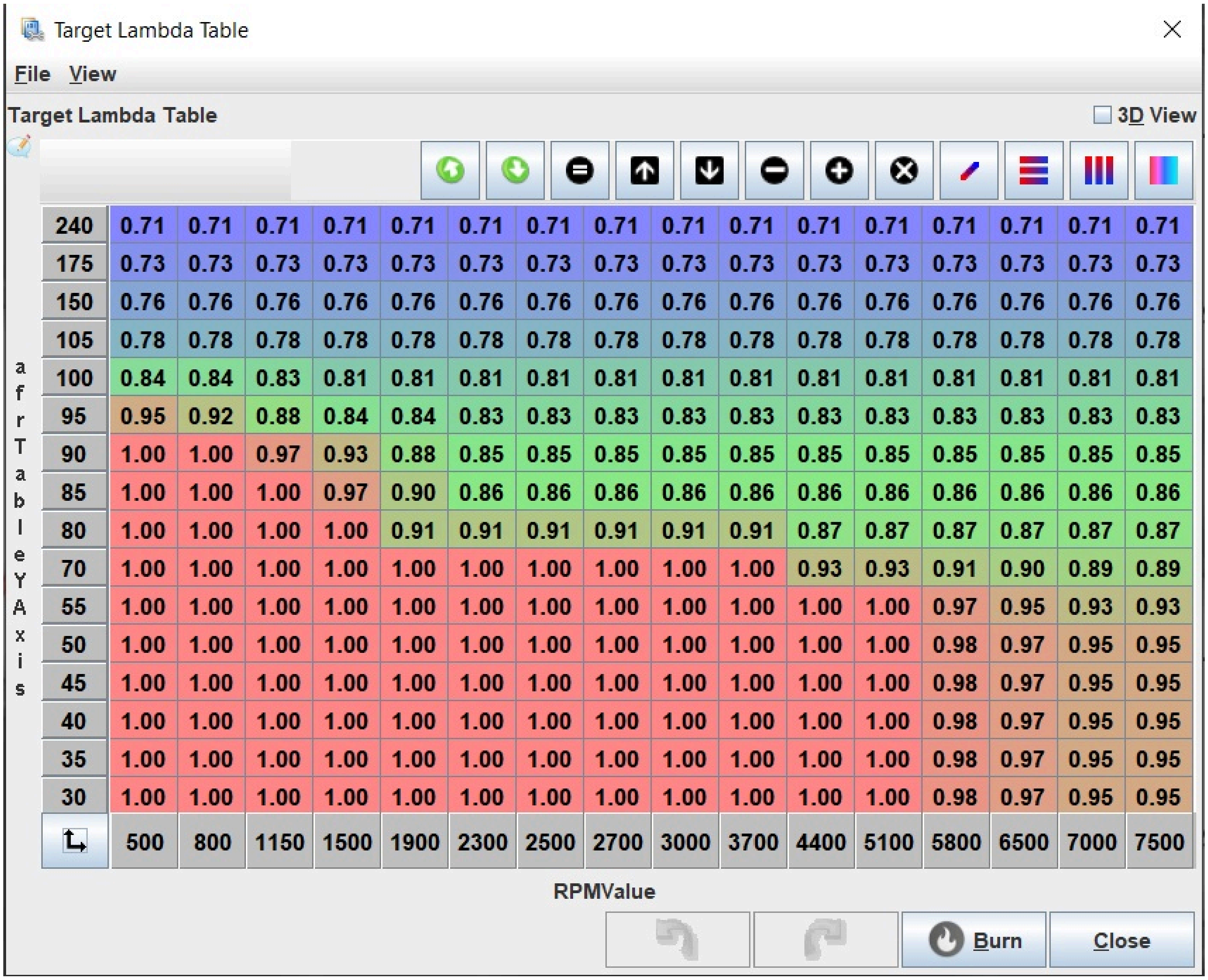
Everything is now ready to take your Miata for its first drive. You can't go and thrash it straight away though as the VE table which determines the fuelling needs to be tuned for your vehicle. Before you take the car for a drive, make sure your laptop is charged.

Start the car and plug the laptop in. Within 30 seconds, the lambda gauge should wake up and start displaying a value. For now, you want that value to be around 1 meaning that the exact amount of fuel is being supplied to the engine for perfect combustion to occur. To change the lambda value, you need to modify the VE Table under *Fuel > VE*. VE stands for volumetric efficiency which is the efficiency that the engine can move the fuel and air mix into and out of the cylinders. An example of a VE table is shown below (do not copy this table as it is off a highly modified vehicle). The table adjusts the VE percentage (represented by the numbers on the grid) based on the engine speed (represented as revolutions per minute - RPM) and engine load (represented as the MAP). With the engine running, blip the throttle and see how the indicator moves around the different table cells as the engine state changes.



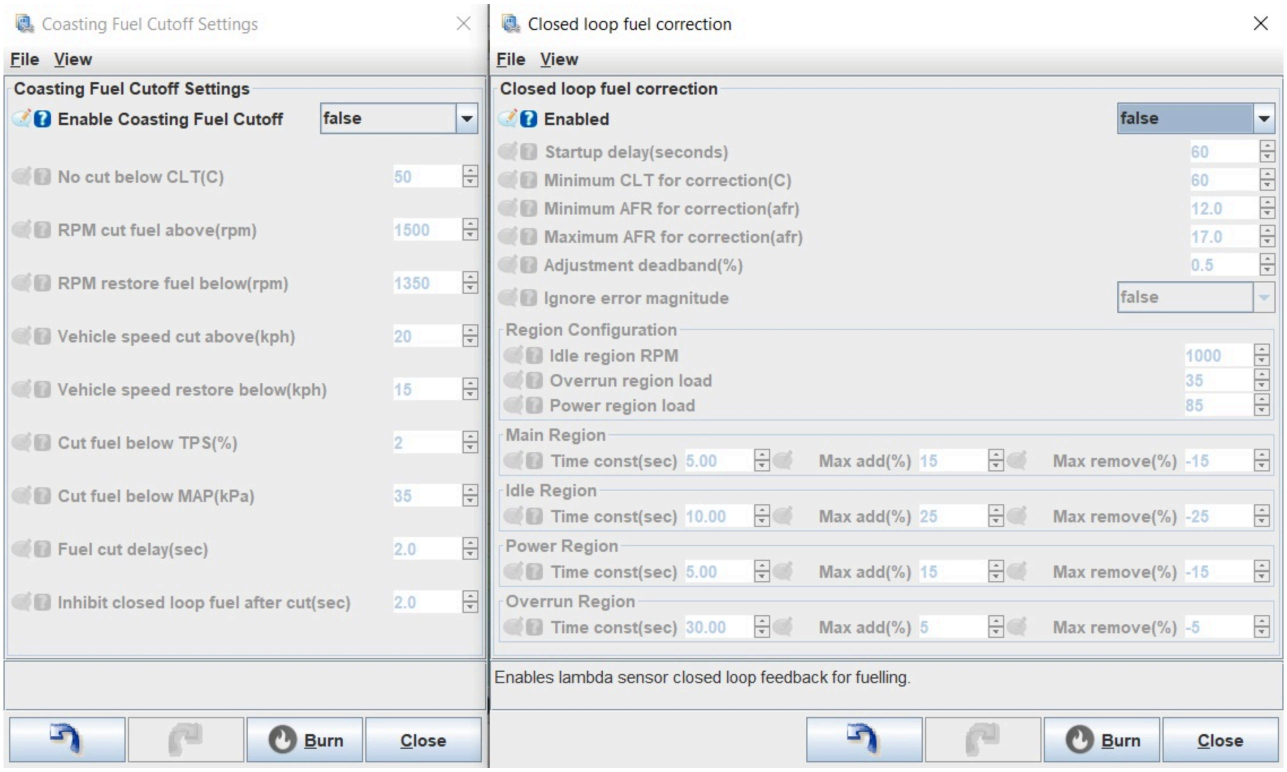
240	72.6	72.6	72.6	72.6	75.1	77.4	76.4	75.5	76.8	84.8	87.0	83.2	82.4	73.0	73.9	74.7
220	72.6	72.6	72.6	72.6	75.1	77.4	76.4	75.5	76.8	84.8	87.0	83.2	82.4	73.0	73.9	74.7
200	72.6	72.6	72.6	72.6	75.1	77.4	76.4	75.5	76.8	84.8	87.0	83.2	82.4	73.0	73.9	74.7
180	72.7	72.7	72.7	72.7	72.7	73.2	74.7	76.9	77.0	89.9	89.0	85.7	84.7	73.6	74.6	75.6
160	72.7	72.7	72.7	72.7	72.7	85.0	83.9	79.3	77.0	89.3	84.6	86.7	80.2	66.8	68.2	69.6
140	72.7	72.7	72.7	72.7	75.2	85.6	81.4	75.3	77.4	79.9	85.3	85.1	80.7	74.7	70.2	76.5
130	73.7	72.7	72.7	72.7	78.4	81.1	81.4	80.5	84.4	94.4	96.9	87.2	86.5	76.7	75.0	76.5
110	72.7	72.7	76.6	80.4	77.8	79.9	79.8	78.3	82.7	97.2	95.5	95.7	87.2	75.9	73.6	76.5
100	67.2	75.9	81.2	87.9	83.6	83.1	82.0	82.0	83.7	94.1	90.5	82.7	79.0	74.1	68.9	76.5
85	61.8	80.6	74.7	83.8	80.7	82.3	81.1	78.4	85.0	94.9	100.0	85.4	73.5	78.3	78.5	80.8
75	69.3	79.3	79.8	79.9	78.5	77.3	76.5	74.7	85.9	97.8	100.0	83.5	87.2	87.6	78.7	80.4
65	59.4	76.2	74.4	73.9	74.7	75.5	74.7	69.2	80.0	91.4	100.0	89.5	88.0	83.4	73.0	74.6
55	59.4	71.7	70.5	67.2	67.9	70.8	68.8	64.8	75.9	90.1	93.2	98.9	89.3	68.2	66.2	71.9
40	55.0	47.2	61.5	56.4	54.7	58.2	56.5	52.6	59.5	82.8	81.7	93.5	76.9	51.8	55.3	59.7
30	52.9	43.8	48.1	32.6	31.6	36.3	35.2	37.0	45.0	61.6	66.5	63.8	62.4	41.3	45.2	54.4
20	45.0	45.0	45.0	25.2	25.0	25.0	25.0	25.0	26.3	38.1	44.0	36.8	33.7	34.6	46.9	46.6
	500	700	1200	1500	1800	2300	2900	3400	3900	4300	4800	5300	5800	6300	6800	7300

The general way to tune the VE table is to go through all the cells which the engine will operate within and to adjust the VE percentage until the lambda gauge matches the value in the *Target Lambda Table* shown below and in TS found under *Fuel* > *Target Lambda*. For example, if the lambda gauge shows 1.1 and the target lambda for that engine state is 1.0, the corresponding VE cell needs to be increased by 10%. The target lambda table supplied with the Miata base map should be sufficient to start with but you can modify it later to make the engine run richer or leaner under certain conditions such as boost or highway cruising respectively.

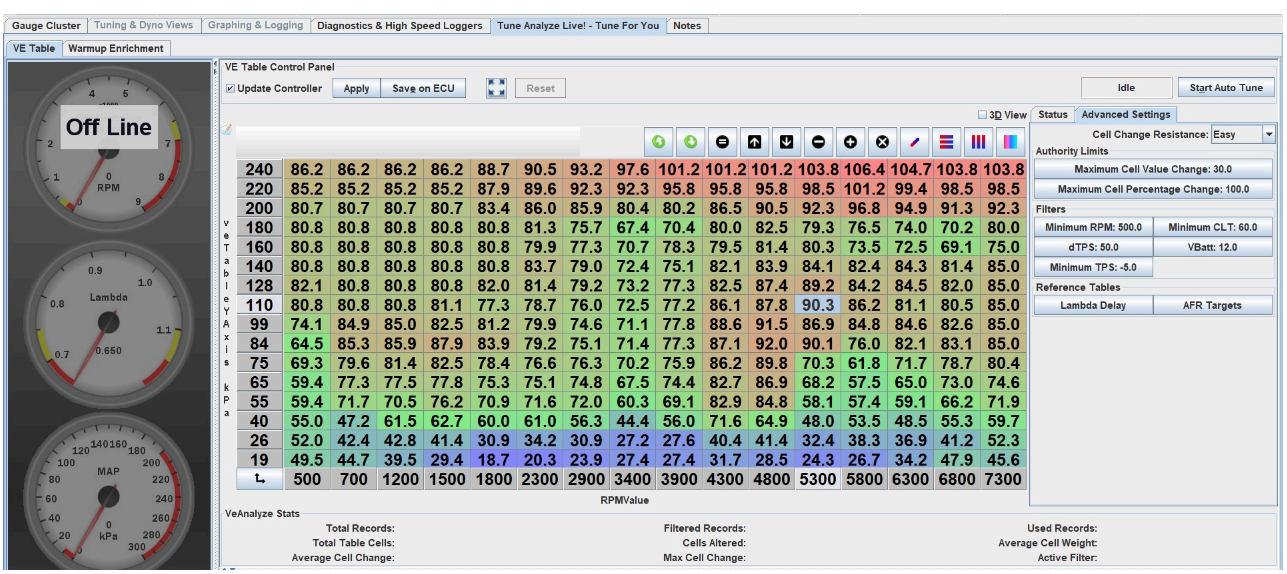


afrTableYAxis																
240	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
175	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
150	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
105	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
100	0.84	0.84	0.83	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
95	0.95	0.92	0.88	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
90	1.00	1.00	0.97	0.93	0.88	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
85	1.00	1.00	1.00	0.97	0.90	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
80	1.00	1.00	1.00	1.00	0.91	0.91	0.91	0.91	0.91	0.91	0.87	0.87	0.87	0.87	0.87	0.87
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.91	0.90	0.89	0.89
55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.95	0.93	0.93
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.95	0.95
45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.95	0.95
40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.95	0.95
35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.95	0.95
30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.95	0.95
RPMValue	500	800	1150	1500	1900	2300	2500	2700	3000	3700	4400	5100	5800	6500	7000	7500

There are three ways of tuning the VE table. The first way is to drive the car around smoothly as a mate in the passenger seat goes through and changes the VE values until the lambda gauge matches the target lambda. The second and easier way is to use the TS autotuner which is only available in the full version of TS but absolutely worth it. To tune this way, you first need to disable some parameters. Under *Fuel*, open *Closed loop fuel correction* and *Deceleration fuel cut off (DFCO)*, set them both to false and click *burn* with the engine off. The third and easiest (yet most expensive option) is to take the car to a dyno for tuning where they will do either the first or second option themselves. The advantage of a dyno is that they can set it to bring the engine into any state they wish to perfectly configure the VE table.



Next, click the tab labelled *Tune Analyze Live! - Tune For You* to bring up the autotuner. Click to the *Advanced Settings* tab and configure it as shown in the image below. These configuration settings are deliberately quite loose so that TS can quickly tune the general shape of the VE table. On the left side of the *VE Table Control Panel*, you also need to check the box marked *Update Controller* which ensures that the VE table is updated on the ECU as the autotune corrects itself.



Now that the autotuner is set up, start the car and click *Start Auto Tune* on the autotuner. Let the car idle in park whilst it gets up to the minimum temperature. While this happens, you can attempt to change the idle cells in the VE table to get them to a lambda of 1. Once the car has warmed up, **smoothly** drive it around going through the gears and all the way through the rev range. A mix of flat, uphill and downhill driving in different gears is optimal to tune the majority of the engine's operating range. After you are sufficiently happy, click *Stop Auto Tune*, turn the engine off and click *Save on ECU*. You will want to repeat this process several more times, every time dropping the *Cell Change Resistance* and *Authority Limits* to slowly refine your VE table.

When you are satisfied with your VE table, turn closed loop fuel correction and *Deceleration fuel cut off (DFCO)* back to true. You don't actually need DFCO to be enabled although it will save fuel by turning the injectors off when the car is rolling in gear. Your Miata should now be relatively safe to drive but this is only the start of the tuning journey. As you read through the more advanced guides in this wiki, you will learn about all of the different ways the ECU can be configured to improve the drivability and squeeze every drop of performance out of your Miata.

Fundamentals of FOME tuning

The place to learn how to start tuning your FOME Hardware

Air Fuel Ratio

Air fuel ratio or AFR refers to the mass ratio of air to fuel involved in a combustion cycle. The AFR is important as the amount of fuel injected into the engine is the most significant combustion parameter that the ECU can control. The ECU takes the target AFR and determines the correct mass of fuel to inject based on the mass of air approximated using the temperature and pressure.

Why AFR Matters

An engine operates most efficiently and cleanly when the air-fuel ratio is at a specific value called the stoichiometric ratio. This ratio depends on the type of fuel being used, but for gasoline, it is approximately 14.7 parts air to 1 part fuel (14.7:1). When the air-fuel ratio is at the stoichiometric value, all of the fuel is burned, and there is no excess oxygen or unburned fuel left in the exhaust. This results in the least amount of emissions and the highest fuel efficiency. If the air-fuel ratio is too lean (excess air), there is not enough fuel to burn, and the engine may misfire or stall. If the air-fuel ratio is too rich (excess fuel), there is not enough oxygen to burn all the fuel, and the engine may emit more pollutants, have reduced fuel efficiency, and may even cause damage to the engine over time. Therefore, maintaining the proper air-fuel ratio is essential for optimal engine performance, fuel efficiency, exhaust gas temperature, engine knock and emission control in a car engine.

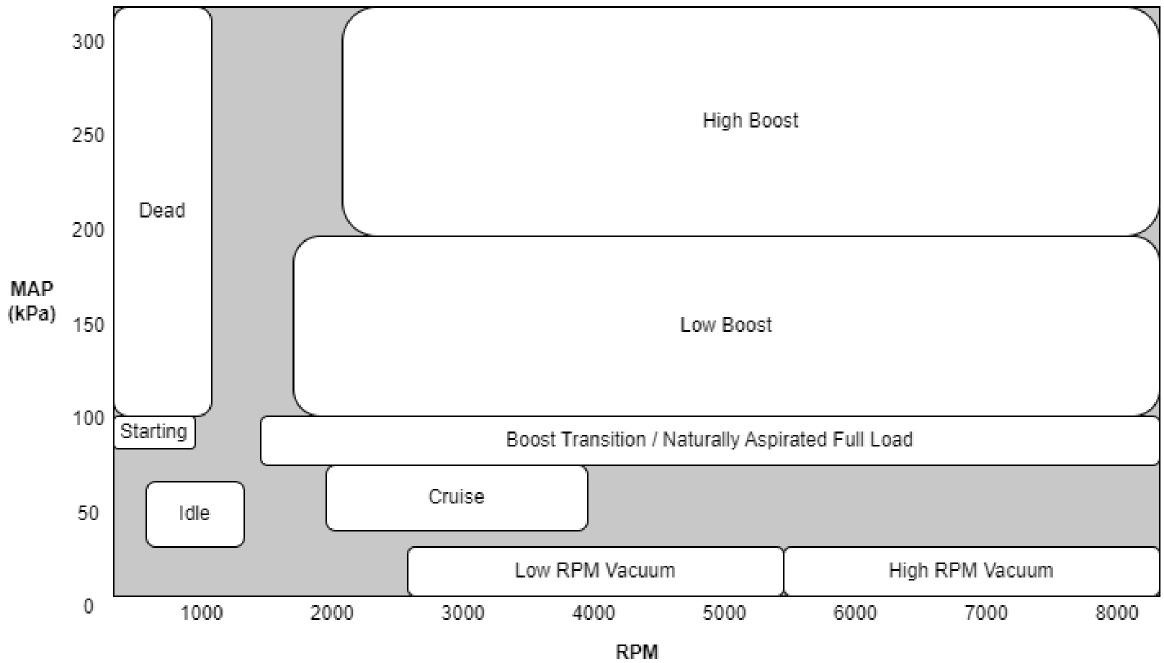
What is Lambda and Why it is a Superior Metric

Lambda, is a dimensionless ratio of the actual air-fuel ratio to the stoichiometric air-fuel ratio. In other words, it is the ratio of the AFR to the stoichiometric AFR (or the measured AFR divided by the stoichiometric AFR). Lambda is a more universal measure of the air-fuel ratio, as it is not affected by the specific fuel being used. The stoichiometric lambda value for any fuel is always 1.0, regardless of the fuel type. For example, if the actual AFR in an engine is 14.7:1 (stoichiometric AFR), then the lambda value is 1.0. If the actual AFR is leaner than 14.7:1, then the lambda value is greater than 1.0, and if it is richer than 14.7:1, then the lambda value is less than 1.0.

Lambda is preferred in engine tuning because it allows for a more precise control of the air-fuel ratio across different fuels and is generally easier to comprehend. For example, if a gasoline car is running 10% lean, the AFR would be 16.17 and lambda would be 1.1. If the car is 10% rich, AFR would be 13.36 and lambda would be 0.9. Looking at lambda, it is instantly obvious what percentage rich or lean the engine is running but with AFR, it requires more effort.

AFR Targets - When to Run Rich, Lean and Stoich

The ideal AFR targets will vary for every engine however there are guidelines for what the targets should be for each operating zone of the engine. These targets will be represented on an AFR target table or map, shown below, which characterizes the various engine operating conditions for their respective engine RPM and MAP. Generally speaking, running richer will decrease engine response at a gain of extra combustion chamber cooling and slightly higher power to a point. Inversely, running leaner will increase engine response at a loss running hotter and reducing power.



Idle and Cruising

For idle, a lambda of 1.0 is generally recommended to achieve a stable idle. When cruising, a lambda of 1.0 is also recommended however this can be raised up to about 1.05 to improve the fuel efficiency of the vehicle on the freeway or traveling a constant speed for long periods of time.

Low and High Load Vacuum

In the low vacuum section of the map, the engine will only operate here when the engine is under minimum load such as rolling in gear with the throttle closed. To save fuel, the engine can be operated up to about 1.05 lambda here or Deceleration Fuel Cutoff (DFCO) can be enabled to disable to injectors entirely and let the vehicle engine brake. DFCO is found under the *Fuel* tab in Tuner Studio.

The high vacuum part of the map is typically only used in the short period between high RPM gear changes or throttle lifts. The engine is usually being driven hard if this part of the map is being used so a target lambda of 0.95 to help cool the cylinders is recommended although a value of 1.0 is also acceptable.

High Load Naturally Aspirated/Boost Transition Zone

For a naturally aspirated (NA) engine, this zone represents the peak operating load which the engine will be placed under. A lambda of about 0.9 is recommended to balance performance with cylinder cooling.

For a forced induction engine, this zone represents the engine's transition into boost. As the engine usually isn't under a lot of load here, a slightly higher lambda of 0.95 is recommended to balance the engine response with some degree cylinder cooling.

Medium and High Boost Zones

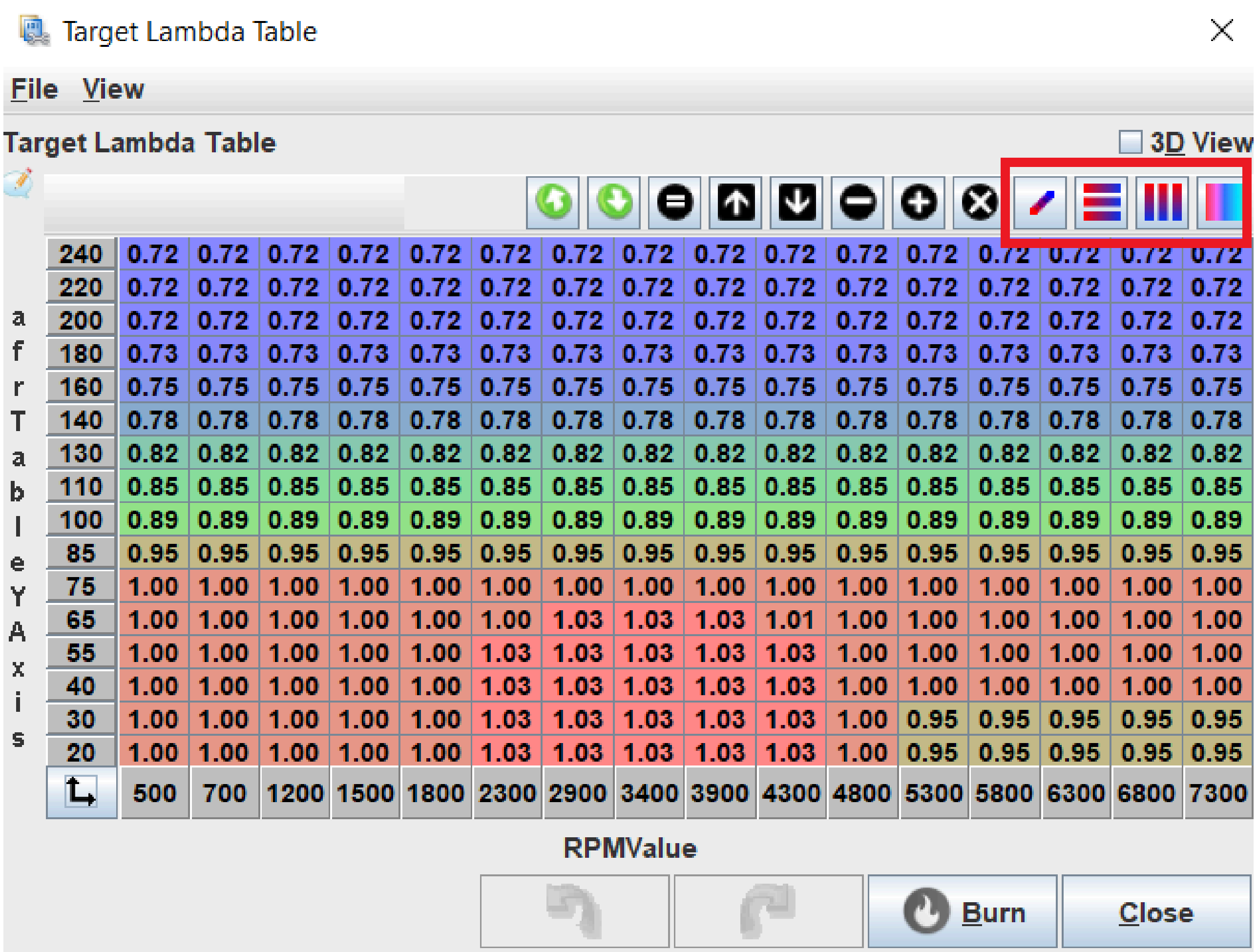
When the engine moves into boost, the engine load increases as does the temperature and pressure of the combustion. Hence, as the boost pressure increases, the AFR needs to get progressively richer. A good starting point for about 200kPa MAP or 14.5PSI of boost is a lambda of 0.78-0.82. For 300kPa MAP or 29PSI of boost, a 0.76-0.8 is generally a good starting range. Of course, every engine will differ so it is important here to research what others have successfully run on similar platforms to you.

Engine Start and Dead Zone

In both of these zones, their target AFRs do not matter a whole lot. The dead zone will never be operated in and the starting zone will never operate with closed loop fuelling as the lambda sensor will only activate after the car is running. The best configuration for these zones it to copy or transition them from the target AFR columns directly next to them for the sake of smoothness in the map.

Merging the zones

On the AFR target diagram, certain operating zones have missing values. To properly select targets for these zones, it's recommended to interpolate and smooth out the values between the defined sections of the map. It's important to create a smooth AFR target map that avoids abrupt changes, as the engine requires gradual variations in AFR to function optimally. To smooth the map in Tuner Studio there are four buttons in the map shown below. From left to right, these buttons interpolate across the entire selected zone, interpolate horizontally only, interpolate vertically only, and smooths out changes between selected cells.



240	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
220	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
200	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
180	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
160	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
140	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
130	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
110	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
100	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
85	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
65	1.00	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.01	1.00	1.00	1.00	1.00	1.00	1.00
55	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00	1.00
40	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.00	0.95	0.95	0.95	0.95	0.95
20	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.00	0.95	0.95	0.95	0.95	0.95
	500	700	1200	1500	1800	2300	2900	3400	3900	4300	4800	5300	5800	6300	6800	7300

AFR For Different Fuels

Fundamentally, an oxygen sensor works in lambda. It measures the oxygen content in the exhaust relative to the open air and outputs a voltage which the ECU or wideband controller can directly convert to lambda. The ECU then converts this to AFR if required by multiplying the lambda by the stoichiometric value of the fuel (typically 14.7 for unleaded). Regardless of the fuel, the oxygen sensor will read the same lambda for any fuel that is burning at its stoichiometric point. A table is shown below comparing the stoichiometric AFR values of common fuels.

Fuel Type	Stoichiometric AFR
Unleaded Gasoline	14.7
E85	9.76
E100	8.98
Diesel	14.5
Methanol	6.46

Acceleration Compensation

What is acceleration compensation and why do I need it?

What types of acceleration compensation are there?

What is charge temperature estimation

What is knock and why it matters

Multi-Dimensional Mapping, what is it and how to benefit from it

Spark timing, MBT and combustion

What to put into this section

Use this folder for covering the overall topics of why things are needed, this is the place to talk about things like why an engine needs certain AFRs, why timing needs to be reduced, what is knock, why do you need to add fuel on acceleration etc

Leave the details of how FOME works for each feature to the specific pages, when relevant we can link the firmware specific page and visavis, keep this and overview as a nuggets intro area

This can likely kill any dumb questions at source and prevent many user issues down the line

Sensors and gauges

Information on all sensor inputs and data outputs

🗃️ General sensors

9 items

🗃️ Temperature sensors

3 items

🗃️ Pressure sensors

3 items

🗃️ Fuel sensors

3 items

🗃️ Driver controls and feedback

7 items

General sensors

General sensors

Mass Air Flow Meter

Throttle position

Throttle position sensors are used to tell the FOME ECU the angle of the throttle blade. Most are 3 wire:

Turbo Speed Sensors

Vehicle Speed Sensor

Notes on setting VSS

Analogue Input Settings

ADC V-Ref

Analogue Divider

Smoothing Factor

AUX Sensor Inputs

Aux Speed Sensor

Aux linear sensor

Aux sensor serial comms settings

Camshaft position

Crankshaft Position

ETB Throttle Position

Mass Air Flow Meter

Throttle position

Throttle position sensors are used to tell the FOME ECU the angle of the throttle blade. Most are 3 wire:

1: Power (Provided from FOME ECU Power Output) 2: Ground (provided from FOME ECU Ground Output) 3: Signal (sent to FOME ECU Lowside input)

*ensuring power and ground come from the FOME ECU will make sure the signal is clean and consistent)

For vehicles with electric throttle bodies, throttle position sensors will need to always have two redundant signals (usually opposite ie 0-5v and 5-0v). This is to ensure safety of the operation of the vehicle.

Turbo Speed Sensors

Vehicle Speed Sensor

Notes on setting VSS

When setting VSS up calculate correct wheel rotations per km, use correct final drive ratio and then use the speed sensor gear ratio as a tuning factor to achieve correct speed reading.

Temperature sensors

Temperature sensors

Auxillary Temperature Inputs

Coolant Temperature

Intake Air Temperature

Pressure sensors

Pressure sensors

Barometric Pressure Sensing

Manifold Absolute Pressure

MAP sensors

Oil Pressure Sensors

Barometric Pressure Sensing

Manifold Absolute Pressure

MAP sensors

MAP settings

MAP sampling angle - See MAP sampling Angle page

Oil Pressure Sensors

Fuel sensors

Fuel sensors

Flex Fuel sensors

Flex fuel sensors measure the amount of ethanol content in the fuel passing through it. The flex fuel sensor has a pre calibrated signal that is sent from the sensor in a 0-5v voltage in…

Fuel Level Sensing

Fuel Pressure Sensors

Flex Fuel sensors

Flex fuel sensors measure the amount of ethanol content in the fuel passing through it. The flex fuel sensor has a pre calibrated signal that is sent from the sensor in a 0-5v voltage indicating which amount of ethanol is present. The FOME ECU has the ability to use this data. The signal circuit carries the ethanol percentage via the frequency signal.

The normal range of operating frequency is between 50-150Hz. The microprocessor inside the sensor is capable of a certain amount of self-diagnosis. An output frequency between 180Hz and 190Hz indicates that the fuel is contaminated.

In TunerStudio you select which input pin you have used for the signal from the flex fuel sensor. You can view % of content using a gauge in TunerStudio.

Fuel Level Sensing

Fuel Pressure Sensors

Driver controls and feedback

Driver controls and feedback

Accelerator pedal

Battery Settings

Brake position and pressure sensing

BeerMoneyMotorsports CAN Gauge

This is a page for discussing the setup of the CAN gauge, Installation information and hardware details can be found in the Hardware section at ...linky...

Clutch position sensing

Rev Counter/Tachometer

WBO2 Wideband Lambda Sensor

Accelerator pedal

Battery Settings

Brake position and pressure sensing

BeerMoneyMotorsports CAN Gauge

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Clutch position sensing

Rev Counter/Tachometer

WBO2 Wideband Lambda Sensor

Limits and Protections

Limiters, engine protections and safety features

Boost pressue limit

Coolant Based RPM limit

Fuel Pressure Compensation

Minimum oil pressure protection

Minimum oil pressure after start

Rev limiters

Hard cuts

Boost pressue limit

Coolant Based RPM limit

Fuel Pressure Compensation

Minimum oil pressure protection

Minimum oil pressure after start

Rev limiters

Hard cuts

Fuel cut

Spark cut

Both cut

Soft limiting

ETB soft limit

Basic Features

Basic Features

🗃️ Cranking control

4 items

🗃️ Idle control

6 items

📄️ Bench Test Commands

📄️ Boost Control

Before you start tuning the boost control, it is essential the make sure that you have a safe boost cut pressure set under Base Engine > Limits and Fallbacks. Within this menu, it is al…

📄️ Cylinder Bank Selection

📄️ Data logging settings

Basic Data logging settings

📄️ Fan Controllers

📄️ Fuel Pump Control

📄️ General Purpose PWM (GPPMW)

Main Relay Control

Cranking control

Cranking control

Cranking fuel

3 items

Advanced Cranking Features

Cranking Idle Air Control

Cranking RPM Limit

Cranking fuel

Cranking fuel

Cranking Duration Fuel Multiplier

Cranking Fuel Coolant Multiplier

Fuel priming pulse

Advanced Cranking Features

Cranking Idle Air Control

Cranking RPM Limit

Idle control

Idle control

Advanced Idle Control Features

Idle tables for cranking taper

Idle Control Hardware

Solenoids

Idle Specific Ignition Table

The idle ignition table acts much like the open loop idle control in the regard that it is another open loop system contributing to the idle of the vehicle. Adjusting the engine ignition timi…

Idle settings

The idle settings menu can look daunting at first but this guide will help to decode the mystery of all the various idle settings.

Idle Tuning

One of the most challenging aspects of achieving optimal engine performance is idle tuning. Unlike fueling, which can be quantified with instrumentation like an AFR gauge, idle tunin…

Idle Specific VE Table

image

Advanced Idle Control Features

Idle tables for cranking taper

Coasting Idle tables

Idle Control Hardware

Solenoids

Single wire

Dual wire

PWM frequency

Stepper Motors

Dedicated stepper hardware

Step pin, direction, mode, enable etc

Dual H bridge

Direction 1/2, disable etc

PushPull outputs

Stepper a+,b+,a-,b- etc

Idle Specific Ignition Table

The idle ignition table acts much like the open loop idle control in the regard that it is another open loop system contributing to the idle of the vehicle. Adjusting the engine ignition timing at idle changes the engine torque output where an increase in timing produces more torque and a reduction reduces the torque. This change in torque can be used to adjust the engine speed and achieve a stable idle by reducing the timing above the idle RPM target and increasing it below the target.

Before tuning the ignition table, make sure to have your base open loop idle position set.

To tune the ignition table, start by setting the maximum and minimum values about 500RPM above and below your target idle speed. At your target idle speed, put in your desired timing angle. 10 degrees is a good starting point but a higher timing angle such as 14 degrees will give the engine a bit more torque at idle which helps the engine to quickly rev up from idle. Start by making a linear curve between the maximum and minimum RPM values in the table with values in the range of 20 to 5 degrees. As all engines respond differently, you may want to use different starting values but these are good generalizations. Run the car with your values and see how well it maintains idle. Start to adjust the timing values so that the timing pushes and pulls the engine RPM to the target. You may need to change the shape of the curve so that only small timing adjustments are made near target and large corrections are made if the RPM significantly deviates.

Idle settings

The idle settings menu can look daunting at first but this guide will help to decode the mystery of all the various idle settings.

Idle target RPM

TPS threshold

RPM upper limit

RPM deadzone

Max Vehicle speed for idle

Idle Tuning

One of the most challenging aspects of achieving optimal engine performance is idle tuning. Unlike fueling, which can be quantified with instrumentation like an AFR gauge, idle tuning involves tweaking a range of options to achieve a specific RPM. However, the choices made in the tuning process have a significant impact on the stability and robustness of the engine's idle.

Idle can be compared to a see-saw with three main factors affecting it: fuel, ignition, and air. These elements determine the amount of torque produced by the engine, which in turn affects idle stability. To maintain a steady idle, the torque output must also remain relatively constant. Essentially, idle represents a state of balance, where the motor's load (caused by internal friction, accessories like the alternator, AC, torque converter/trans pump, or supercharger) is counterbalanced by the amount of torque generated by the engine. When load and torque are equal, there is no net acceleration, and the RPM remains constant. In essence, this is the overall concept to grasp.

Prerequisites to a Stable Idle

The foundation for a stable idle is reliant on a motor that already runs well. Before tuning the idle, there are several features which must be tuned relatively well first.

Battery Voltage

Battery voltage tends to be lowest at idle because the alternator is spinning at a slower speed. As a result, voltage can fluctuate frequently, especially when electrical loads such as blower motors and headlights are turned on or off. It is essential to fine-tune the battery and alternator control settings to prevent sudden AFR swings due to voltage changes.

This can be challenging to tune, but intentionally creating electrical loads by turning on the headlights, AC or blower fans is a good way of changing the alternator load so it can be tuned to output a near constant voltage under all conditions.

Idle Detection Thresholds

Within the idle settings, the first set of parameters to configure are the idle detection thresholds. These are a set of conditions which must be met for the ECU to establish that the car is idling. The first is the *TPS Threshold (%)* and is the maximum throttle position for idle to be enabled. After calibrating your TPS through *Tools* > *Calibrate TPS*, 1-2% is a good range to set this to. The *RPM upper limit* is the maximum RPM above the idle target that will still be considered idle. Typically 300-500 RPM is a good range so that the car won't move out of idle if the AC or another load requiring an RPM increase is enabled. *RPM deadzone* is the range around target in which the closed loop controllers will be disabled to prevent oscillations. 50-100 RPM is a good range here but this is discussed later. The *Max vehicle speed* dictates the maximum vehicle speed which can be considered idling. Setting this to 20-40 Kph prevents a scenario where the car is slowing down, still in gear, and the car goes into idle which tries to drag the RPM down and can lead to an idle droop when the clutch is pressed in.

Idle AFR

The quality of the fuel and ignition tuning around and inside the idle region can significantly impact idle stability. It is crucial to tune the fueling in and around the idle region to maintain a consistent AFR, as any changes in AFR due to load or RPM can also affect the torque output. It is recommended to enable the *Idle VE Table* so that the fuelling in the idle region can be more finely tuned. Like tuning the battery voltage, you want to intentionally create more loads on the engine to tune the ide VE values for different loading conditions. You can get this relatively dialled in however, it is likely that this table will need tweaking during the idle tuning process to maintain stable AFRs in idle. It is also important to merge the edges of the idle VE table with your normal VE table so that the fuelling transitions coming off idle are constant.

Idle Air Control Valve Offsets

Load can vary during idle and AC is the most significant factor that can significantly impact the engine load at idle. For engines equipped with an automatic transmission, the load in park/neutral is significantly different from that in drive. It is usually necessary to add IAC duty cycle/air to compensate for the torque required to spin the AC compressor. Again, it is crucial to ensure that AFRs don't swing excessively when moving between different idle operational areas. In the idle settings, start with about 10-15% for the *A/C adder (%)* parameter. As the AC increases the alternator load, the engine torque also needs to increase when the AC is enabled so it is recommended to do this by increasing the engine RPM by 100-200 with the *A/C target adder (RPM)*. The cooling fans also have associated adders (*Fan #x adder(%)*) although these don't usually need to be increased unless you notice a significant drop in RPM when the fans come on.

Open Loop Idle

Tuning the open loop idle is the first step in achieving a stable idle. In some cases, an open loop idle may be good enough for your purposes although it is highly recommended to set up a closed loop idle after perfecting the open loop. To start with, you must decide on what RPM the engine should idle at. To determine this, you must consider various factors such as flywheel and rotating inertia, driven accessories via belt or gear, noise level, personal preference, among others. It may involve an iterative process of selecting a target RPM, attempting to achieve it, and revising expectations. Generally, higher RPM idling is more manageable because the engine produces more torque. Although it is not used in the open loop idle configuration, open the *Target RPM* table in the idle settings and put in the target RPM you decided on. In the table, it is recommended to taper the idle RPM from about 200 RPM higher than target when the coolant temp is at about 20C to the actual RPM target at 60C approximately. This is to compensate for the extra drag on the engine as it heats up and the tolerances become looser.

Idle Airflow

The first step of tuning the idle RPM is to set up the open loop idle airflow. Suppose you aim to set the engine to idle at 800 RPM (minimum), the airflow must be tuned to make the engine idle 50-150RPM higher than the 800 RPM target. This can be done by adjusting the *Open loop base position (%)* parameter, the idle adjustment screw, or the throttle end stop. It is recommended to tune these adjustments so the *Open loop base position (%)* parameter (which is the base duty cycle of the IACV) is at about 30% when the engine is idling 50-150RPM above target. This gives some room for the closed loop controller to adjust the duty cycle. It's essential to ensure that AFRs remain stable as you adjust the airflow. Before enabling idle control, a stable foundation is necessary. In this example, we will say that the engine idles at 950 RPM (150 RPM above target) with 10 degrees of timing, 1.0 lambda and 30% IACV duty cycle.

Idle Ignition Table

The idle ignition table acts much like the *open loop base position* in the regard that it is another open loop system contributing to the idle of the vehicle. Adjusting the engine ignition timing at idle changes the engine torque output where an increase in timing produces more torque and a reduction reduces the torque. This change in torque can be used to adjust the engine speed and achieve a stable idle by reducing the timing above the idle RPM target and increasing it below the target.

To tune the ignition table, start by setting the maximum and minimum values about 500RPM above and below your target idle speed and interpolate the values between these. At your target idle speed in the table, put in your desired timing angle. 10 degrees is a good starting point but a higher timing angle such as 15 degrees will give the engine a bit more torque at idle which helps the engine to quickly rev up from idle. The idle timing angle will vary from engine to engine so it is always worth researching what others have used on your specific engine.

The next step is to fill in the remaining cells of the idle timing table. At the minimum RPM, a value of 20 degrees is recommended as this is roughly where maximum brake torque (MBT) is. To fill in the gaps between the minimum and target RPM, use the interpolation button. For the maximum engine RPM value, a value in the range of 0-10 degrees less than the target is recommended (do not go below 0 degrees of timing). Once again, interpolate the values between the maximum RPM and target. For the RPM values above idle target, if you have AC, it can actually be beneficial to leave the spark angles as the same as the idle target. This allows the engine to idle up and increase the torque to compensate when the AC is enabled. If the timing reduces above target, the idle air valve (when tuned for closed loop) may need to compensate more for the extra load on the engine.

Run the car with your values and see how well it maintains idle. Give it a few throttle blips to see how the idle settles. Start to adjust the timing values so that the timing pushes and pulls the engine RPM to the target and stabilizes within 50 RPM. You may need to change the shape of the idle timing curve so that only small timing adjustments are made near target and large corrections are made if the RPM significantly deviates. The trick is to essentially make a table of accurate guesses for what the timing will need to be in order to kick the engine RPM back to the target. The better your guesses are, the less work the closed loop timing controller will need to do when you implement it.

Closed Loop Idle

Closed loop idle control uses a combination of closed loop timing adjustments and idle air control valve adjustments to achieve a stable idle. Achieving a stable idle can be difficult as it requires tuning two separate controllers which operate in parallel to control the engine RPM. The best way to achieve a good idle is to use the closed loop idle timing for the larger and quicker corrections with the idle air controller acting to compensate for slower changes.

Before tuning the closed loop idle, you need to have properly tuned the idle VE, idle ignition table and open loop idle control. To tune the closed loop controllers, you also need some understanding of a closed loop controller called a PID controller. [This video by RC Model Reviews] (https://youtu.be/0vqWyramGy8) perfectly explains PID controllers in basic terms.

Closed Loop Timing

It is now time to turn on closed loop idle timing. It's important to note that closed loop idle should not make significant changes all the time for a stable idle. However, closed loop idle timing adjustment is crucial for long-term stability, and it's necessary to keep the engine idling when changes occur such as AC, headlights, fans, etc. Closed loop idle timing relies heavily on the proportional gain with little to no derivative gain to act as a damper. A good place to start is with a proportional gain of 0.1 and a derivative gain of 0.05. For every engine, these values will need to be varied until the idle remains stable within 50 RPM of the target. To ensure the closed loop idle doesn't cause issues such as knocking, it's recommended to set boundaries on timing with an overall minimum and maximum adjustment from the open loop table values. A good starting point is a -5 degree minimum and +5 degree maximum but these can be increased up to 10 degrees if you need more aggressive control.

Closed Loop Idle Air

Closed loop idle air control is a powerful tool, but one that requires extreme caution as it can dramatically impact the engine RPM. Even small changes in airflow can have a significant impact, and this is compounded because the speed which an electronic throttle body or idle valves operate is much slower than spark control. To effectively use closed loop air control, a deadband of about 50-100RPM must be established around the target to allow for minor corrections to work.

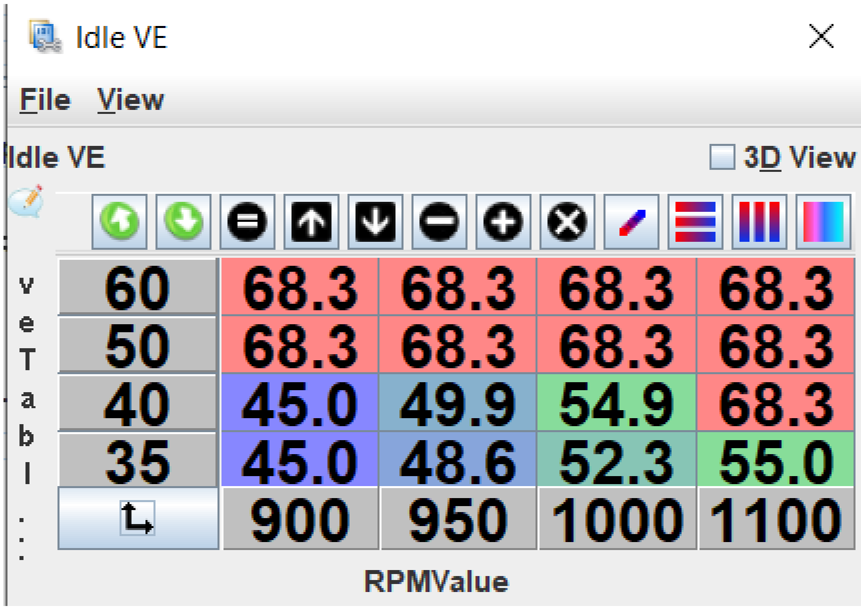
In the *Closed Loop Idle* box in the idle settings, the controller should be set up with a very small proportional gain and a sufficiently larger integral gain. This ensures that the idle air controller reacts slowly and only to relatively large disturbances which the closed loop timing cannot compensate for itself. You may need a very small derivative gain however the controller should react slowly enough that it might not be necessary.

One of the things to be wary of here is that an integral dominated controller can suffer from a phenomenon known as windup where the integral gain becomes very large if the RPM stays high or low for a long period of time. This causes the RPM to massively overshoots the target. To mitigate this, you can clamp the amount which the integral term can increase or decrease the IACV duty cycle by. A safe recommendation is to set the *iTerm Min* & *iTerm Max* to -/+10 respectively but anywhere up to -/+20 should be reasonably safe.

To assist in the overall effectiveness of the controller, the minimum and maximum duty cycle variation of the entire idle air controller can be clamped. This effectively limits how fast and with how much force the idle controller is allowed to increase or decrease the RPM. A safe range for the *Min* and *Max* is -10 and 20 respectively however these values can be changes around if the controller is responding more or less than you desire. For example, sometimes it is worth putting the maximum to a value such as 50 so that the controller has the authority to bring up the RPM if it gets sufficiently low.

Another setting of interest that should be used sparingly is the *PID Extra for low RPM(%)*. This effectively gives the controller a kick if the RPM gets too low and needs to take dramatic action. This parameter can be used to compensate for the recommended small proportional gain which is usually responsible for kicking the RPM up if it deviates too far from target. Realistically a well tuned idle controller shouldn't need this but the world isn't perfect so this serves as a band-aid for scenarios where the controller is struggling to increase RPM and is at risk of stalling. Normally, set this to 0% but if you absolutely can't fix an idle drooping problem, experiment with values up to 100% gradually increasing the percentage until the idle is kicked up to around target. Be sparing with this as a high percentage can kick the RPM way above target causing an unstable idle.

Idle Specific VE Table



The idle specific VE table is a smaller 4x4 table referenced only when the engine is operating in the idle condition. As the engine is under very little load during idle, changes in engine load can have a significant effect on the AFR. These loads can be from the air conditioning compressor engaging or from the alternator duty cycle increasing from extra electrical loads such as cooling fans, headlights or even electric windows. By adjusting the idle VE table to encapsulate the finite idle RPM and load ranges, you can tune the idle to operate close to the AFR target regardless of the engine load.

To tune the idle VE, make sure *closed loop fuel correction* under *Fuel* is disabled. Proceed to warm the car up and switch off all cooling fans, headlights and air conditioning. Tune the corresponding idle VE table cells until the AFR target is reached. Now turn on the accessories one by one, tuning the corresponding cells the idle VE table. Next repeat this process with multiple accessories on at once such as the air conditioning and headlights. Once the cells have been tuned, interpolate to fill any unused cells and smooth the cells together. In the circumstance that engaging the accessories has a large effect on the AFR, you may not be able to smooth the table much.

Bench Test Commands

Boost Control

Before you start tuning the boost control, it is essential the make sure that you have a safe boost cut pressure set under *Base Engine > Limits and Fallbacks*. Within this menu, it is also recommended to set only fuel to be cut on the RPM limit as cutting fuel and spark can lead to excess fuel igniting inside the turbine housing causing excess wear to the turbo.

Electronic boost control (EBC) is a method of controlling a vehicle's boost from an ECU or boost controller. EBC allows for more precise control of boost resulting in the ability reduce spool up time, set the boost to an exact figure or tune the boost to flatten a torque curve.

Boost Control Options

Three Port Boost Control Solenoid

A three port boost control solenoid works by quickly alternating between diverting boost pressure to atmosphere and to the wastegate. By adjusting the duty cycle or time spent diverting air to atmosphere, the solenoid effectively changes the boost pressure that the wastegate sees allowing it to stay closed for up to three times the wastegate spring pressure.

For most vehicles, this is the most common method of electronic boost control as it it cheap, can be easily plumbed into most turbos and for the most part does a good job of controlling the boost.

A three-port boost solenoid has three ports: an inlet port, an outlet port, and a control port. The inlet port is connected to the turbocharger outlet, the outlet port is connected to the wastegate actuator, and the control port is connected to the ECU. The ECU sends a signal to the control port to regulate the amount of boost pressure produced by the turbocharger.

Four Port Boost Control Solenoid

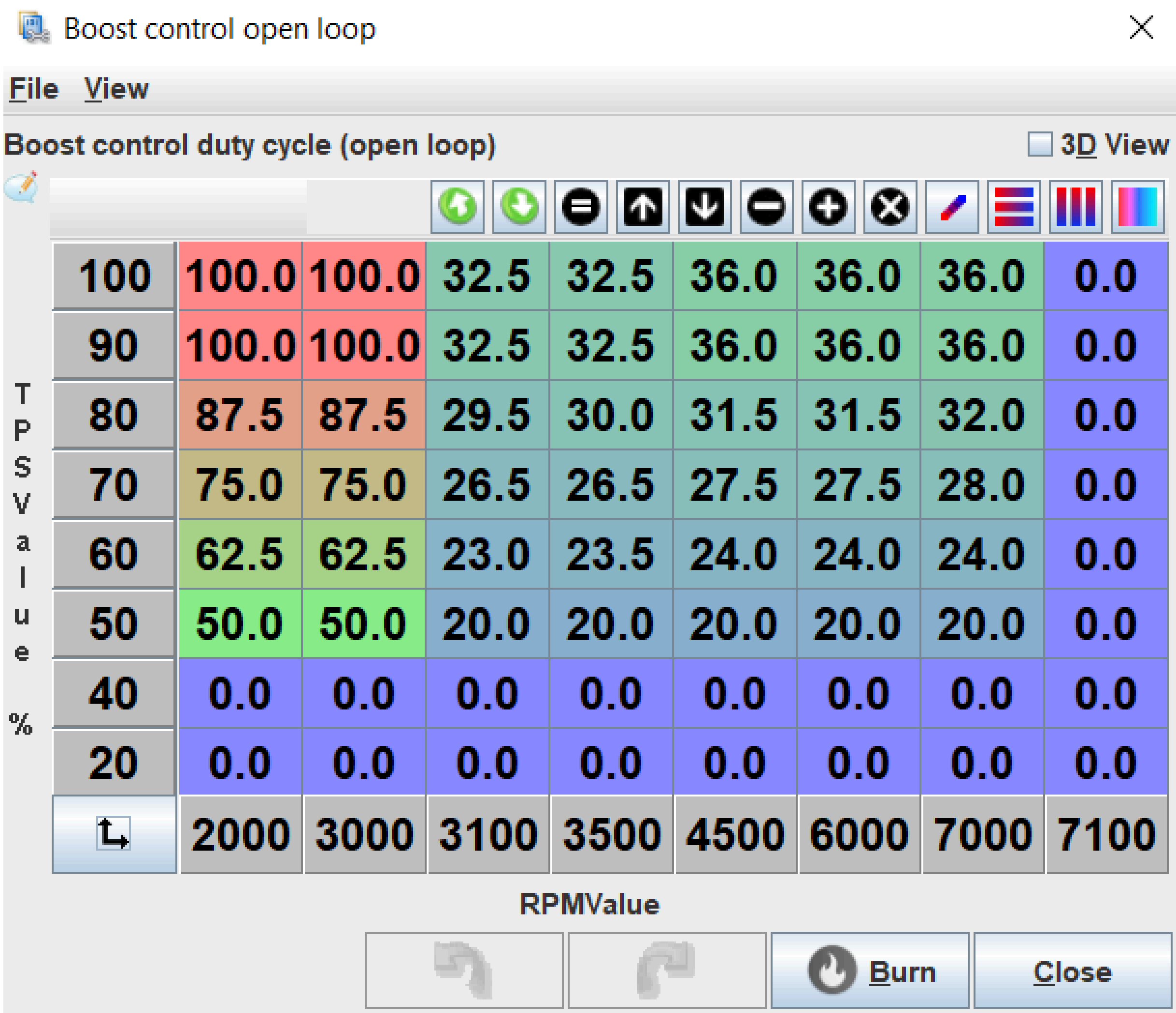
A four-port boost solenoid has an additional port, known as a reference port. The reference port is connected to the intake manifold or the atmosphere, and it provides a reference pressure to the boost solenoid. The boost solenoid uses this reference pressure to regulate the boost pressure produced by the turbocharger. The four-port design allows for more precise control over the boost pressure to a three port solenoid because it takes into account the reference pressure in addition to the control signal from the ECU. By bleeding off excess pressure when needed, the four-port boost solenoid can maintain a consistent and accurate boost pressure, resulting in better performance and reliability for the turbocharged engine.

Electric Wastegate Actuator

An electric wastegate actuator replaces a conventional spring based wastegate with an electric actuator to regulate the boost pressure.

Open Loop Boost Control

Open loop boost control is the simplest form of electronic boost control where the boost control solenoid is assigned a specific duty cycle based on the engine RPM and throttle pedal position. With open loop control, you need to guess what duty cycle will correspond with your desired boost pressure and work from there. An example of on open loop boost control table is shown below.



TPSValue %								
100	100.0	100.0	32.5	32.5	36.0	36.0	36.0	0.0
90	100.0	100.0	32.5	32.5	36.0	36.0	36.0	0.0
80	87.5	87.5	29.5	30.0	31.5	31.5	32.0	0.0
70	75.0	75.0	26.5	26.5	27.5	27.5	28.0	0.0
60	62.5	62.5	23.0	23.5	24.0	24.0	24.0	0.0
50	50.0	50.0	20.0	20.0	20.0	20.0	20.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RPMValue	2000	3000	3100	3500	4500	6000	7000	7100

Tuning Open Loop Boost Control

Before you start tuning the boost, consider what you are looking for the boost controller to do. Do you want the fastest possible spool up? Do you want the boost to come on all at once or progressively build up? Do you want to accelerate as fast as possible right on the limit of grip or to spin the tyres?

1. Decide what the minimum boost pressure you want to run will be and install the corresponding wastegate spring.

2. Disconnect any boost control solenoids and connect the wastegate directly to a source of boost pressure.

3. Verify that the boost cut works by setting it to a low value such as 100kPA. Once verified that it works, move it 10-20kPa above your desired boost pressure.

4. Take the car for a drive doing a range of pulls and take notice of how the boost responds. In first and second gear, when does the car move into boost and when does it stabilize? In higher gears, when does the car move into boost and when does it stabilize? Once the boost stabilizes, does the boost curve increase, decrease or stay flat? As an example, say that you have a turbo Miata running at sea level (100kPa atmospheric pressure) and the turbo moves into positive boost at 2000RPM and stabilizes at 3500RPM where it stays at 150kPA (50kPA or ~7PSI of boost) until redline.

5. The safest way of determining the ideal duty cycle for your boost goals is to start at the minimum and work up from there. Start by setting every cell on the open loop table to 20% duty cycle and do several full throttle pulls in 2nd-4th gear noting the boost it reaches. 20% is generally the minimum duty cycle the solenoid needs to run and this can be tested by turning the key to *On* and with the engine off, push the throttle listening for the solenoid clicking. Gradually increase the duty cycle in steps of up to 5% until the car car reach your desired boost pressure at full throttle.

6. Once the desired boost pressure is reached, look at how the boost curve moves once it stabilizes. If it continues to rise past target pressure, progressively raise the duty cycle in the table as the RPM increases. If the boost drops, do the opposite and raise the duty cycle as the RPM increases. Continue to adjust the duty cycles until the stable boost stays within 5-10kPA of target.

7. In your boost control table, decide on the minimum throttle position where you would like the boost control to activate. 40-50% is generally a good starting point. Below the starting point, set every cell to zero. At the starting throttle position row, set the duty

cycle to the minimum duty cycle required to operate the boost solenoid which is usually 20%. Now interpolate vertically between the minimum boost throttle position row to the 100% throttle position row so that at in a given RPM column, the duty cycle will increase as the throttle is pushed more.

8. Optionally for a fast spool up time, recall what RPM the boost reached target in 3rd or 4th gear. Now rescale the table by so that the new lowest or second lowest RPM column is 1000RPM below the boost target and the second or third RPM column corresponds to the RPM when the boost target is reached. Set the columns below target boost to 100% and test it out with some pulls in different gears. Progressively raise the RPM of the 100% duty cycle columns as much as you can before the boost goes above the target pressure and leave them there. It is recommended to back off the 100% duty cycle RPM slightly from the absolute highest it can be as a factor of safety. To make transition to boost smoother, the 100% duty cycle columns can also be vertically interpolated between 100% and a lower duty cycle such as 50% at the minimum boost RPM.

Closed Loop Boost Control

Closed loop boost control builds on the open loop boost controller and actively adjusts the solenoid duty cycle to reach the specified target pressure. The controller starts at the specified duty cycle in a given cell in the open loop table and adds or subtracts to that value until the target pressure is reached. The closed loop boost controller uses a PID controller to adjust the duty cycle. A PID controller works by measuring the error between the measured boost and the desired boost and calculating values for the P, I and D terms based off of the error. These terms are then added togethor to form the calculated duty cycle which the controller will measure the boost pressure response to and will continually adjust its calculated duty cycle until the target pressure is achieved.

The P-term multiplies the duty cycle per kPa of error. For example, if P is set to 0.2 and there is a 20kPa error, it will add a value of `0.2 * 20 = 4%` to the duty cycle.

The I-term multiplies the duty cycle by the kPa of error and the seconds that there is error. For example, if I is 0.1 and there is 10kPa of error for 2 seconds, it will add a value of `0.1 * 10 * 2 = 2%` to the duty cycle.

The D-term multiplies the duty cycle by the kPa of error per second (or rate of change of kPa). For example, if D is 0.2 and the boost is rising at 10kPa per second, a value of `0.2 * 10 = 5%` would be subtracted to the duty cycle to slow the rate of approach to the target.

Cylinder Bank Selection

Data logging settings

Basic Data logging settings

SD card logging

Diagnostic and High speed logger

Fan Controllers

Fuel Pump Control

General Purpose PWM (GPPMW)

Main Relay Control

Advanced Features

Information on all sensor inputs and data outputs

📄 CANBUS settings

📄 Cylinder Angle Offset Configuration

Manual configuration of the cylinder bank angles for oddfire and difficult engines.

🗃️ ETB

6 items

🗃️ Fuel-Related

5 items

GDI

1 items

Knock Control

LUA scripting

Launch Control

Or how to break your gearbox and engine

MAP Sampling Angle

Multi Dimension Mapping

Basic outline

📄 Override VE. Ignition and AFR table axis

🗃️ Rotary

1 items

📄 Smart Alternator Control

🗃️ Spark-Related

1 items

🗃️ Variable-Cam-Timing

3 items

CANBUS settings

Cylinder Angle Offset Configuration

Manual configuration of the cylinder bank angles for oddfire and difficult engines.

Electronic Throttle Bias Table

ETB feed forward setup

Idle control using ETB

All features needed to do ETB idle control discussed here, needs to cover the way ETB changes some of the basic idle settings to function differently when ETB idle is operational.

ETB PID and Autotune

ETB pedal target mapping

Electronic Throttle Settings

ETB enable/disable

H-bridge function

PWM frequency

ETB idle - See Idle control using ETB page

ETB PID - See ETB PID page

Redundant Sensors for ETB Position

Reason for redundancy in ETB position sensing

Basic redundant sensors

Things like 0.5-4.5v with inverted or half value signal for the secondary

Ford Redundant TPS Mode

Ford Pedal and ETB with the weird cut off on the secondary signal

Barometric-Pressure-Compensation

Charge Temperature Estimation

Closed Loop Fuel Correction

Injection Phase Settings

Injector Testing Mode

Not sure if we keep this?

High Pressure Fuel Pump Settings

Knock Control

LUA scripting

Launch Control

Or how to break your gearbox and engine

MAP Sampling Angle

Multi Dimension Mapping

Basic outline

Multiplier and Bias tables

VE multiplier

Ignition Adder

What can be done with them

Flex-Fuel or Dual Fuel

ITB TPS blending

Something Wacky

Override VE. Ignition and AFR table axis

Rotary engine specific settings

Smart Alternator Control

Multispark

On/Off VVT Control

VVT PID Control

VVT Target Tables

Fuel

Fuel

🗃️ Fuel algorithms

3 items

🗃️ Fuel settings

10 items

🗃️ Acceleration

2 items

Fuel algorithms

Fuel algorithms

AlphaN fuel

MAF based fuel control

Current Status

The MAF based fueling of FOME is still undergoing development, the current status has the fueling functioning correctly but presents a few tuning challenges due to TunerStudio integration and the Spark Table still being reliant on the old engine load math.

This is an evolving situation at present and thus MAF fueling is still considered experimental.
Please only use for development work at your own risk.

MAF fuel theory - The detail

The implementation of the MAF in FOME is intended to replicate the functionality of OEM systems and as such is more complex than some other systems.

The foundation of the MAF system is the Mass Air Flow sensor itself, this is a device using a hot wire, hot film or vane to directly measure the flow of air into the engine. Obviously this sensor does not give out an airflow value, it gives us a voltage, current or PWM signal that represents the flow. FOME can interpret a voltage or current MAF at this time via a transfer function table.

The Transfer function table is used to convert the raw MAF sensor reading into a Kg/h (Kilogram Per Hour) airflow.

This Kg/h value is then processed into a required fuel quantity by the following calculations:

```
g/s = Kg/h * 1000 / 3600
```

n/s = rpm / 60

airPerRevolution = g/s / n/s

cylinder Airmass = airPerRevolution / half Cylinder number

In FOME we use a correction factor table to modify this measured air mass to allow correction of any errors in the measurement due to dynamic air flow effects. To do this we need to have a "load" value that allows us to have a Load Vs Speed fuel table.

```
StandardAirCharge = engine displacement / number of cylinders *
1.2929
```

This produces the air mass for cylinder filling at 100% VE under standard SAE conditions. Using this we can relate our cylinder air mass back to a standardised 100% cylinder filling and thus we have a "load" value to use when tuning.

```
airChargeLoad = 100 * cylinder Airmass / Standard AirCharge
```

The required fuel is now simply corrected by adjusting the measured air by the value in the VE table, this value is simply a %.

```
corrected Cylinder Airmass = cylinder Airmass * (VE map value /
100)
```

fuelMassGram = corrected Cylinder Airmass / desired AFR

```
pulse Width = fuelMass / injector flow (in g/s)
```

Using this method FOME is able to directly measure the air flow into an engine and calculate the required fuel with minimal tuning.

MAF fuel tuning - The quick version

To tune FOME using the MAF is probably the quickest and easiest method provided you have a working MAF sensor and the correct information to input in the Transfer Function Table.

The first thing to do is input the voltage (or current) to Kg/h information into the Transfer Function Table in TunerStudio.

Secondly you will need to decide what Air/Fuel ratio you would like your engine to run at and input this into the AFR table in TunerStudio. For a first start a value of 14 is perfectly acceptable for gasoline. This table is the primary source of the desired fuel mixture, it will be this table that is tuned to decide the engines target AFR. A future update will make this fueling table dynamic so that an input % of ethanol in the main fueling dialog will change the fuel density and thus the required fuel mass injected. The result of this will be that users can leave this table tuned as though it were for pure gasoline (14.7:1 stoichiometric) and the % ethanol input will make sure the fuelling stays at the same Lambda value. This has the advantage of working well with aftermarket wideband controllers that generally work in AFR using pure gasoline as the standard.

Before starting the engine for the first time it is wise to ensure the Fuel Table is filled with values of "100", a value of 100 means that the fuel calculation uses 100% of its measured air mass to decide on the fuel injection pulse.
Tuning this table will adjust for dynamic airflow effects that happen in the inlet of an engine and will allow small (or large but hopefully not) corrections to the fuel injection which may be required to have the engine meet it's desired air/fuel target.

This table should only be tuned if the engine is not meeting the desired air/fuel target under relatively steady state conditions (i.e. without any acceleration enrichment or overrun fuel cut). If a different air/fuel ratio is desired at a specific load or RPM then the AFR Table is the correct table to adjust instead.

Some useful MAF sensor maths in this link

Speed Density Based fuel control

Fuel settings

Fuel settings

Fuel injection Mode

Place to cover the simultaneous, batch and sequential fuel injection

TPS fuel multiplier

Intake Air Temperature Fuel Multiplier

Fuel injector dead time settings

Small Pulse Width correction

Polynomial

Air Fuel Ratio Setting

Coolant Temperature Multiplier

Individual Cylinder Trim

Deceleration fuel cutoff

How flex fuel works in FOME

Place to cover the flex fuel, how it works and how it is related to the multidimensional mapping.

Fuel injection Mode

Place to cover the simultaneous, batch and sequential fuel injection

TPS fuel multiplier

Intake Air Temperature Fuel Multiplier

Fuel injector dead time settings

Small Pulse Width correction

Polynomial

2 slope/Ford method

Acceleration

Acceleration

TPS Based Acceleration Correction

Wall Wetting Based Acceleration Compensation

Hardware

Hardware

🗃️ Hardware-Circuits

8 items

🗃️ Hardware-Details

6 items

Discrete-VR

High-Low Driver Circuits

Highside Driver Circuits

Lowside Driver Circuits

PT2001 Low-Z driver

12v, 5v and 3.3v regulation circuits

STM32 Compatibility with FOME

What to write in this section

Details on our various generic driver layouts, what they are and the basics of how they work

Base Boards

Brain Boards

BeerMoneyMotorsports CAN gauge

A page to outline the hardware and wiring of the BMM can gauge

FOME low-z injector driver

Details on the low impedance injector driver board, its wiring and function

Power steering controller

Wide Band Lambda Module

Ignition

Ignition

🗃️ Ignition-Hardware

3 items

🗃️ Ignition-Settings

7 items

🗃️ Ignition-Types

4 items

Ignition Modules

place for listing known good ignition modules

Ignition coils

Place for listing known good ignition coils

Smart and Dumb Coils

Dwell settings

How to correctly configure the firing order and ignition pins

Place to describe the correct settings of firing order with regard to the pin config.

Intake Air Temperature Ignition Adder

Ignition advance table

Ignition coolant correction

Ignition Cylinder Trim

Ignition Mode

See Ignition Types Section?

Individual coils

Something to explain individual coils can be set up in either wasted or sequential

Sequential ignition mode

Single coil or distributor ignition

Wasted spark ignition mode