

# Spectre eMS-pro Tuning Guide for MegaTune



Adapted from the MS1 extra code tuning manual by Philip Ringwood, James Murrey, and Ken Calver for use and distribution with the Spectre eMS-pro, a MegaSquirt based engine management system.

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## Introduction

Before you start, please take time to read this entire manual and the MegaTune reference for the Spectre eMS-pro. As the eMS-pro is a MegaSquirt based system, you may find useful information and tips by visiting the Spectre eMS-pro forums at <http://www.spectreperformance.com/emspro> and the MS-Extra EFI forum at <http://www.msextra.com>.

### ***Pre-Start checklist***

If the car was running before the eMSpro was installed, most of these tests should pose no problems. In the case of newly built engines, these basic checks are essential. If in fact there are issues, it is better to discover and correct them before you attempt firing the engine up and damaging something.

#### Mechanical

- Check for vacuum and boost leaks
- Cylinder compression test
  - Equal across all cylinders
- Fuel system test
  - Leak inspection
  - Pressure test
- Oil level and pressure test
- Coolant check
- Sparkplugs - proper spec, gap and tight

#### Electrical

- Battery voltage - 12 - 13 volts
- Chassis grounds - 1 ohm or less
- Visual inspection

## Tuning Your eMS-pro

Now that you have installed your eMSpro, performed and checked your basic set-ups and your pre-start checklist (see above) is clean, it's time to get your engine started and tuned. This is not too difficult if you take your time and pay attention to detail. If after starting your engine and anything feels odd get off the throttle and view the datalogs, to determine where your issues are and take the appropriate corrective action.

Read the entire Installation/Operations Manual first, before attempting to start or tune your car. There may be some later passages that will help you in earlier steps, depending on your installation details. You will get the 'big picture', and the tuning process should make more sense to you. Reread this section several times.

You need Windows 95/98/ME/XP to use the Megatune software or Linux/Windows 95/98/ME/XP for the Megatunix software. A USB port is the best type of com port to use to communicate with eMSpro however, if your laptop does not support USB, the eMSpro

also has a serial input as well. You do not need a fast computer to tune your eMSpro, just about any computer that is capable of booting Windows 95 (or better) will be fast enough, but may experience slower performance when analyzing large datalogs with low end / older laptops.

## **Tuning Software**

There are a few software applications to help you tune and configure your eMSpro.

- Megatune - for tuning and data logging MegaSquirt with a laptop computer running Windows 9x/ME/XP. (Eric Fahlgren) We strongly recommend using the MegaTune-Extra Installer download [HERE](#) as it is setup for the Extra code
- MegaLogViewer - A very good log viewer, which is configurable making it suitable for MSnS\_Extra's extra features.

Please note:

Windows XP occasionally gives an error when trying to open Megatune for the first time. If this is the case, right click on the desktop link to Megatune and select Properties then Compatibility. Then set Compatibility mode to RUN this program in Windows 95 mode.

Note: If you get a pop-up message stating,

Component 'COMDLG32.OCX' or one of its dependencies is not correctly registered: a file is missing or invalid.

You need to download this file and/or register it.

To fix this error,

- Download COMDLG32.OCX You can download COMDLG32.OCX from: [http://www.ascentive.com/support/new/support\\_dll.phtml?dllname=COMDLG32.OCX](http://www.ascentive.com/support/new/support_dll.phtml?dllname=COMDLG32.OCX) or <http://www.snapfiles.com/help/missingfiles.html>
- Copy it into the \Windows\System directory (Win 9x/Me) or \Windows\System32 (WinXP) directory.
- Open the run dialog box using "Start Run..." and enter:  
"Regsvr32 c:\windows\SystemXX\comdlg32.ocx"  
to register the file. (SystemXX should match the directory to which you saved the file)

To tune all the parameters of eMSpro so that your engine runs the best it can, you will need to do the following in order, a more detailed description of these procedures follows, keep reading.

1. Connect your PC to the eMSpro controller and verify that Megatune can communicate with the eMSpro
2. Set the engine constants.
3. Set the Codebase and output functions.
4. Verify your tach input (nothing happens without this).

5. If the eMSpro is controlling the ignition timing, verify that you have accurate control of the ignition timing.
6. Connect or enable the injectors.
7. Key on the ignition and verify that your fuel pump primes ( this can be disabled later if desired)
8. Check that all gauges displays are reasonable. (Pay particular attention to your O2 sensor display, see section below pertaining to O2 sensors))
9. Get the engine started and idling.
10. Adjust the PWM criteria.
11. Tune the VE table.
12. Then adjust the cold start and warm-up enrichments.
13. Set the acceleration enrichments.

### **Wideband Lambda Sensors**

Before we start tuning you should ensure that the lambda sensor that is installed is correctly set in MegaTune. If you have a normal lambda then this is simply called a Narrow band lambda sensor, it gives 0-1V output. The voltage at 14.7:1 AFR (Lambda 1.0) is usually 0.5V, anything lower is lean, anything higher than 0.5 is rich. These can only be used to tell you that your lean or rich of 14.7, they are not accurate at any other value other than 14.7:1AFR (0.5V output)

A wideband lambda sensor can tell you accurately the AFR from around 10-20:1. These usually have a voltage output range of 0-5V and some can be programmed to give a straight-line output with respects to the AFR. e.g. Innovates LC-1 can be set up for 0V = 10:1AFR and 5V = 20:1AFR, so 2.5V output would be 15:1AFR, etc. The WideBand Lambda sensors will need a control circuit/box to run them, the MS ECU can NOT simply plug into the sensor like a narrow band sensor.

In order for the MegaTune software to be able to distinguish between what sensor you are using, and therefore tell what the output voltage means, you will need to set your the settings.ini file up for your lambda sensor. Simply run MegaTune and go to File - Configurator

Next select Car1 - Settings.ini - Settings - Lambda\_Sensor

In the top scroll down menu select your sensor and then save the file. Run MegaTune again and then the AFR meter will show your AFR accurately.

### **Tuning Theory**

Tuning involves setting all the parameters that eMSpro uses correctly to be optimal for your engine, injection, and driving. These include things like cold start pulse widths and acceleration enrichments. The most fundamental parameters are in the 12×12 volumetric efficiency table.

In general, this is all much easier to understand when you are working on a running engine. Trying to estimate what your engine will specifically need beforehand can be more confusing than productive. It is worthwhile to understand the requirements, but always remember that ultimately you will rely on your “seat of the pants” and O2 sensor (as well as drag strip times, exhaust gas temperature sensors, etc. etc., if you have them available) to tune your engine.

Remember that people tuned engines for maximum performance and efficiency for many years with carburetors without any quantitative feedback at all. They often got very good results. The O2 sensor makes tuning much easier. By the time you have had a few sessions with MegaLog Viewer, you will have a better idea of how to tune the remaining areas.

When tuning:

- Read this entire section first before starting to tune, and be sure you understand what you read,
- Do not change more than one thing at a time and always be able to get back to where you started. Save the files in Megatune using “Save As”( use a descriptive and unique name ) before making another change.
- Do not try to drive the car if you can not get it to idle properly, fix the idle first.
- Do not try to tune accel before you have tuned VE,
- If you have a problem that you need assistance with, have all detail regarding the engine application and specifications available. This will ensure a quicker resolution when dealing with our professional tech support team. You may also check the FAQ located on line at [www.spectreperformance.com/techsupport/eMSpro/faq](http://www.spectreperformance.com/techsupport/eMSpro/faq)

If you have a settings file from someone else's similar configuration, by all means use it as a guide. Using other people's settings and tables is a reasonable starting point for tuning. However, no one should ever assume another person's table is totally right for their engine, even if it is seemingly identical. The reason is that the tolerance build-up of variables makes things different. Small changes (within acceptable tolerances) in injector flow rates, regulated fuel pressure, MAP sensor output, regulated pressures etc., can add up to needing quite different settings and tables. This is especially true of the more subjective parameters, like accel enrichment, and those that interact, like after start enrichment and warm-up enrichment.

Also when transferring configuration files (msq files) from others or from the Internet or simply changing settings in Megatune please ensure that the Outputs are setup for your ECU before downloading it to your MS ECU.

To check this open Megatune without the ECU connected and open the msq file you are going to use. Ensure that the all configuration settings are correct!!

Note that in this manual we assume you are running gasoline. Other fuels have different Air/Fuel Ratio (AFR) requirements. Below is a chart of the equivalent air/fuel ratios for several popular fuels:

Air/Fuel Ratio Equivalents					
<i>Lambda</i>	Gasoline	Propane	Methanol	Ethanol	Diesel
<b>0.70</b>	10.3	11.0	4.5	6.3	10.2
<b>0.75</b>	11.0	11.8	4.9	6.8	10.9
<b>0.80</b>	11.8	12.5	5.2	7.2	11.6
<b>0.85</b>	12.5	13.3	5.5	7.7	12.3
<b>0.90</b>	13.2	14.1	5.8	8.1	13.1
<b>0.95</b>	14.0	14.9	6.1	8.6	13.8
<b>1.00</b>	14.7	15.7	6.5	9.0	14.5
<b>1.05</b>	15.4	16.5	6.8	9.5	15.2
<b>1.10</b>	16.2	17.2	7.1	9.9	16.0
<b>1.15</b>	16.9	18.0	7.4	10.4	16.7
<b>1.20</b>	17.6	18.8	7.8	10.8	17.4
<b>1.25</b>	18.4	19.6	8.1	11.3	18.1
<b>1.30</b>	19.1	20.4	8.4	11.7	18.9

Lambda is the ratio of a given AFR (air/fuel ratio) to the stoichiometric AFR for that fuel. So if a gasoline engine is rich, say 12.5:1, lambda is:

$$12.5:1 \div 14.7:1 = 0.85$$

### ***Using MegaTune***

MegaTune is the Windows 95 and later configuration editor for the eMSpro controller. MegaTune allows all of the parameters to be modified and has a real-time VE table editor, which allows a vehicle passenger to tune the engine while driving.

On the Communications/Settings page:

**Port** - The communications port number should correspond to the port to which the eMS-pro controller is attached.

**Timer Interval (ms)** - The timer interval dictates how frequently the runtime and tuning displays are updated. An interrupt is generated at the specified interval, and the real time data is pulled down from the eMS-pro controller. Use 100-200 ms to start; you can try to smaller values (ex. 50 ms) if your computer is fast enough.

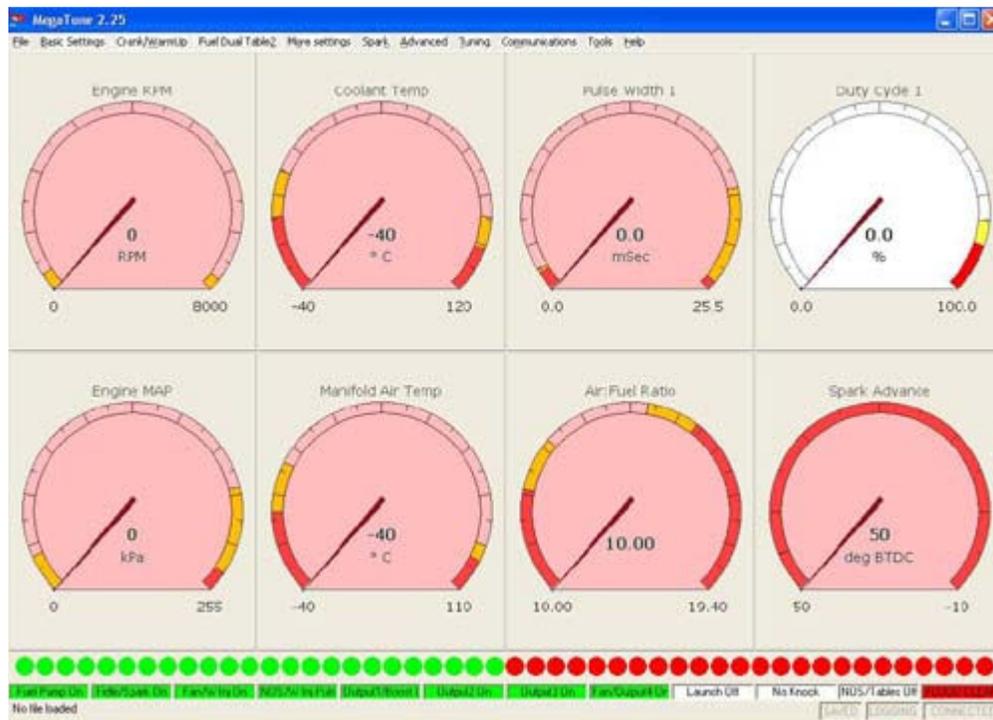
**Verify ECU Communications** - Click this button to attempt communications with the eMS-pro controller. Success will be reported.

Pulse width is the measure in milliseconds (1/1000 of a second) of how long the injector is opened for each pulse, regardless of how many times it is opened in a cycle. Duty cycle gives the percentage of time the injector is open irrespective of individual pulse duration. 50% means open for 360deg of the 720deg (One engine cycle 4 stroke)

The bar gauges across the bottom of the window shows the oxygen sensor reading. The scale is determined by ego Gauge value in the Tuning section of the megatune.ini file. This same setting controls the analogue and bar gauges on the tuning page.

The bottom of the front page contains a status bar. The current file name (used for Save operations) is displayed in the left part of the status bar, followed by "saved" status. When the memory image has been modified since the last Open or Save operation, this entry shows "SAVED" in bold face.

MegaTune allows you to save and restore configurations as files. Use the "Open", "Save" and "Save As" menu items to do this.



- Pressing 'F1' in any of the setting boxes will show some Help files and some suggested values.

You should check that MegaTune reads approximately the correct barometric pressure when no vacuum is applied (i.e. the engine isn't running), also check that the air temperature, coolant temperature and throttle position sensor value are reading correctly.

Below is a chart of the 'normal' barometric pressures for various geographic elevations. The eMS-pro should generally be within 4 or 5 kPa of the value below for your elevation. If it is significantly different, check that you have the correct ".inc" files loaded for MegaTune. See the MegaTune help file for more details.

**Barometric Pressure vs. Elevation**  
(Map reading with key on and the motor NOT running)

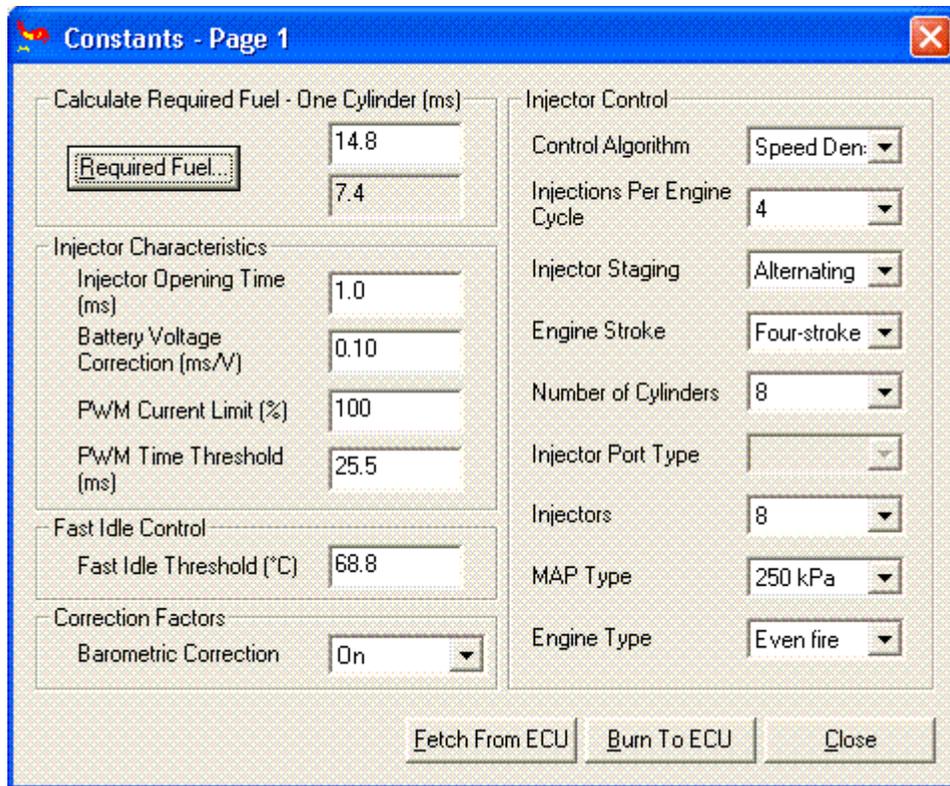
Elevation above Sea Level		Atmospheric Pressure	Example
Feet	Meters	Kilopascals (kPa)	
0	0	101.33	New York, Vancouver, Washington
500	153	99.49	Dallas (435 ft), Detroit (585 ft)
1000	305	97.63	Geneva (1230 ft), Kelowna (1129 ft)
1500	458	95.91	Helena (1404 ft), Wichita (1290 ft)
2000	610	94.19	Canberra (1886 ft), Las Vegas (2030 ft), Regina (1893 ft)
2500	763	92.46	
3000	915	90.81	Red Deer (2968 ft)
3500	1068	89.15	Brasilia (3480 ft), Calgary (3750 ft)
4000	1220	87.49	
4500	1371	85.91	Banff (4500ft)
5000	1526	84.33	Albuquerque (4945 ft), Denver (5280 ft)
6000	1831	81.22	Colorado Springs (5890 ft)
7000	2136	78.19	Mexico City (~7200 ft)
8000	2441	75.22	
9000	2746	72.40	
10,000	3050	69.64	
15,000	4577	57.16	La Paz (13,169 ft), Mauna Kea (~14,000 ft)

Note that weather reports usually report the barometric pressure 'corrected' to read as if 101.3 kPa was the 'normal' for your elevation. Do not expect these reports to correspond to what you get on the eMS-pro unless you are at sea level.

**Setting the Constants**

Before attempting to start your eMSpro equipped engine, you will need to set a number of parameters that determine how eMSpro injects fuel. These include the injector open time, Req\_Fuel, injector control criteria, PWM criteria, EGO characteristics, etc. These constants are either calculated, or based on the configuration of your sstem.

Note that for a Wankel rotary engine (Mazda 13B, etc.); see the MegaSquirt & Rotary Engines document for settings and other advice.



On the Settings/Constants page:

If you are running **high-impedance injectors** (greater than 10 Ohms), then set the:

- PWM Time Threshold to 25.5 msec, and the
- PWM Current Limit (%) to 100%.

If you have **low impedance injectors** (less than 4 Ohms), set the:

- PWM Time Threshold is the time required to open the injector, this is when full power is used to open the injector. Start at 1.0 msec, and
- PWM Current Limit is the Pulse Width that's used after the Time Threshold, this actually pulses the injectors on and off, keeping the injector from over heating at high duty cycles. Try starting at 30%

You will tune these after getting the engine running. See “Setting the PWM Criteria” in this section. **Failure to perform these steps can result in damage to your injectors.** If you have high-impedance injectors, set these values to 25.5 ms and 100%, and you do not need to tune them further.

“**Control Algorithm**” lets you choose between Speed Density (MAP) and Alpha-N (TPS). In almost all cases, **you should choose speed density unless you have a good reason to do otherwise**, and understand how this will change your tuning efforts. Alpha-N uses the throttle position (alpha) and RPM (N) to calculate the amount of fuel to inject as opposed to using the manifold absolute pressure (MAP) and RPM to calculate the amount of fuel to inject. Alpha-N is useful for long duration cams where the resolution of

manifold air pressure (map) would be small. It is also useful to get a smoother idle on engines that have erratic map values. eMSpro can be converted from its default speed-density calculations to Alpha-N, which uses RPM, temperature and TPS only. Start up the tuning software, go to the Constants dialog and change Speed Density to Alpha-N. Re-map your VE table. You will no longer use the MAP sensor for estimating the load on the engine -- the throttle position and rpm are used instead. This can help with cams with long duration and/or a lot of overlap, as they have low and unstable vacuum at idle, making tuning very difficult. Please also see Hybrid\_Alpha\_N for turbo applications running Alpha\_N. You will need to change the "Settings.ini" file in Megatune before you can proceed.

**Required Fuel** – (Req\_Fuel) this is top field of the Constants window. It has a calculation dialog to help you find an appropriate value. It should contain the injector pulse width, in milliseconds, required to supply the fuel for a single injection event at stoichiometric combustion and 100% volumetric efficiency.

**Ensure that the NUMBER of CYLINDERS has been set before using the wizard!**

In order to come up with this value, MegaTune provides a calculator that will suffice for 99% of applications (those for which it will not work generally require changes to the eMSpro controller code itself, and that is beyond the scope of this manual). To use the wizard, click on the Required Fuel button, and fill in the fields (Engine Displacement, Number of cylinders, Injector flow, and Air:Fuel ratio(14.7), then click 'Okay').

For a 4-stroke, a complete stroke cycle is 720 degrees of crankshaft rotation (i.e. two revolutions); for a 2-stroke, it is 360 degrees (this is also factored in the REQ\_FUEL value down loaded to eMSpro).

In the tuning software, the upper REQ\_FUEL box is the amount per cylinder, as noted above. The lower REQ\_FUEL box is the value down loaded to eMSpro. It is the REQ\_FUEL number on top, but scaled by your selected injection mode (number of squirts and alternate/simultaneous), this can be ignored as it is the upper number that's the important value.

For example, if you inject simultaneous and one injection, and have the same number of injectors as cylinders [i.e. port injection], then REQ\_FUEL on the bottom is the same as REQ\_FUEL on top. Same with alternate and two squirts. If you put in simultaneous and two squirts, then REQ\_FUEL is divided in half - because you squirt twice, you need to inject 1/2 the fuel on each shot.

Note: if you choose alternating for port injection, make sure your number of squirts is an even number (2,4,...) and evenly divisible into the number of cylinders. For example, with an eight cylinder engine, you could use alternating and 2, 4, or 8 squirts/cycle. With a six cylinder, if you choose alternating, you MUST use 2 or 6 squirts/cycle. Also, the only possible combinations for an odd-cylinder count engine are either 1

squirt/simultaneous or N squirt/simultaneous combination, where N is the number of cylinders."

**Permissible Combinations:**

**Permissible Combinations:**

Number of Cylinders

	1	2	3	4	5	6	8	10	12
1	OK	<i>Sim. only</i>							
2	no	OK	no	OK	no	OK	OK	OK	OK
3	no	no	<i>Sim. only</i>	no	no	<i>Sim. only</i>	no	no	<i>Sim. only</i>
4	no	no	no	OK	no	no	OK	no	OK
5	no	no	no	no	<i>Sim. only</i>	no	no	<i>Sim. only</i>	no
6	no	no	no	no	no	OK	no	no	OK
7	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>
8	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	OK	<i>no</i>	<i>no</i>
9	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>
10	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	OK	<i>no</i>
11	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>
12	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	<i>no</i>	OK

"OK" means the combination will work with either simultaneous or alternating. "no" means it will not work with either, i.e., not at all. Virtually all installs will use 2 (4 is ok for lower RPM engines like V8's) Values of 7 and above would most certainly not be used.

**Injector Opening Time** (ms) is the amount of time required for the injector to go from a fully closed state to a fully opened state when a 13.2 volt signal is applied. Since fuel injectors are electro-mechanical devices with mass, they have latency between the time a signal is applied and the time they are in steady-state spraying mode. Typically, this value is about 1.0 millisecond.

The eMSpro code assumes that NO fuel is injected during the opening (and closing) phases. However, it is very likely that a small amount actually is injected. Thus making this value larger will enrich the mix and will have a much greater effect at low pulse widths. The eMSpro also uses this value as an additive constant in pulse width calculation, thus making this the lower limit for pulse width.

**Injections per Engine Cycle** is set the number of squirts you want per engine cycle. You want this to be set so that your idle pulse width is no less than 2.0 ms, if possible, and your Req\_Fuel is less than 12-15 milliseconds, but more than 8 milliseconds. These values allow proper tuning of the idle mixture while maintaining the ability to apply

enrichments (acceleration, warm-up, etc.) under full throttle. This is the total injector events that you wish to occur for every engine cycle (360 degrees for two stroke engines and 720° for four strokes).

**Injector Staging** values for injector staging are simultaneous or alternating. If you want all your injectors to fire at once, select simultaneous. If you want half your injectors to fire at each injection event, and the other half on the next event, select alternating.

Note that with port injection, you must choose at least 2 squirts per cycle with alternating injection, otherwise every other cycle for each cylinder will get NO fuel! The engine will run very badly.

There is some benefit to choosing 2 squirts/alternating for port injection, since only half of the injectors fire at once, the pressure drop in the fuel rails is reduced and the fueling is more consistent.

With throttle body injection, the number of injection/cycle you can will depend on your number of cylinders, plenum size, Req\_Fuel, etc. You have to experiment to see what works best for your combination.

**Engine Stroke** values for engine stroke type are two-stroke or four-stroke. EMSpro uses engine stroke to determine how many degrees are in an engine cycle.

**Number of Cylinders** is the count of the cylinders on your engine. If you are unsure how many cylinders your engine has, you should not be installing EMSpro on it.

**Injector Port Type:** This is not used in MSnS\_Extra, so no settings needed for this, it should be grayed out.

**Number of Injectors** is the total number of injectors EMSpro is controlling, whether port or throttle body injection. (this is used in the Required Fuel calculation)

**MAP Type:** this should be set to 400Kpa if you are using the standard EMSpro internal 4-bar map sensor. If using an external MAP sensor, set this to match the Kpa range of the external sensor.

### ***Before Starting Your Engine***

The cranking pulse width at -40°F should be about 3 to 5 times the 170°F value. To begin, set the -40°F cranking pulse width to about 88% of your "upper" req\_fuel value, and the 170°F cranking pulse width to about 23% of your req\_fuel. Those should get you 'in the ball park' for starting. (Once you have the engine running, you can tune the cranking pulse widths with small changes, moving them up or down together, and check it over a few days worth of starts before deciding which direction to go next.

Before starting, make sure to:

- Have two fully charged fire extinguishers on hand,
- Check the entire fuel system, from the tank to the injectors and back, for leaks while running the fuel pump. DO NOT attempt to start the engine if there are ANY leaks whatsoever. **Fix any leaks before proceeding.**
- Check that the fuel pressure is appropriate for your system (usually about 42-45 psi for port injection when not running, usually around 12-15 psi for throttle body systems).
- Verify that you have powered your EMSpro from a +12V source that will supply current **while cranking**. Many reported problems with EMSpro have been traced to power sources that are connected in “run” but not while cranking. Check your vehicle wiring diagrams if you are not sure.

**Resets** - A reset can be seen in Megatune in the bottom right hand corner. Some resets can be the USB adaptor (if being used) simply overflowing. The eMSpro has a USB communications port and a serial port, if your tuning computer does not have USB capabilities, utilize the provided serial port. If the engine runs smoothly but you are seeing resets and you are using an USB adaptor try setting the Received and Transmitted buffers as low as they will go. If the engine is stumbling and there are resets on the Megatune screen (bottom right corner) then these are probably real resets, but to confirm this unplug the laptop if using a USB adaptor and see if it cures it. In datalogs you can see them as massive spikes in all of the logged variables.

- If you have a throttle body injection (TBI) system, verify that there is a small squirt of fuel (equal to the “prime pulse”) when EMSpro is powered up (by turning the ignition key to run), and that no more fuel is injected until cranking starts. If this is not the case for your system, find out what is wrong and correct it.
- Connect your laptop to your EMSpro using an USB cable or db9 serial cable, turn the ignition to run (do not start it), and verify that all the sensors give reasonable values. The MAP should be about 100 kPa, the coolant and intake air temperatures should be approximately the same as the outside air, and the TPS should read from 0 to 100% as you open the throttle. Note that MegaTune has a two-step calibrating function for the TPS. The throttle position sensor is often used for accel enrichment, and also for flood clear mode, and EGO enrichment:
  - **Flood clear mode** this can be set in "More Cranking Stuff" Sometimes you might want to temporarily stop the injectors from injecting fuel during cranking to clear a flooded engine. This is achieved by holding down the gas pedal during cranking. The EMSpro needs to know at what point of gas pedal deflection it should turn off the injectors and a good starting point would be just before flooded.

To get this value, go to **Tools, Calibrate TPS**, and push the gas pedal almost all the way

to the floor - about where you think the fuel should be cut off and hit **Get Current**. Remember this value and hit **CANCEL** on the Calibrate TPS dialog. Insert this value for the **TPS Flood Clear**. If this value is set too low then you will not get any fuel during cranking. If you set this value too high, then you won't be able to press the pedal enough to trigger the Flood Clear.

- **EGO feedback** In "Open Loop Mode" you can turn off closed loop oxygen sensor monitoring above a TPS position or kPa value. The aim of this is so that only the VE table is used to control fueling, typically at full throttle/load conditions

## ***Getting the Engine Started and Idling***

Okay, the hard stuff is done now, the eMSpro is installed and configured, the electrical and mechanical pre-start check list is complete. You are now ready to begin the fun part, successfully starting and tuning the engine! Just remember to take your time and be methodical...

If you are running ignition control and fuel then you should read the ignition setup pages from your relevant system on the [MSnS Extra Ignition Hardware Manual](#) there are more details [HERE](#) too on starting up and ignition control.

If you are running fuel only then be sure to set your base timing before starting your car (if it hasn't previously been set).

Typically, the first time someone tries to start their engine with EMSpro, it starts after about 5 minutes of alternating various cranking pulse widths numbers to get started (on the [Crank/Warmup](#) page), and REQ\_FUEL to keep it from stalling but only once it has started (on the tuning page). It may take a bit of cranking, so you might need to keep a battery charger on hand. Remember that the only fuel added during cranking is the Cranking PW in the [Crank/Warmup page](#). The fuel map has nothing to do with initially starting the engine.

During cranking the RPM gauge in Megatune should read somewhere around 50-300rpm, if it isn't displaying a steady tach the engine more than likely will not start. The reasons are likely to be the lack of a trigger signal on pin 24 of the 37pin connector. If using a VR sensor ensure the gap is 0.75-1.0mm from the teeth. Another gauge to look at is the PW in Megatune, if this is showing zero during cranking and the RPM is between 50-300 then the chances are the Flood Clear value is set too high, see the flood clear section.

Once you have it started and running, allow the engine to warm up and tune the idle VE values in the TUNING -- VE Table1 screen. Then you can reset the REQ\_FUEL value back to its original number. It is very easy to change without having to re-enter the VE numbers. Go to **VETable1** then **Tools->Scale VE Table**, and enter your original and new REQ\_FUEL values. This adjusts the VE table.

Remember that when you start to drive the car be gentle on the throttle and keep an eye on your O2 readings. Pull over, if it is too lean and adjust the table manually where it was too lean if necessary. It is really helpful to have someone with you holding or tuning with the laptop whilst you drive.

Then go to **Settings->Constants** and change the REQ\_FUEL from the value you used to start the engine to the value calculated in MegaTune. The injector pulse widths will be the same, but the VE numbers will more accurately reflect your actual volumetric efficiencies.

If you have been trying to start your engine for more than 10-15 minutes, you ought to investigate other sources of problems before continuing to try to start the engine.

Properly tuned, EMSpro will start your engine quickly and reliably. If you have trouble with starting, either hot or cold starts (or both):

- Be certain you have a valid VE table in your EMSpro. Check this with MegaTune ('Settings/VE Table'). If your table is all ones, you will have to create a new table. You can either:
  - Use a base setup from [here](#), open the file and go to 'Settings/VE Table/File/Table Export'), then save it and re-open your Config file and go to 'Settings/VE Table/File/Table Import')
  - Generate a new table based on your peak horsepower and torque figures ('Settings/VE Table/Tools/VE Specific/Generate VE Table').
- Use the "Tools/Calibrate TPS" function in MegaTune to ensure that you have an ADC count value well below the setting in "More Crank Settings" at closed throttle (ideally, your TPS at closed throttle will be 30 or less), and above 178 at wide open throttle (WOT). Many TPS are adjustable by loosening the screws and rotating it a bit. Also verify that the ADC count **increases** as you open the throttle, otherwise you have the TPS wired backwards. You should recheck the TPS range each time you change the idle position or reassemble the throttle linkage.
- Verify that the source you have chosen to supply +12 Volts to EMSpro with is receiving power **while cranking**. Some sources give 12 Volts in **RUN** but not **CRANK**. The engine will be very difficult to start if EMSpro is connected to such a source.
- If your motor refuses to start make sure the fuel pump is connected to a source that supplies 12 volts in **RUN** and **CRANK**.
- Make sure that you have enough voltage during cranking to open the injectors. For cold starts, you have a cold engine, and a cold battery that make a lot of demands on the starting system. Make sure your battery/alternator, etc. are *"performing correctly"*
- Make sure your PWM setting are not so low that your injectors no longer fully open for the commanded pulse widths in worst-case scenarios, which cold starts definitely are! Note, however, that the code disables PWM during cranking. This was done so that PWM values (% and threshold) could be lowered under running

conditions. However, the PWM set-up needs to be sufficient for a poorly charged battery that has just had to start a cold engine, with the heater/defroster running full-blast, etc.

- Remember that the cranking pulse widths need to be with  $\sim 0.5$  ms of the optimal value at both  $-40^{\circ}\text{F}$  and  $170^{\circ}\text{F}$ . Generally the  $-40^{\circ}\text{F}$  cranking pulse widths should be about 3 to 5 times the  $170^{\circ}$  number. If you overestimate the correct values, you WILL flood the engine.
- For tuning, the engine needs to be in a true “cold-start” state. That means not flooded - which can easily happen when you are playing with the numbers. If you suspect you may have flooded the engine, disconnect EMSpro and crank the engine for at least several seconds or more. Keep a battery charger handy!
- Check to make sure the injectors are actually firing, so that you are sure there is not a fault in the wiring causing you to run without all of the injectors. This is easy with throttle body injection, just look at them with the air cleaner off. With a port injection system, see if you can smell gas at the exhaust.
- Verify that your fuel lines to the fuel pressure regulator are the right way around. If your fuel is pumping, and your injectors are opening, but the spark plugs are dry, there's no fuel. So pull a spark plug to have a look. If they are dry, check your regulator connections.
- If the engine tries to start, but dies right away, you need to adjust the after start enrichment. Generally this should be between 20-30% for 100 to 250 cycles.
- If the engine starts but dies after a several seconds or minutes, then you need to adjust your warm-up enrichment.
- Check a data log of your cranking to verify that your cranking speed is 300 rpm or less. If it is more than 300 rpm (not very common, but possible), you need to alter the setting in "More Cranking Settings"
- If the engine leans out when on overrun and the Injector PW drops to 0.0mS in the datalogs look at the overrun settings and turn them off during early tuning.

You start tuning by just getting it to idle properly by adjusting the speed [with the throttle stop and/or FIdle solenoid], and mixture [with the VE table or REQ\_FUEL]. There is little danger of harming anything, as there is not enough load on the engine to build enough heat to hurt anything. The engine will idle on a very wide range of mixtures, so it is not too hard to get it started, you just play around with the REQ\_FUEL until it fires. After you have the engine idling, note the pulse widths at idle. Then you can reset your REQ\_FUEL to the calculated value as described above.

Once you can start the engine and have it idle, proceed by tuning your idle AFR. At idle, the exhaust gases may not be hot enough for a one wire  $\text{O}_2$  sensor to read correctly, even though the engine is fully warmed up. In that case it will read lean all the time. Header wrap helps get the  $\text{O}_2$  up to temperature. This is especially true if you have:

- Headers (the thin metal and increased surface area conducts exhaust heat away much faster than a cast iron manifold),
- High compression (gives cooler exhaust gases), or
- Your  $\text{O}_2$  sensor located far away from the head.

In any case, unless you are tuning for minimum emissions, the best strategy is to tune your idle for a minimum MAP reading at your chosen idle speed (by altering the VE values around the idle point). This will give you the smoothest idle, and best off idle response. You may have to reset the idle stop a few times as you adjust the mixture.

Just watch the MAP reading as you adjust the VE table. It should move up or down if you adjust the VE table enough.

If it is cold out, you may need to adjust the [warm-up enrichments](#) before you can get the engine warmed-up so that you can adjust the idle mixture, etc. The easiest way to do this is to use Megatune's Warmup Wizard ("Runtime/Warmup Wizard"). There are more details [here](#).

Later, when you have the engine started and idling well, you can fine-tune the cranking pulse widths. General Motors uses stoichiometric mixtures for both idle and cranking pulse widths at full coolant temperature, and a 1.5:1 cranking AFR at -30°F or so. For example, to establish out some starting point pulse widths, lets assume a 4-cylinder engine, with the injector staging set to 2-squirts/alternating. The injector pulses look like this (0 = injector pulse, - = no injector pulse):

o---o---o---... Bank 1  
--o---o---o---... Bank 2

The picture when cranking is much easier, since it fires every injector on every ignition event:

oooooooo... Bank 1  
oooooooo... Bank 2

So what we have is four times as many injection events when cranking compared to running. Now let's assume we have tuned:

- the idle so that the best idle PW = **2.2** ms,
- our "well-tuned" injector open/close time is **1.0** ms (this is important!), and

Then we get our "best idle" fuel delivery amount of:

$$2.2 - 1.0 = 1.2 \text{ milliseconds fuel deliver per injector pulse}$$

Split this up into the 4 times as many injector events we see during cranking, add in the Open/Close time and get our hot cranking PW.

$$(1.2/4) + 1.0 = 1.3 \text{ ms}$$

Now for cold we want 1.5:1, which is close to ten times as rich as 14.7:1, so just multiply that first part by 10 and we get our cold cranking PW.

$$(1.2/4)*10 + 1.0 = 4.0 \text{ ms}$$

This calculation requires:

1. Good idle tuning to get that initial pulse width, and
2. Good tuning of the open/close time so that the actual fuel delivery number from the first equation is correct.

### ***Setting the PWM Criteria***

To tune the PWM [pulse width modulation] values for your engine, you need to know what kind of injectors you have: low impedance or high impedance.

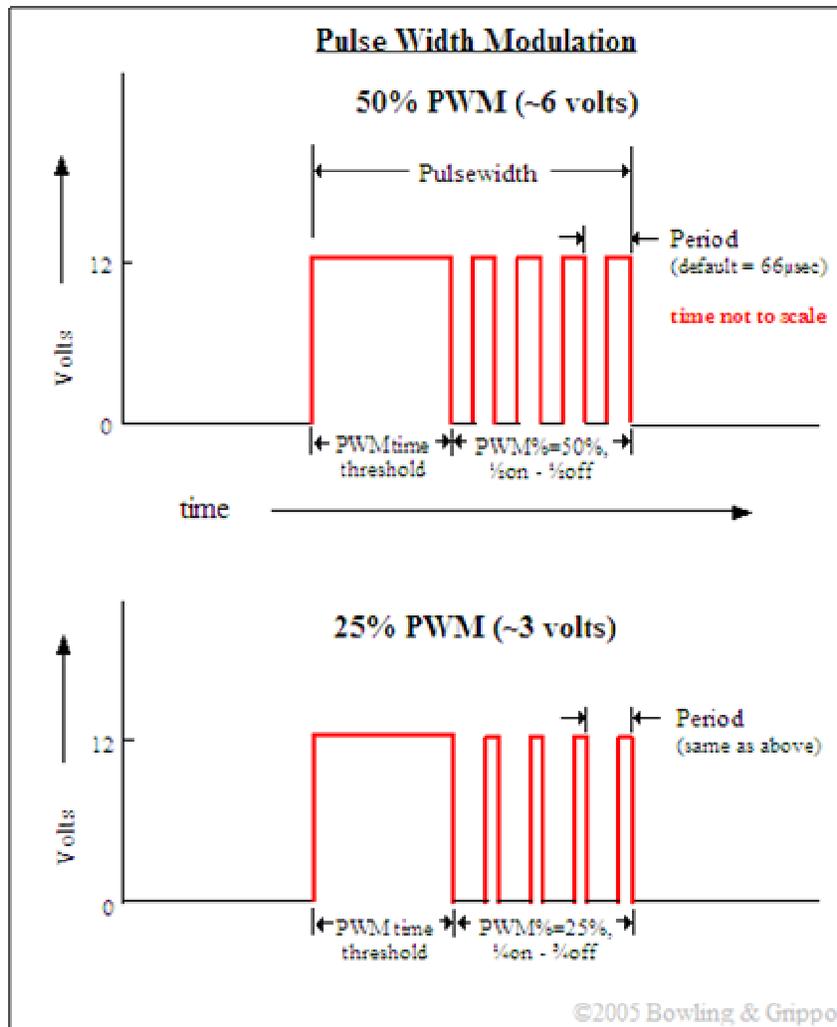
- If you are running **high-impedance injectors** (greater than 10 Ohms), then set the:
  - **PWM Time Threshold** to **25.4 msec**, and the
  - **PWM Current Limit (%)** to **100%**.

In essence you are disabling the PWM mode. This allows full voltage to the injectors throughout the pulse widths.

- For **low-impedance injectors** (less than 3 Ohms), you need to limit the current to avoid over heating the injectors. To do this, there is a period of time that you apply full battery voltage [peak] current, then switch over to a lower current-averaged [hold] current, i.e. peak and hold.

To run low-impedance injectors with the PWM current limit mode, you need to set two parameters - the "**PWM Current Limit (%)**" and the "**PWM Time Threshold (ms)**" - both are on the "Constants" page. The current limit % is the percent duty cycle when the current limit is invoked. The time threshold is the amount of time from when the injector is first opened until the current limit is activated.

1. Start with:
  - **PWM Time Threshold = 1.0 millisecond**, and
  - **PWM Current Limit (%) = 30%**
2. Once you get your engine idling, then first adjust the PWM duty cycle down in 1% increments until you notice a change in idle quality (be sure to hit the "send to ECU" button each time you change the value). This is the point where the current limit is too much and the injectors are not being held fully open.
3. Then move the value back up 3 - 5% (for example, if the idle falters at 45%, then put in a number of 48% to 50%).
4. Move on to adjusting the time threshold. Lower the time threshold by 0.1 milliseconds at a time until the idle quality deteriorates.
5. Then increase it 0.3 ms.
6. Now, repeat these steps (starting at #2). Adjust the duty cycle and time threshold alternately to get the optimum values for your set-up. You will converge on a set of numbers that work well for your set-up.



The injector opening time and PWM time threshold should be set to the same value. So adjust the PWM time threshold, and the opening time together. However, once you start to tune the 'fine tune' the idle, if you have to revisit the PWM parameters, change the PWM time threshold, not the opening time.

The reason for this is that changing the opening time also changes the AFR, especially at low rpms, so it forces you to also retune the VE table. So unless they get to be different by more than about 0.5 milliseconds, leave the opening time alone after tuning the idle and cruise VEs (unless you are willing to retune those areas).

On the car, setting the PWM parameters is very easy to do and only takes a few minutes. At idle the overall injector pulse widths are small compared to their close time, so this will allow you to adjust the values. In other words, adjust the PWM current limit before taking the car out on the street where injector pulse widths become high, increasing the possibility of overheating your injectors.

You may find that you can idle at a very low PWM%, but the engine will stumble or cough if given any throttle. This can be due to a too low PWM% especially if your injectors are large and the idle pulse width is approximately equal to the PWM Time Threshold. In that case you may be idling almost entirely on the PWM Time Threshold. So rev the engine occasionally as you are tuning the PWM parameters, to ensure that you haven't gone too low.

Also, for some setups, an initial PWM Current Limit of 75% may be too low, so they will need to increase this value - same for the time threshold. **Use PWM time threshold values greater than about 1.5 to 1.7 milliseconds only with great caution – it is possible to burn out your injectors!**

### ***Setting the Cold Start and Warm-Up Enrichments***

If it is cold out, you have to figure out the cold start enrichments/warm up enrichments right away to keep the engine running as it warms up. Otherwise you can leave this until you experience some cold weather. During cranking mode (defined when RPM is less than around 300 RPM, this can be set in "**More Cranking Settings**", but 300RPM is around the normal setting), EMSpro shoots out cranking pulse widths depending on the settings in "**Cranking Settings**". Please note that the fuel map is completely ignored during cranking, so don't alter it if it doesn't start, only alter the PW on the Cranking settings.

A typical setting for a Chevrolet small block V8 with a Tuned Port Injection set-up and 30 lb/hr injectors is 2 milliseconds at 170°F and 10 milliseconds at -40°F. The values for your combination are likely different, though generally should follow a similar pattern. During cranking, EMSpro injects one pulse for every ignition event, so for an 8-cylinder it shoots out 8 times for 720 degrees crankshaft, with all injectors squirting. So with the above values, at 170°F, the effective amount of fuel per cylinder is  $8 * 2 = 16$  milliseconds. For -40°F it is  $10 * 8 = 80$  milliseconds.

Once the engine fires up (defined by engine RPM greater than the setting in "**More Cranking Settings**" typically 300RPM), the engine starts to use the VE Table's fuel map and if the coolant is under 71C (170F) it goes into after start enrichment. The afterstart (ASE) enrichment is generally set to increase the percentage of the fueling map it will run at for a pre-determined amount of time or ignition pulses so the engine has a chance to start and smoothen out. This can be set to a different value depending on the coolant temperature in "After Start Enrichment Settings" Start out at a user-defined percentage enrichment value (typically around 25%), and then it ramps down to 0% after so many ignition trigger events, which is user-defined (use about 200 for this number to start). This is enrichment above the normal warm-up enrichment, which is temperature dependent. Please note that 0% means that it will run exactly what the VE table values are and 50% would mean 50% increase over the VE table.

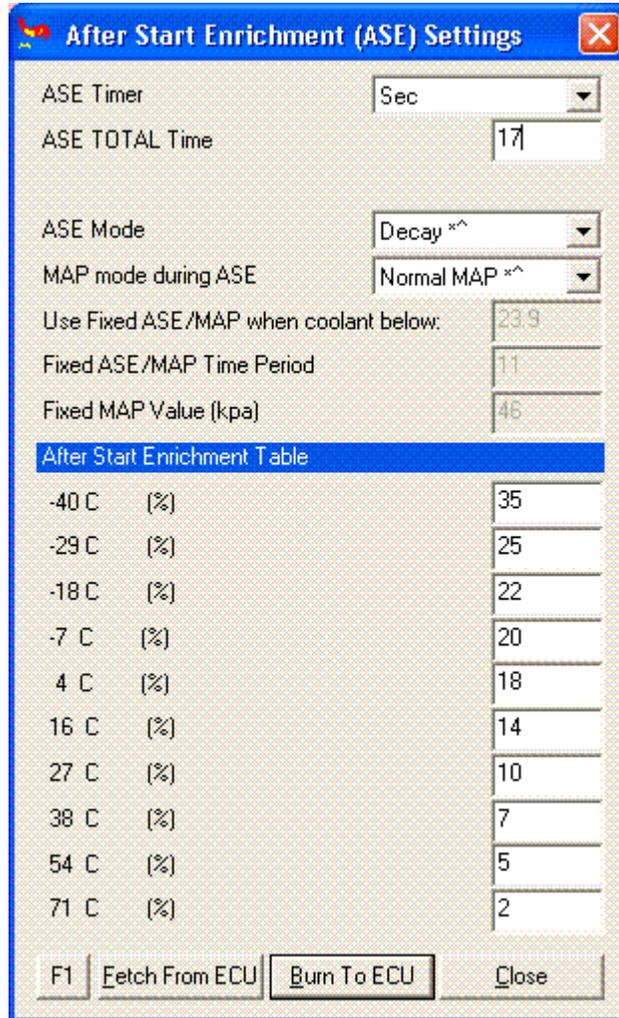
It's been found that during winter the cranking and after start enrichments need tweaking in order to get the engine to start and run without restarting it several times from cold.

The reason is felt that the after start and cranking enrichments don't necessarily follow temperature in a linear format.

After Start Enrich Counter is the length of time in Seconds or engine cycles that the after start enrich runs for. The percentage added is decayed down to zero as the time expires

Set ASE Mode to FIXED for a timed period of ASE that does not decay, after the timer the ASE will then decay as usual during the TOTAL ASE time period that's left. This has a temp set point as it should only be needed when the coolant temperatures are fairly low.

Setting MAP to a fixed value helps to maintain a constant PW during the initial start where the map drops quickly from around 100KPa to the tickover KPa. This is held during the FIXED time period. The FIXED period is a period of time at the start of the TOTAL ASE time. FIXED must be less than TOTAL.



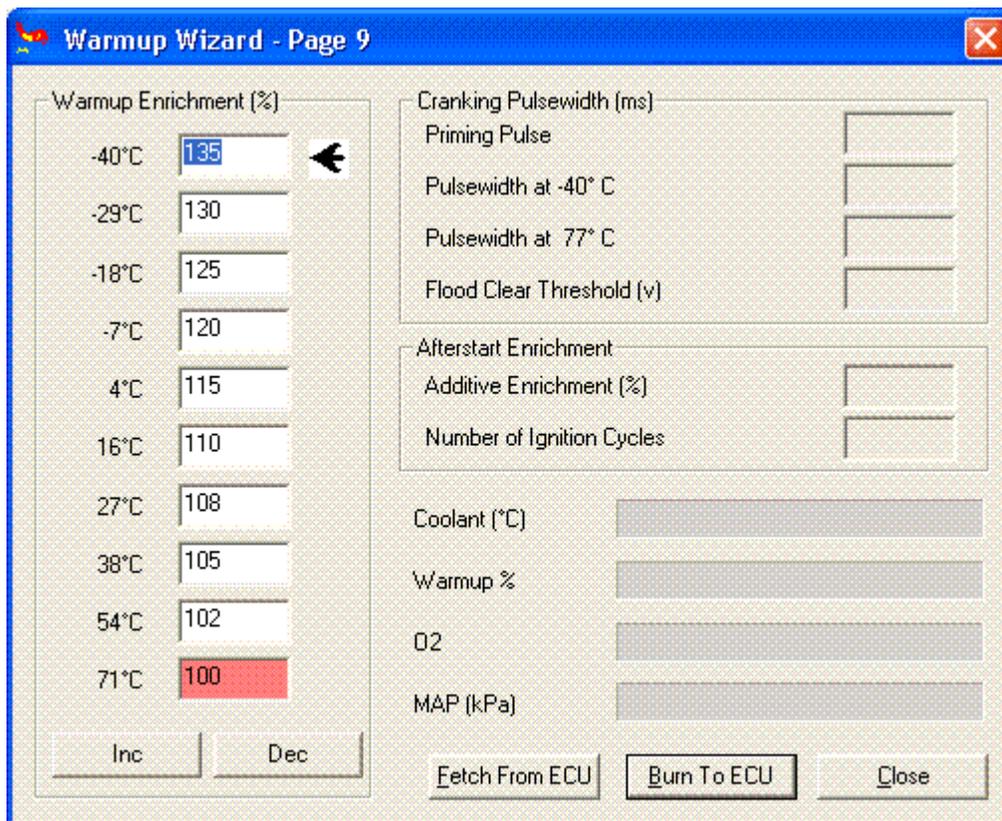
If the engine starts and runs for a few seconds, then stalls, this is usually a sign that the afterstart (ASE) enrichment isn't quite right. Leave everything else the same, and adjust the afterstart % and number of cycles. 20% to 30% and 200 cycles are reasonable starting

points for most engines, but yours may run better with more or less. There should be a point at which it works without stalling.

If the engine starts and runs for more than 20 seconds or so, then stalls, you need to adjust your warm-up enrichment bins. As you adjust your warm-up bins, you may need to re-adjust the afterstart, since these interact (i.e., a larger warm-up value may require a shorter or smaller afterstart enrichment).

To set the **Warm-Up Enrichments**, use the "**Warmup Wizard**" under "**Crank/Warmup**" on the main menu. This lets you adjust the warm-up bins while indicating which bin(s) are currently active. The engine needs to sit for several hours, before trying to adjust the warm-up enrichments after running the engine. Please note that the **Warmup Enrichment** is an additional fuel added to the base VE table, it is best to have a good tuned idle when warm then adjust the warmup when next cold without tuning the VE table.

With the above numbers tuned properly, nearly any engine can be tuned to fire immediately, every time, just like any OEM fuel injected car. It takes a while to converge on the best numbers, especially the after start enrichment, which needs to be just right, or the engine will run rough or stall immediately after starting.



You can do this as the engine warms by adjusting the warm-up bins, loading it to the ECU, and noting the effect on idle quality. It will take several starts {from a cold soak} to

get this close. Then you can play around with revving the engine in neutral and adjusting the mix to stoichiometric. Up to here it easy enough to do without an O<sub>2</sub> sensor by adjusting for maximum vacuum (lowest MAP kPa) ant any given rpm.

## ***Setting the VE Table***

To set up the fuel curves for the engine with EMSpro, you have a number of parameters to work with. The most important of these are the Req\_Fuel value and the VE table (12x12 volumetric efficiency table). You are aiming to achieve 12.5-13.1:1 air/fuel ratios under full throttle, and 15-17:1 under light loads for a naturally aspirated engine. Boosted engine may require a richer mixture under power.

The VE table represents the volumetric efficiency and air/fuel ratio at each rpm and kPa (0=total vacuum, 100=atmosphere, etc.).

Volumetric efficiency is the ratio of the amount of air actually fills the cylinder to the amount that would fill the cylinder in a static situation. The VE is used in the '[fueling equation](#)'.

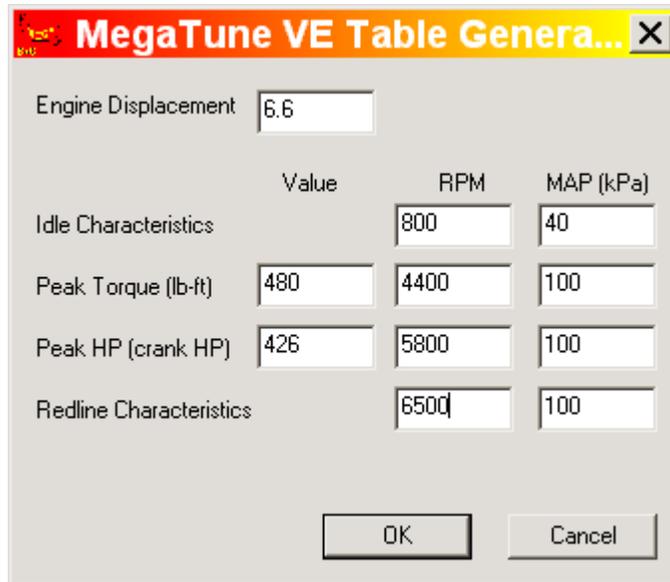
There are a number of ways to specify VE. EMSpro specifies it relative to the manifold absolute pressure and includes the AFR in the VE table.

That is:

$$\mathbf{VE = (actual\ air\ mass)/(theoretical\ air\ mass)*AFR_{stoich}/AFR_{actual}}$$

So for EMSpro, entering a larger VE in the table makes that point richer, and a smaller number makes that point leaner.

To start you tuning efforts with EMSpro, you can calculate an initial VE table that has sufficient RPM and kPa bins, as well as an estimate of the VE based on your maximum torque and horsepower figures. The calculator is under the "Tools" section of MegaTune (version 2.25 and higher). This calculated VE table would need to be tuned carefully to avoid damage to your engine, however.



Before starting to tune the VE Table it is recommended that you turn the Acceleration Enrichment (AE) off so you can see what's happening to the mixture as a direct result of the table rather than having fuel added from Accel Enrichment. To do this set the thresholds to 30V/S or 5000KPa/S see [HERE](#) for more details on AE. You may find that you'll need to be light on the throttle as the AE is needed to fill 'holes' that occur when the throttle opens quickly. Remember to tune the AE when you have a tuned VE Table.

Another item to turn off during tuning is the Overrun settings as the PW may drop to 0.0mS causing lean spots.

Tuning the VE table involves richening (by increasing the VE) or leaning (by decreasing VE) at each point in the VE table. Most of your driving will occur in a diagonal strip of the VE table, from low rpm, low kPa (i.e. idle) to high rpm, high kPa (i.e. WOT). You can adjust these values using the O<sub>2</sub> sensor, data logs and MSTweak, and/or the seat of your pants. Low rpm and low kPa (say less than half of the max rpm and max kPa) might be able to use stoichiometric or leaner. Richer mixtures would be used at high rpm and high kPa.

However, the low rpm/high kPa and high rpm/low kPa are not seen as often driving your vehicle. Basically, if the engine never runs in certain parts of the MAP, then the numbers there should not matter. However, since you may not be able to guess where you will run under every possible set of conditions, you put estimated VE numbers that make sense into the little used areas.

From this frequently used diagonal strip of the VE table, you will be able to see how much the VE rises from one rpm bin to the next, and use these differences to estimate the low rpm, very high kPa numbers and the high rpm, very low kPa numbers. Since you

rarely (if ever) run in these parts of the table, the actual numbers will not make much difference, but they will be there "just in case". You are looking to create a smooth VE map wherever possible.

To set the VE table entries near idle, you should try to achieve the lowest MAP (in kPa) that you possibly can, at your chosen idle speed. This will give the highest idle vacuum and the most efficient idle. Don't try to get to a target idle mixture (stoichiometric, or some other number), instead adjust the VE table entries around your idle rpm and kPa to achieve the lowest MAP reading as seen in MegaTune. As you work to lower the MAP, the rpm will likely rise, and you'll have to reset the throttle stop to lower the rpm to your desired idle speed. When you have it set so that **either** raising or lowering the VE table entries increases the MAP, then you have the best idle mixture for your engine (it will require the smallest throttle opening).

At non-idle areas of the VE table, you will generally run lean (low loads and speeds) or rich (high loads and speeds). High loads are associated with high kPa MAP values. Deciding exactly when (and how much) you should run rich is mostly a "seat of the pants" thing. When tuning, you will find the engine will surge (at low loads) and "coughs" at higher loads if it is run lean. Adjust the VE at the point where this happens so this does not occur. Check the plugs for detonation (tiny black and white flecks) when tuning at high loads and rpms if you suspect detonation at all. A narrow band should read at least 0.8 volts under full throttle, at least for a starting point in tuning WOT. There are more details later in this section.

For an example, look at the sample VE table later in this section. It is the default eMSpro table, from the 350cid Chevrolet V8 engine that Bruce Bowling has in his Jaguar. It will work adequately for starting your tuning efforts in many more applications than you might suspect.

Volumetric Efficiency (VE) entries in 12x12 EMSpro VE table actually are  $VE * \gamma$ , where  $\gamma$  is the (stoichiometric AFR)/(actual AFR), and VE is expressed as a percent (i.e. 65 represents 65% volumetric efficiency at 14.7:1 AFR).

*Note: If you do not use the "correct" REQ\_FUEL value, the VE numbers in the VE table will be skewed by the amount REQ\_FUEL is "incorrect".*

For EMSpro (and most MAP based EFI controllers), VE is based not on the percentage of cylinder filling relative to atmospheric pressure, instead it is based on the percentage of filling relative to the intake manifold pressure. So even with a highly "boosted" engine, VEs will not be much above 100%, except to richen the mixture.

You can tune your engine to a stoichiometric mixture with NB O<sub>2</sub> sensor, but not at high loads/rpms. You can then use a little math to "correct the mixtures". For example, if you get a stoichiometric mixture with 65% VE at a certain RPM and kPa, then to lean the mix to 16.0:1 you need:

$$65\% * (14.7 / 16.0) = \mathbf{60\%}$$

To richen an 80% VE entry to 12.5:1 from stoichiometric:

$$80\% * (14.7 / 12.5) = \mathbf{94\%}$$

Note that with MSTweak3000, you will get stoichiometric mixes if you set the crossover voltage to 0.45 - 0.50 volts with a narrow band O<sub>2</sub> sensor. This is where you should have the EGO switch point set on the enrichments page in MegaTune as well. You can then adjust the MSTweak suggested VE table as described above to get other mixtures. **Note the you will want to be sure of running rich mixture under high load/high RPM conditions.** This makes a narrow band sensor somewhat less useful. As a starting guide, make sure you have at least 0.8 - 0.9 volts from the sensor under “wide open throttle” (WOT).

MAP sensor values can be between 0 and 250 kPa for all V2.2 and V3 EMSpros. Naturally aspirated V1 EMSpros (from the very first group buy in 2001) can have MAP values between 0 and 115 kPa. Idle RPMs below 300 rpm will induce “cranking mode”, so should be avoided.

You can set RPM and MAP sensor values for table wherever you want them, but they must be in the same order as in the table supplied with the software. Put them so they cover entire rpm/boost range of your engine. That is, you want to cover from your slowest idle speed to your red line, and from the kPa at idle or deceleration (whichever is lower) to full throttle (with boost, if applicable). Evenly spaced values work well, but you may choose different values to suit your combination.

Generally, VE table numbers above 100% are used only to richen mixtures. Even a turbocharged engine capable of 20 lbs/in of boost will generally not have extremely large VE numbers. The addition of fuel for boost comes through the MAP term in the fuel equation:

$$\mathbf{PW = REQ\_FUEL * VE(kpa,rpm) * MAP * E + accel + Injector\_open\_time}$$

Thus increasing the VE at higher boosts makes the mixture richer, but it would not have run leaner simply because of the higher boost.

In essence, the mass of the air is computed using the ideal gas law ( $PV=NRT$ ), where the pressure  $p$  is a function of VE and MAP, the volume  $v$  = cylinder displacement, the air temperature  $t$  is a function of E,  $r$  is the gas constant. We are looking for  $n$ , the mass of inducted air) and then that result is combined with a characteristic number for a given injector.

If you get the injector opening time correct, and the REQ\_FUEL accurately represents the flow rate of your injectors, then the VE entries will be close to the VE\*gamma noted above. **However**, if your opening time is not right, or your REQ\_FUEL is not, then the

numbers will be skewed by the amount the values are in error. In general, except for when you are first trying to get your engine started, use the calculated value for REQ\_FUEL and do not change it.

Here is a sample VE table (it is the default table in EMSpro, used for a 350 Chevy V8 with Tuned Port Injection). Note that the engine rpm range is from 500 rpm to 5200 rpm, and the MAP values range from 30 to 100 kPa (telling us that this is a naturally aspirated engine). Beyond these values, EMSpro will use the last value from the “edge” of the table. (It does not “shut down” by substituting zero values.) In theory, at stoichiometric mixtures, the values at 100kPa would reflect the torque curve of the engine at WOT, assuming a constant AFR level.

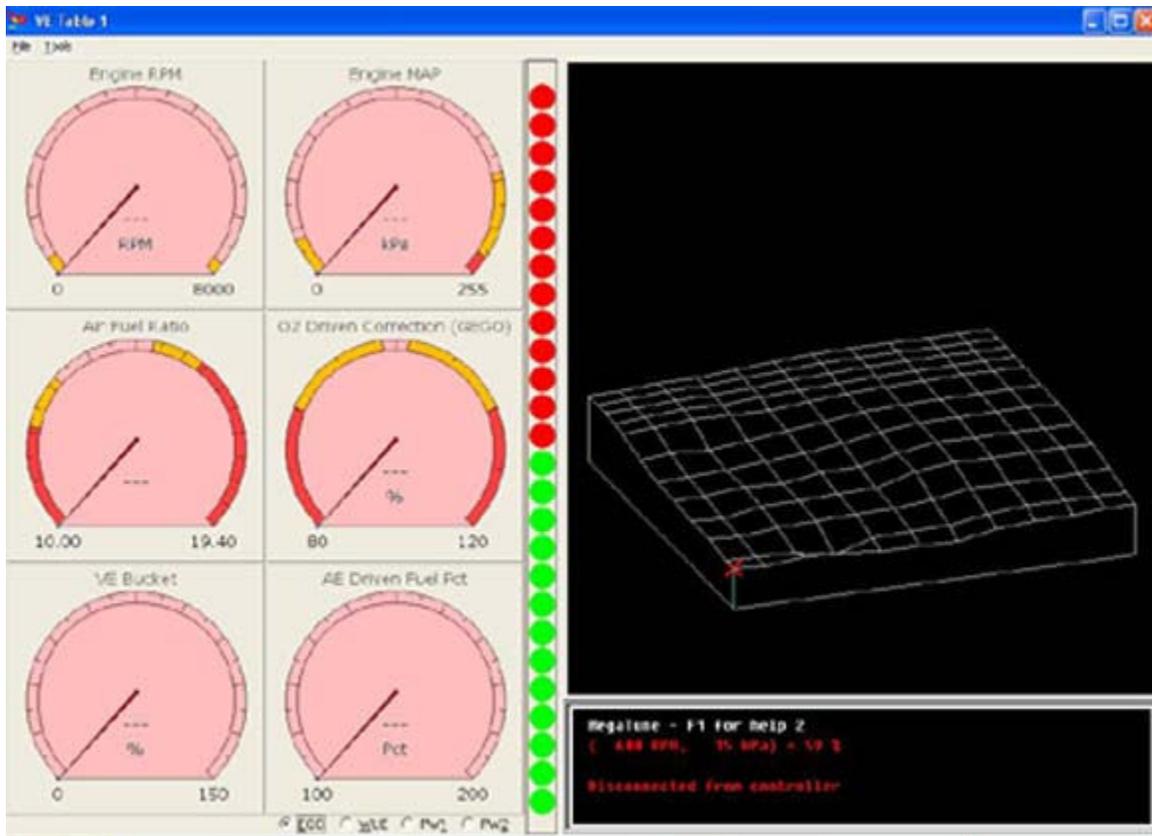
idle and cruise - lean	~stoichiometric - 14.7:1 AFR	WOT and acceleration - rich 12.5:1 -13.5:1 AFR	not normally seen
------------------------	------------------------------	--	-------------------

	100												
	95												
	90												
	80												
	75												
	65												
<b>KPA</b>	55												
or	45												
<b>TPS</b>	35												
	30												
	25												
	15												
		600	900	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
						<b>RPM</b>							

Having an O<sub>2</sub> sensor makes the driving part of the setting up much easier, as you can datalog and use MegaTweak to get the VE table set up with a few easy drives up and down the street, a bit more tuning, and you are ready to go a bit harder. You do not go harder if there are any problems [typically a backfire means too lean, sluggish revving

means too [rich]. Read the "Datalogging and MSTweak3000" section for more information.

Have someone ride with you and bring up the tuning page. See where the "Green dot" hangs around when you are under load - this is where you need to focus on tuning. Use the **up-arrow + shift** to richen the VE values - enrich (with increased VE number) the four corners around where the dot is - give each corner five up-arrow-shifts, and see if this helps. Turn off the O<sub>2</sub> closed-loop mode by setting the step size to zero. Watch the O<sub>2</sub> gauge on the tuning page and use this as feedback for rich and lean. The O<sub>2</sub> gauge may move to fast from rich to lean to be able to tune. Another strategy that works is to turn on EGO correction, and then tune using the EGO correction gauge rather than the EGO voltage gauge. If correction is below 100%, then raise VE to raise correction and so on.



Basically, the strategy for tuning with an oxygen sensor is:

- If you're driving around tuning "real-time" with a laptop, then turn the EGO off (step size=0). This means you are directly affecting the fuel, so that the changes you make to the VE table are adjusting the fueling immediately. Otherwise the EGO can be pulling the injector pulse width back to some value, and not allowing your changes to have any effect (until you exceed the EGO authority range [EGO ± limit (%)], at which point it will Probably run poorly.

- However, if you are trying to create a datalog to feed to MSLVV or VEXME, then turn the EGO feedback on (say step size ≈3%, limit≈30%, ignition events=8), so that you generate lots of crossover points. Don't tune the VE table at all while you do this, just drive it There is more on this [below](#).

If you have a "strip-only" vehicle, an EGO feedback is less useful. Some tuning hints are:

- Watch for increases in trap speed, this will be an indication of increasing power (under similar conditions),
- Cut the ignition at the end of the run, and coast down to a stop, then check the color/condition of the spark plugs. This can be a pretty good indication of the AFR (light tan is best with gasoline),
- Start rich and work towards lean very carefully (your O<sub>2</sub> sensor, if you have one, should always read rich during the run, at least 0.80 volts for a narrow band),
- If you experience detonation, or the engine backfires at all, you are probably too lean,
- If you can, have someone watch the exhaust during a run (from the sidelines) - there should not be big clouds of black smoke. If there is, you are probably too rich,
- Try to keep the VE table reasonably smooth.

### ***Tuning with Alpha-N (TPS rather than MAP)***

EMSpro can be converted from speed-density to use RPM , temperature and TPS only. This is called "***Alpha-N***". Alpha-N uses only the throttle position and RPM to calculate the amount of fuel to inject as opposed to using the manifold absolute pressure and RPM to calculate the amount of fuel to inject.

**With a boosted engine using Alpha\_N, you MUST use the Hybrid\_Alpha\_N setting (See Advanced Settings) with Mega squirt, because the throttle position bears little relationship to the amount of air going into the engine. Alpha-N is for naturally aspirated engines ONLY, the Hybrid Alpha-N adds the MAP value into the fueling algorithm, (obviously the map sensor will need to be connected to the inlet manifold) so fueling is increased with boost pressure.**

***Please Note: There is no extra table or any other settings other than selecting the option in Advanced Settings. It is simply used to add the MAP value to the equation. To use Hybrid Alpha\_N simply set your Constants - Control Algorithm as Alpha\_N and set the ini file in MegaTune as Alpha\_N. Hybrid can then be used if it's set in Advanced settings.***

***Hybrid Alpha-N =***

**PW = REQ\_FUEL \* VE \* TPS \* MAP \* E + accel + Injector\_open\_time**

***Normal Alpha-N =***

$$\text{PW} = \text{REQ\_FUEL} * \text{VE} * \text{TPS} * \text{E} + \text{accel} + \text{Injector\_open\_time}$$

Alpha-N is useful for long duration cams where the resolution of manifold air pressure (map) would be small. It is also useful to get smoother idle on engines that have erratic map values. It can also be helpful for ITB setups when atmosphere is reached very quickly under light throttle openings.

For example: On a flat part of the torque curve, going from half to  $\frac{3}{4}$  throttle might not require the value to change in the VE map on speed-density if the air/fuel ratio is the same for the 2 loads as the change in MAP will do this. On the alpha-N system the map bins will be different as this is the only way the EMSpro can find out about the higher fuel demand.

In Alpha-N mode MS still makes O2 corrections (i.e. runs 'closed loop'), if you have it enabled.

One thing you have to always remember with alpha-N that you don't actually know where the effective WOT is anymore (i.e., when you have enough throttle that opening it further doesn't affect the amount of air being ingested). At low RPM WOT could be only 20% throttle.

As an aside in the MSnS\_Extra embedded code the fuel equation (minus the enrichments and open/close time) looks like:

$$\text{PW} = \text{Req\_Fuel} * \text{VE}(\text{tps}, \text{rpm})$$

as opposed to the MS B+G V3..xxx codes, which looked like this:

$$\text{PW} = \text{Req\_Fuel} * \text{tps} * \text{VE}(\text{tps}, \text{rpm})$$

Note the extra factor of TPS (in red) is not in the MSnS\_Extra code.

Tuning with alpha-N is much the same as speed-density, except you no longer have an input for load. What this means is that you don't really know what full throttle is at the low and mid RPM ranges. For example, at 2000 RPM, 20% throttle might flow all the air the engine needs. So the usable area of the table will end up looking a bit like a triangle. The table itself will be actual fuel rather than a VE multiplier.

Please Note: In Megatune the TPS scale is the RAW data from the TPS, so its scale is 0 to 255 (0-5V). In order to find the scale of your TPS, go to Tools, Calibrate TPS, and with your foot completely OFF the throttle hit Get Current. Remember this value (e.g. 33). Put your foot flat to the floor on the accelerator (engine not running!!) and hit Get Current on the Calibrate TPS dialog, remember this value too (e.g. 225). This is the scale of your TPS and should be the first and last entry in the load scale of the VE table.

The tricky part with tuning alpha-N is working out where the effective WOT is. It is a very non-linear relationship and depends critically on the sizing of the throttle body.

Also, with alpha-N, the final fuel pulse is a simple product of the VE table entry and enrichments, so your VE table is far more critical than in speed-density mode.

If you are running alpha-N, disable closed loop operation until you have a good handle on where the effective WOT is. If you still have a MAP line connected you can (and should) log map to give you an idea of where full throttle is across the rev range.

If you are going to have varying loads, or are going to tow with your EMSpro managed vehicle, and you have good vacuum at idle and a good vacuum range, then go with speed-density because it reacts to changes in load a lot better than Alpha-N.

Alpha-N does have legitimate uses, and one would be an engine with a small intake vacuum range and a poor vacuum at idle. A strip/drag vehicle where there will be small changes in load and it'll see most of its use at WOT might benefit from alpha-N.

In alpha-N, if you use barometric correction, it will look at the pressure at first power up and set the offset from that value. Otherwise if baro correction is off it does not use the map sensor at all.

Alpha-N still uses the temperature sensor to increase or decrease the fueling based on the ambient air temperature.

Even if you only plan to use alpha-N in your EMSpro, it is a good idea to build up the complete board. Use all the sensors. If you do not use liquid cooling and do not want cold start enrichment, hang the sensor in the air. Set the warm up bins to 100% across the board. Place the intake air temperature sensor in the intake or as close to the incoming air as possible. That way you have all the hardware and the board will operate properly. You can turn off almost any thing in EMSpro by placing the key values out of range.

### ***Idle Pulse Width***

You have to select your injectors based on the maximum horsepower your engine can produce to prevent the engine from running lean at wide open throttle. But why not just pick the biggest ones you can find?

The answer has to do with idle and cruise pulse widths. If you use very large injectors, your idle pulse widths get very short. This can drastically reduce the mixture ratio control that you have during idle and cruise situations, and lead to very poor drivability and seemingly strange tuning behavior.

To illustrate, suppose you have established that your engine produces the lowest MAP reading at an idle pulse widths of 1.2 milliseconds, and your opening time is 1.0

milliseconds (considered the 'standard opening time'). Recall that EMSpro can only change fuel by 0.1 milliseconds at a time.

And also recall that EMSpro assumes NO fuel is injected during opening (which is close to true, since the injectors remain closed until the coils charge, then they snap open at the end of the opening time). Now if the net effect of the enrichments change by 2%, the pulse widths don't change at all. Even if they change by 49%, nothing changes. But once they change by 50%, the pulse widths suddenly change to 1.3 seconds.

So the next leaner possibility is 1.1 seconds, and the next richer is 1.3 seconds. However 1.3 milliseconds is not  $1.3/1.2 \times 100\% = 8.3\%$  richer, instead it is  $(1.3-1.0)/(1.2-1.0) = 50\%$  richer! The mixture becomes very, very rich, and the engine runs poorly.

To confuse your tuning efforts further, it may be that you are already near a threshold, so that a small change in one parameter makes a very big change in the air/fuel ratio in one direction, but no difference at all in the other direction!

But doesn't the EGO correct? Actually, it can't. Even if you set the step size to 1%, nothing happens until the 50% (i.e. 1.3 milliseconds) threshold is reached. That is, the step size only takes effect once the 0.1 threshold of PW is reached. And if the number of ignition events between steps is large, the engine may stumble and die before it recovers and leans out. So in fact you may be better to set the O<sub>2</sub> step high (50%), and the number of ignition events low (say 2) so that the average over just a few injections is correct. It is a band-aid approach, however, and likely to induce ignition related problems.

Obviously the converse is true if the engine goes lean. It has to go at least  $(1.1-1.0)/(1.2-1.0)=50\%$  lean before anything happens. If does go lean, it may back fire and die before it gets a chance to become richer.

You might think you can get around this by decreasing the injector opening time (to get a larger "adjustable time") and increasing the VE (or req\_fuel), but that doesn't work because the 'ideal' injection time is still 1.2 seconds, and the permissible step is still 0.1msec, regardless of the way you add the components of the pulse width up.

And making matters worse is the fact that many high-performance engines will want even lower pulse widths at cruise than at idle, compounding the tuning problems and introducing more drivability issues. A system with a very short pulse widths like this will be difficult to tune. It will appear not to respond at all to enrichments over a certain range of a parameter (say IAT), then suddenly it will seem to change so drastically that you seem to require an entire new set tuning values.

Now even if your engine idles perfectly at a very low pulse widths, changing load, speed, and other variable (EGO, IAT, etc.) will demand slightly different air/fuel ratios. However, none of them are likely to need exactly the  $\pm 50\%$  you have to choose from!

This is why several aftermarket ECU manufacturers recommend an idle pulse widths of not lower than 1.7 milliseconds. If yours is lower than this, you need to address it before you will be able to tune your engine for all operating conditions. Ultimately the best solutions are appropriately sized injectors or staged injectors.

## **Datalogging**

Datalogging allows you to create a running record of the EMSpro real-time variables. Once you have enabled datalogging (by clicking on the Datalog menu item on the File list), MegaTune polls the EMSpro controller when any of the front page, runtime display or tuning page are active, and writes this data to a file. The file has a comma-separated value format and defaults to having an extension of “.xls”, so Microsoft Excel will open them automatically.

When datalogging is enabled, the second status box (bottom right corner) contains a bold “LOGGING” indicator. The rightmost indicator contains either grayed-out “CONNECTED”, meaning that MegaTune is not communicating with EMSpro, dark “CONNECTED”, indicating that MegaTune and EMSpro communications is working properly, or dark “RESET n”, indicating that the EMSpro controller has been erroneously re-booted n times since MegaTune started talking to it.

Note: the **Logging** option under the *Communications* menu is a different function, and does not need to be selected to enable datalogging of the real time variables. See the MegaTune help menu for details on the Comm. Logging function. If you can drive the car at all, start datalogging. Look through the log and MAP-RPM pairs that are near grid points in your VE map, when they O<sub>2</sub> sensor reading is significantly below 0.500 (say 0.014), jack up the VE at that point by 10%. When the O<sub>2</sub> sensor is significantly above 0.500 (say 0.825) then drop it down by 10%. A couple runs around the block should get things running pretty well.

The critical settings are O<sub>2</sub> step% and ignition events per step.

- When tuning anything in the lower RPM range (1000-3000 rpm) set the **EGO step (%) = 1** and **ignition events per step = 32** (2000 rpm with a V6 = 100 events per second = about 3% change in a second).
- Then when tuning the higher RPMs with a rough map; **EGO step (%) = 3** and **Ignition events per step = 64** (about 3.5 changes per second at 4500 rpm).
- When the map is tuned better set the **EGO step (%) = 1** and **ignition events per step = 72** which gives the closed loop control some more stability and allows for better fine tuning at the higher RPMs.

For fine-tuning, keep the O<sub>2</sub> adjustments per second between 3 and 5. For roughing in VE maps, set the O<sub>2</sub> adjustments between 5 and 10 per second (depending on how good the O<sub>2</sub> sensor is, if it is old, go lower).

Once the map is tuned in, set the:

- **EGO ± limit (%) = 5%** (it can go higher depending on how questionable the map is)
- **EGO step (%) = 1**, and
- ignition events to a value that would switch about 4x a second at your average cruising speed.

You can calculate your:

$$\text{O}_2 \text{ adjustments per second} = ((\text{rpm}/120) * \text{cylinders}) / \text{ignition events per step}$$

Note that the datalog includes an 'EngineBit' field. This bit will tell you if the engine was accelerating, warming-up, etc., and can be used to sort unsuitable data lines (because O<sub>2</sub> correction is not active under acceleration, warm-up, etc.) from the file.

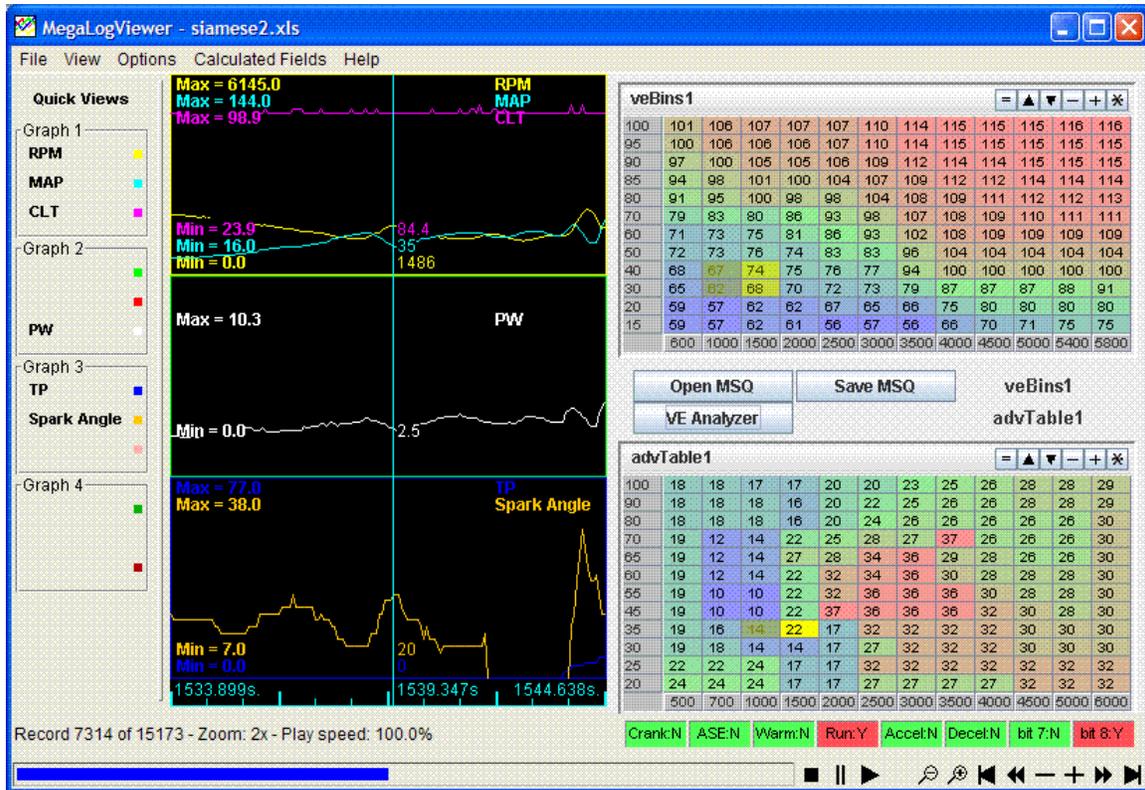
The engine bit has 6 binary bits. The rightmost bit represents running. It is 1 if running, zero if not running, so 000001 = 1 or 000000 = 0. The next rightmost value is for cranking, 000010 = 2 if cranking. Note that an engine is never both running and cranking, so you should never see 000011 = 3. The fields are:

Binary Bit	Decimal	Meaning
00000X	1	Running
0000X0	2	Cranking
000X00	4	Start-Up enrich
00X000	8	Warm-Up enrich
0X0000	16	TPS accel enrich
X00000	32	TPS decel

Note that the only suitable value for reading O<sub>2</sub> sensor values is when the engine bit is equal to 1 (i.e. running and no enrichments).

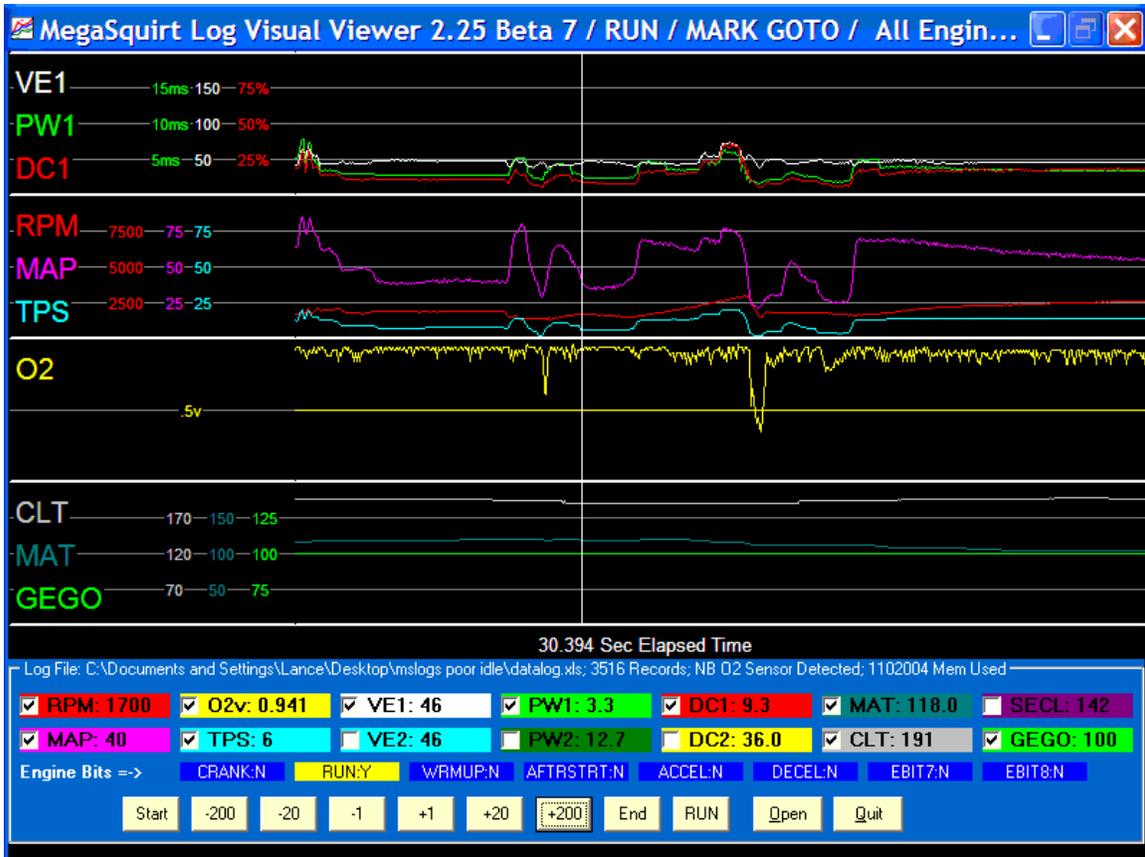
You can view your datalog files in graphical form using Megalog Viewer by Phil Tobin. This can be set for either narrow-band or wide-band oxygen sensor readings. Megalog Viewer is very configurable so it is highly recommended for the MSnS-Extra code. Using this viewer, you can see the trends in your datalog, and spot trouble areas more easily than viewing the numbers in a spreadsheet or punching the log through VEXME or MSTweak. When using Megalog Viewer the VE table and the spark table can be loaded into the screen, this makes tuning and reviewing the log much easier, as the running area of the log that you're looking at is highlighted in the tables, (see the yellow highlights) so it is easy to see where you need to adjust the maps. Adjustment of the tables is easy too, as

there are buttons to increment / decrement the values directly. The file can then be saved ready to be loaded into the ECU via Megatune. This program is well worth a look and is highly recommended for all to try, as it can make tuning a lot easier!

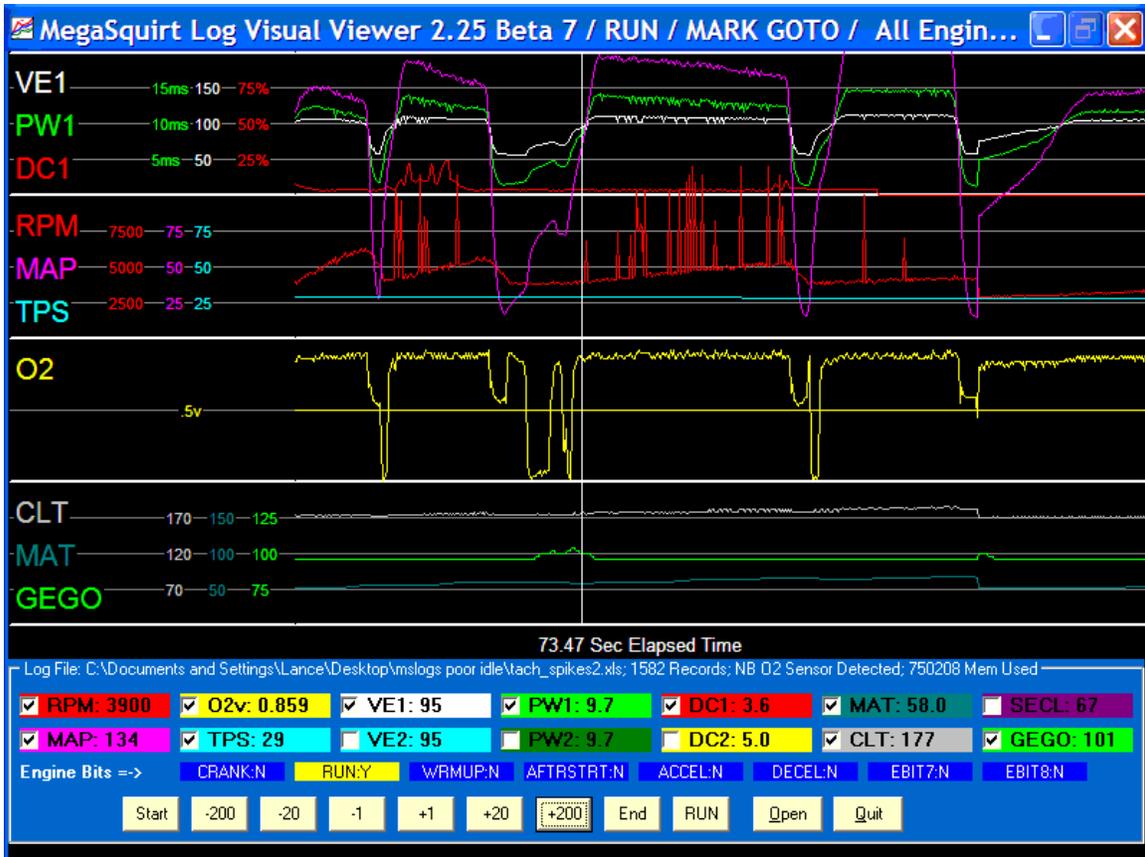


### Using Datalogs for Tuning and Troubleshooting

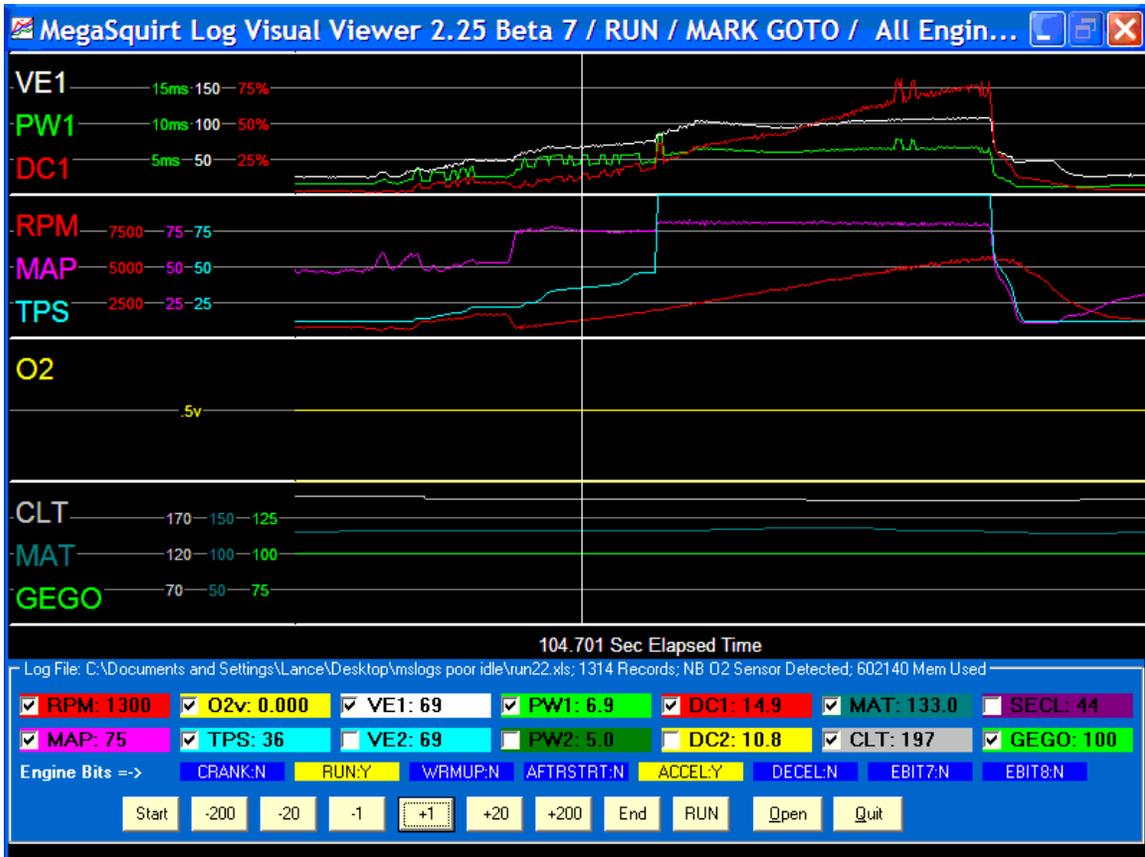
Below are some screen shots of MSLV showing datalogs with various diagnostic conditions, these can be seen in a similar fashion using [Megalog Viewer](#) too.



Above is an example of a good datalog. The sensors are all responding, and the MAP and RPM go up when the throttle is pressed, and not otherwise.



Above is a datalog showing the classic tach spikes. You can see that the RPM appears to rise very high, with the TPS seeming to be opened at all. The person tuning this engine has made the best of it by minimizing the accel enrichments (otherwise the pulse width and duty cycle would also rise very high), but the better solution is to fix the tach signal. There are hints on how to do this [here](#).

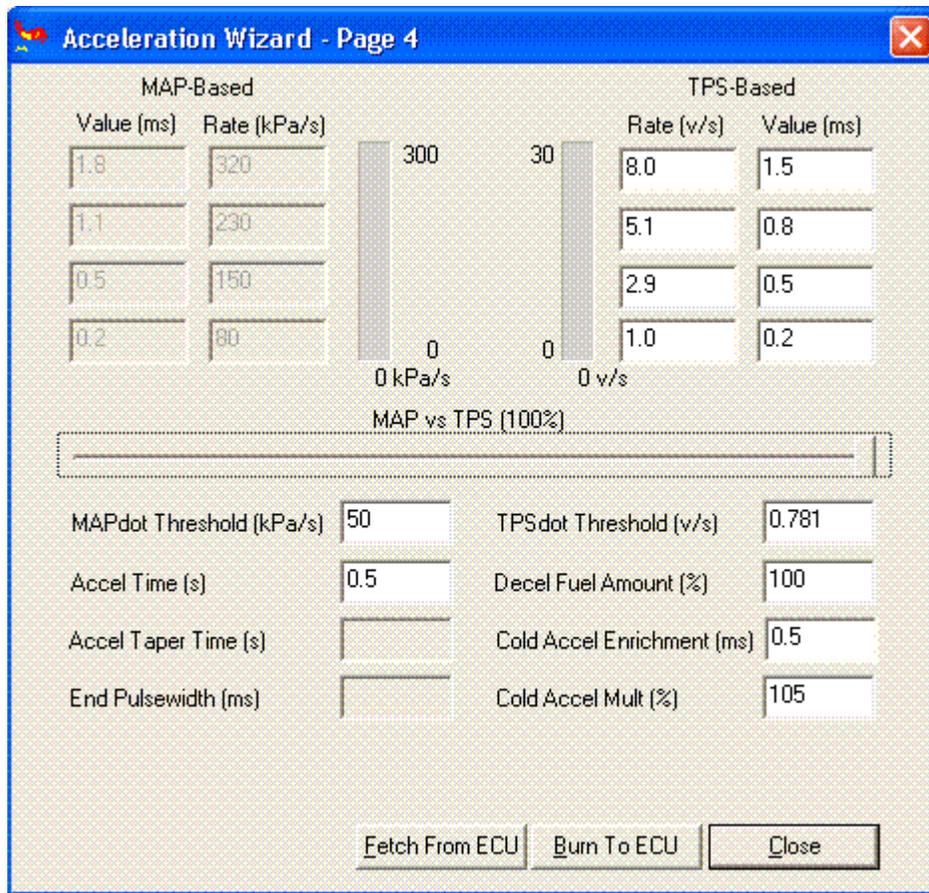


Above is an example of what happens when the TPSdot parameter is set too small (under ~1.0 is considered small). The usual amount of 'noise' in most TPS signals triggers the accel enrichment, and greatly increases the pulse width. The result is a very rich mixture and a poorly running engine that doesn't respond well to tuning. The solution is to increase the TPSdot parameter to 1.0 to 2.0.

## Setting the Acceleration Enrichments

After you have the VE table dialed in, or if you have drivability problems initially, then start adjusting the acceleration enrichment. A need for Acceleration Enrichment can be felt by the driver as a sudden total drop in power after application of the throttle. Too much or too little AE can have the same feel. Turning on the AE Driven Pct Gauge and watch for bout 150% at low rpm and about 5% at higher rpm. The goal is a consistent AFR as the throttle is applied.

The first thing to do is to ensure RPM Based Accel is not on, as this is for highly-strung engines. Go into "RPM BASED ACCEL" and set it to Normal Based AE\*^ . The next thing to set is your **TPSdot threshold (V/s)** or **MAPdot threshold (KPa/S)**, try setting it to **MAPdot** first then if your not happy try **TPSdot**, this is in the Acceleration Wizard.



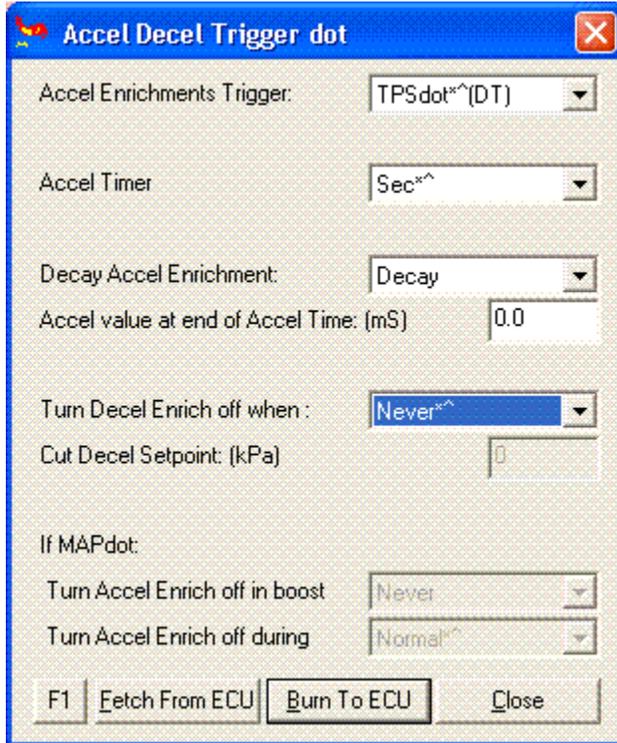
The **TPS/MAPdot threshold** setting determines the rate at which acceleration enrichment begins. If you set it too high, no accel enrichments will be applied, and the engine may respond poorly, backfiring or coughing under sudden throttle movements. If you set it too low, however, you may have inadvertent enrichment triggered by noise on the TPS signal. In general, use a setting between 0.5 and 2.00 (MegaTune may round these number slightly) - start with 1.00 unless you have a reason to do otherwise (it will be rounded to 0.977, which is fine). If using MAPdot then try 50-80KPa/S. I usually find 0.5V/S or 30-40KPa/S end up being the best settings for the dot threshold once everything is tuned.

The **value (ms)** is the additional fuel added in ms.

The **Rate** is the speed of throttle application.

*Be careful when setting the MAPdot or TPSdot Threshold, that the Enrichment doesn't cut in when the engine is idling or cruising due to setting the threshold being set too small. If AE cuts in during cruise or idle or at any time other than when your accelerating then the engine will feel sluggish and bog down, at idle the engine can stall or hunt due to AE cutting in. Looking at the datalogs in one of the viewer programs can check this.*

Other settings for Acceleration Enrichment can be found under "Accel Decel Mode"



The **Accel Timer** can be changed from Seconds to Engine Cycle counts. Note that a value of 0.3 could mean 0.3 seconds or 3 ignition pulses. The Cycles option is useful because the enrichment will reduce at higher rpms

By setting **Decay Accel Enrichment** to **Decay** the code will start by adding the usual amount of additional fuel set in the **Value mS** then it will linearly decrease this amount until the added fuel is the same as the **Accel value at end of Accel Time**. The **Accel value at end of Accel Time** value is reached by the end of the Accel Time. This gives it a more realistic fueling characteristic that should follow the requirements that the engine needs. (0.0 - 0.5mS is the normal setting here.)

If in **MAPdot** mode then you can turn off the accel/decel enrichment when the engine goes into boost.

You can also turn just the **Decel** off in either mode when in Boost, this is to prevent the ECU cutting fuel down (using the Decel) by you simply easing off the accelerator a little when in boost.

One of the reasons that there isn't a "magic formula" for accel tuning is that it really is a "feel" and "driving style" sort of thing. And it depends critically on your state of tune for the VE table, warm-up enrichments, manifolding, idle and cruise speed and AFR, TBI vs. port, injector flow rate, and a million other things.

In a nutshell, too much accel enrichment produces a sluggish throttle, too little accel enrichment produces backfires in the intake manifold. Way too much AE feels just like too little.

The best way to get a rough accel tune is to "blip" the throttle with no load (at different rates, but you have to guess which bin was active), and adjust the accel bins for the best throttle response (and this will also depend on the decel amount).

The more rapidly you can get the engine to rev and recover, the better your accel/decel enrichments. If they are really tuned in, you should be able to rev the engine repeatedly, with the engine responding 'crisply' every time.

You may want to try a short **Accel Time** (like 0.2 ms) and jack up the accel enrichment bins.

A **Decel Fuel Amount (%)** setting of 100% means no cut. 1% means **reduce** the pulse width by 99%, to 1% of what it normally would be. Start with 100% and tune this by watching the O2 sensors reading. (generally a value of 70-90% is best here) The low MAP part of your VE table is probably a touch lean, so the NB sensor drops below stoichiometric. If the car does not buck too hard, you are close to correct settings. If it bucks and stumbles, then it is going too lean and you need to richen that part of the table.

Before tuning decel [or accel], try to make sure you have your VE table close to correct first. To get the VE table set up, set the TPSdot / MAPdot setting very high (30v/s or 3000KPa/S or something like that) so that **enrich/decel** never kicks in. Then, (in steady state) set up VE table. If the vehicle is not drivable without tuning the accel enrichments, by all means do it, but be sure to revisit the accel tuning as you tune your VE table.

To adjust the bins, start with something like:

TPSdot Bin	MAPdot Bin	Start tuning at (ms)
<b>15 Volt/second</b> (idle to WOT in 2.5 seconds)	<b>800KPa/second</b>	5.1
<b>8 V/S</b>	<b>300KPa/S</b>	2.5
<b>4 V/S</b>	<b>100KPa/S</b>	1.1
<b>1 V/S</b> (idle to WOT in 3/10 sec.)	<b>40KPa/S</b>	0.3

**Some more Accel Enrichment Details**

There is a lot of confusion regarding the tuning of Acceleration Enrichment in the MegaSquirt family of programs. It is far easier to tune AE if you understand the underling causes and effects. For more info see this text file [HERE](#).

## RPM Based Acceleration Enrichment

RPM Based Accel

RPM Based Accel is triggered as usual via MAP or TPS but it is NOT based on a rate of change of MAP or TPS. The fuel added is based on the engine's RPM.

RPM Based Accel Enrichment:

Engine Speed high (RPM)	<input type="text" value="4400"/>
Engine Speed mid - high (RPM)	<input type="text" value="3500"/>
Engine Speed low - mid (RPM)	<input type="text" value="2000"/>
Engine Speed low (RPM)	<input type="text" value="800"/>
Enrichment for high speed: (mS)	<input type="text" value="0.2"/>
Enrichment for mid - high speed: (mS)	<input type="text" value="0.4"/>
Enrichment for low - mid speed: (mS)	<input type="text" value="0.7"/>
Enrichment for low speed: (mS)	<input type="text" value="1.0"/>
MAP Threshold: (kPa/s)	<input type="text" value="50"/>
TPS Threshold: (v/s)	<input type="text" value="0.781"/>
Accel Time: (ms)	<input type="text" value="0.5"/>

THIS OPTION IS USED FOR A VERY SPECIALISED INSTALL!! 90% of installs will not need this option.

This is triggered via a rate of change of TPS or MAP BUT the enrichment is based on how fast the engine is running.

The MAP and TPS based Accel enrichment bins in the **Accel Wizard** will be ignored in this mode. This is often required with high-strung small displacement MOTORS and race motors. The Trigger threshold values will still be current as this is still when the AE cuts in. The **Threshold** values and **Accel time** are doubled up on this setting box and are the same as on the AE Wizard.

### Tuning the RPM Based AE

Tuning is a fairly simple procedure. As with all MS installs, the very first thing to do is sort out ALL input signals to the Squirt. IAT, CLT, RPM, MAF if installed, TPS and MAP signals must be all very stable. The goal of all of these AE methods is to have a

very flat AFR during all transitions of the throttle. Once perfected, the motor will be very smooth throughout the entire power band including throttle stabs, shifts and throttle roll-ons. I always try to run MAPDot if I have a reasonable idle MAP to work with.

This all assumes that you have a tuned VE map. If using RPM based AE, start by setting the lowest of the four bins close to the RPM that your motor idles at. Say 800 RPM. The next cell to set is the highest RPM bin. This is the highest that you are likely to ever activate AE, say 80% of your redline. This should be close to the RPM that your motor drops to after a 3-4 shift. The two other RPM settings should be evenly spaced from the two extremes. For our example 800, 2000, 3000 and 4500 RPM. The second RPM number is where your motor will most likely need the greatest amount of AE in terms of total ms and percent on the AE Driven Fuel Percent gauge. I normally tune the base AE settings by getting on a stim and temporarily set the AE time to 2 sec and the decay to No Decay. Note that you will need to guess the MAP at say 85 KPA for this test. I use a syringe to apply 85 KPA to the Squirt. Play with the ms of AE numbers until from the lowest RPM thru the second RPM setting get close to a flat 150% AE through this range. The 150% is just a guess on my part but it is a place to start. Now go to the third RPM with the stim and set the third ms of AE to get about 115% Next go to the highest RPM and set the highest ms to get about 103% on the gauge. Set the AE time to .7 sec and the decay back on. If you do not own a stim then the numbers can be guessed at. Now start data logging, drive the car locked in second gear and put the motor at 2000 RPM, stab the throttle and have a friend watch the o2 gauge and the AE driven Fuel Percent. Play with the time and ms of the second RPM cell till you get good throttle response and most likely the best response will be when the o2 remains close to about stoich or a little richer. Lean holes are never the correct answer. Now try applying the throttle with a lighter stab. This ends up a compromise. Once a balance is set go to the third RPM and play with just the ms of the third cell to get good response. The highest RPM cell will be for high RPM (redline) shifts. Last go to idle and tune the ms of the lowest cell to get a reasonable off idle response from the motor. Note that as the RPM climbs, the AE will get stepped down by either the timer and the decay function or slammed down by the rising RPM.

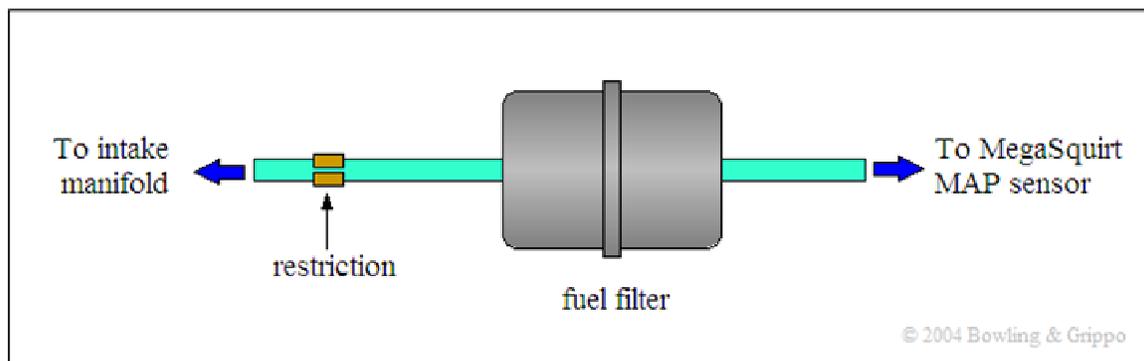
## ***Tuning Issues***

If you have a very long duration cam in your motor, and it idles poorly, you might be able to get it to idle better through careful tuning with MegaSquirt. Often a rough idle may be caused by lean air/fuel ratios. This is really is more of a cam issue than a fueling issue. The exhaust valve is held open later into the intake stroke and the intake opens earlier near the end of the exhaust stroke. At low speeds and relatively high intake vacuum you get more exhaust contamination of the fresh air/fuel charge. As you get more contamination of the air/fuel charge you typically need a richer mixture to get it to ignite and burn properly.

This means you probably cannot run a stoichiometric [chemically correct] mixture of 14.7:1 with your long duration cam. You need to run richer. So you tune your idle by ear rather than with a narrow band EGO [oxygen] sensor. And make sure you are not

allowing EGO correction at idle if you have a rowdy cam! It will be trying to “correct” your mixture back to a lousy idle. If your engine will not idle well at stoichiometric mixtures, set the EGO Active Above RPM to a few hundred RPM above your idle speed. This will ensure that MegaSquirt does not try to lean the mixture back to stoichiometric to compensate for your adjustments. Remember that O2 sensors give wrong readings on a misfiring engine, big cams drive O2's nuts at idle too, so don't rely on their readings at idle.

Another tip you can try if you have a large overlap cam is to pinch off the MAP hose slightly while the engine is idling, and see if the idle quality improves. If so, then try a restriction in the MAP vacuum line. This has the effect of damping the vacuum pulses that the MAP sensor sees. Start with a  $\sim 0.040$ " (1.0mm) hole in the line. You may have to experiment with restrictor sizes to see what works best for your system.



A few more things to try:

- 1) Check your VE table entries near the idle point - if the RPM or MAP fluctuates, then you can get rolling idle, etc. You may have to move some of the bins around to bracket the idle RPM/MAP region, and keep flat VE values within this.
- 2) If you run low-impedance injectors, you need to tune your PWM current limit. Start with 75% PWM and 1.0 millisecond time threshold. Once you get idling, then first adjust the PWM duty cycle down until you notice a change in idle quality, then move the value back up 3 - 5%. Do the same with the time threshold. On the car it is very easy to do and only takes a few minutes. And, at idle, the overall injector pulse widths are small compared to their close time, so this will allow you to adjust the values. In other words, adjust the PWM current limit before taking the car out on the street where injector pulse widths become high.

Your engine will idle at a certain vacuum. It might help on a street use motor on the VE map to use a lower point for starting MAP than idle vacuum. For example you can have yours set at 20 even though you idle at 27 or so. This allows you to run less fuel on overrun deceleration and coast events (not just for a second like the TPS will do). This

allows you a saving of 3-4 MPG on average driving and you might be able to run more advanced timing under this vacuum.

On the other hand, you may want to do the opposite. You can increase the VE values just to the left and above idle. You can make them really rich [say double the idle VE value, to keep the car from stalling. This seems to work really well, if the engine starts to stumble, the pulse width goes up and it recovers.

By working with the RPM and MAP bins, you should be able to work out a set of values that lets you run lean at cruise and decel [where the RPM is above idle, and MAP below idle], but rich when stalling [RPM below idle].

On the warm up enrichments page, the warm up enrichment only goes to 160° F. The 160° F bin value of the enrichment (which should ideally be 100%) is used at all temperatures above 160° F, so it is important to ensure that 100% is entered in there.

The system compensates automatically for any amount of idle solenoid bypass air because of the effect it has on the MAP value [i.e. the vacuum in the manifold is lowered by the bypass air, this is sensed by the Manifold Absolute Pressure sensor, and the processor decides to inject more fuel. The effect is exactly the same as if you had cracked open the throttle a bit. The fuel goes around the throttle plates, which are never truly closed. They are set at the opening required for the slowest throttle speed desired for the engine under optimal conditions, which leave plenty of room for the fuel to get by. The fast idle air then adds to this baseline amount of air to raise the idle speed. In some circumstances, you may want to run without oxygen sensor feedback, called "open loop". The best way of forcing MegaSquirt to run open loop is to change the O<sub>2</sub> sensor step to 0 [zero] on the enrichments page. It will still log the O<sub>2</sub> voltage, but not do anything about it.

The MegaSquirt Fuel Pump output is programmed with a priming pulse option to shut off the unit in case of an engine stall, etc. It can turn on the pump immediately when the power is applied and shuts it off 2 seconds later if the engine is not running. Go into "Cranking Settings"

**PRIME PUMP WHEN** - Values for this item are either Prime Pulse > 0 or Always. If you select the first option, the pump will only be primed if the priming pulsewidth setting is greater than zero. If you select the latter option, Always, the pump will be primed regardless of your priming pulsewidth. You will most likely want to use Always as it will get your fuel pressure up before cranking, but you don't necessarily have to inject any fuel. The priming period is two seconds.

**FIRE PRIMING PULSE** - The **Fire Priming Pulse** option allows you to select when a priming pulse is fired. If you select **Power Up**, a priming pulse will be fired immediately upon turning on the ignition. If you select **Twice**, one priming pulse will be fired when you first key the ignition on and the second pulse will be fired after a second has passed.

If you select After 2 Secs, there will be one priming pulse two seconds after turning on the ignition.

The first option was in the original stock code, however, it will not necessarily work for a cold-start because there may not already be fuel pressure in the rail when you turn the ignition on. The other two options are just different methods of firing the priming pulse. If you select **Twice**, then there will most likely be no fuel injected on the first pulse, unless there is already fuel pressure in the fuel rail, and then there should be fuel injected on the next pulse. If you select the After 2 Secs option, it will give the fuel pump time to build up pressure. With that option, however, remember that if you try and start the car before allowing two seconds to elapse, no priming pulse will ever be injected.

When you start cranking, the pump comes on, and times out two seconds after the last pulse on the tach signal.

If your MegaTune displays bizarre values for the barometer on the runtime display, 76 kPa, for example, you may be resetting while running. MegaTune has a check that detects most resets by watching the seconds value. If the seconds goes to zero from any value other than 255, then it signals a reset with an audible “beep” and sets a counter visible on the lower right corner of the screen, where it normally says "connected".

As well, you can check the datalog seconds count - make sure it counts up to 255, and then rolls over to zero and continues again and again. If you get shorter counts (like say 56 then a roll over) then the processor is resetting. Note that most of the time on the car you will not notice that the reset has occurred because it happens so fast. What happens when the engine has a running reset (when the engine is running and the processor resets), then it grabs the barometer near the beginning of the MegaSquirt processor boot procedure. If the engine is running, then it will grab engine vacuum and use this for barometer. See [HERE](#) for ways to get around this problem in the settings.

For normal operation the processor comes up so fast that it has grabbed the MAP value before the engine has a chance to start cranking, much less running.

## ***Tuning for Economy***

To get maximum fuel economy, you want the engine to run as slowly as you can (hence the proliferation of overdrive transmissions in the last 15 years), and to run an Air/Fuel ratio (AFR) of about *14.7:1* to *17:1*.

To tune for economy with a wide band oxygen sensor is relatively easy. Look up the sensor output at *~16.5:1* for your sensor (*~2.65* volts for the DIY-WBO<sub>2</sub>, for example). Put that value as your EGO trigger point in MegaTune, and if your EGO  $\pm$  Limit (%) is sufficient (given the state of tune of your VE table), you should be getting good economy.

You can try mixtures leaner than  $16.5:1$ , however you may get a lean 'surge' that feels like someone is pushing the car forwards, then pulling it backwards. Generally, this is a sign that you are too lean.

With a narrow band, it's a bit tougher to set it for maximum economy. You can adjust the VE table, but the EGO correction tries to bring it back to a stoichiometric AFR.

You could raise your EGO\_RPM\_limit to just above your cruise rpm, but depending on where that is, it might not be all that workable. A better method, if you have a narrow band oxygen sensor, is:

- first, get the VE table tuned with stoichiometric values around the 'cruise' rpm(s) and kPa(s).
- then recalculate the VE numbers around your cruise rpm and kPa to  $16.5:1$  **minus** 5%. For example, if you had a value of 56% (at stoich. AFR), you would replace it with:

$$\text{new VE} = \{56\% \times (14.7 \div 16.5)\} - 5\% = 45\%$$

- then set the **EGO  $\pm$  Limit (%)** to 5%.

Do this for all the values in the VE table you actually cruise at, but not the higher rpm, higher load areas of the VE table.

That keeps the EGO at  $16.5:1$  at cruise, but lets you set it anywhere else in the rest of the table.

## ***Tuning for Emissions***

To tune your engine for minimal emissions using the eMS-pro properly requires expensive test equipment. However, as a start, you can:

- Make sure your **ignition system is in good working condition** - a tune-up (distributor cap, rotor, wires, spark plugs, PCV, EGR, etc.) is a good idea before emissions testing,
- Make sure your engine is equipped with a **working catalytic converter(s)** if possible,
- Set your **EGO Switch Point** to **0.450 volts** for a narrow band sensor, stoichiometric for a wide band sensor (2.500 volts for the DIY-WBO<sub>2</sub> for example),
- **Retard** your ignition timing by  $\sim 5^\circ$  to  $10^\circ$  (this creates a hotter exhaust that prolongs the burn and also helps the catalytic converters to operate at peak efficiency),
- **Increase your idle speed** slightly - if it idles well at 750 rpm, but stumbles a bit if set lower, set it to about 950-1000 rpm,

- If you have an adjustable electric fan, **increase the fan 'ON' temperature** to about 200°F to 215°F,
- If you have an oiled 'lifetime' air filter, replace it with a **plain paper filter** for testing (the oil in the filter can drive up emissions),
- Make sure your **vehicle is fully warmed-up** before testing,

Here is an example of how a few changes affected one engine:

	Baseline	Timing Retarded 10°	Timing Advanced 10°	Mixture richened	Mixture leaned
<b>HC</b>	1.00	<b>0.78</b>	1.14	1.39	0.88
<b>CO</b>	14.5	11.6	13.0	81.0	<b>9.8</b>
<b>NO<sub>x</sub></b>	2.91	1.89	5.18	<b>0.71</b>	3.03
<b>O<sub>2</sub></b> Not usually tested	22.3	19.8	23.8	<b>17.4</b>	25.4
<b>CO<sub>2</sub></b> Not usually tested	305	307	298	<b>246</b>	310

You can see that retarding the timing and leaning the mixture slightly gives the best possible compromise, increasing only the NO<sub>x</sub> slightly among the regulated emissions. *(The above was without a catalytic converter. With a converter, emissions would have been best at stoichiometric mixtures and the timing retarded somewhat.)*

## **Spark Map Tuning**

Before tuning the spark table, ensure the **Trigger Angle** has been checked and set using a timing strobe.

Tuning the **spark map** may not seem the easiest thing in the world to do and it can be difficult to know where to start. Here is a base map that we enter into the code for you to start from.

The screenshot shows a software window titled "Ignition Advance Main Table" with a menu bar containing "File" and "Tools". The main area is a grid of ignition advance values in degrees. The vertical axis is labeled "kPa" and ranges from 140 down to 30. The horizontal axis is labeled "RPM" and ranges from 500 to 6400. The grid cells contain numerical values representing degrees of advance, with colors ranging from blue (low advance) to red (high advance). The values generally increase with RPM and decrease with kPa.

kPa	500	700	1300	2000	3000	4000	5000	6000	6100	6200	6300	6400
140	10	10	8	10	14	19	19	19	19	19	19	19
130	10	10	9	11	15	20	22	22	22	22	22	22
120	10	10	10	13	16	21	23	23	23	23	23	23
110	10	10	11	14	17	22	24	24	24	24	24	24
100	10	10	13	15	19	23	26	26	26	26	26	26
90	10	10	13	15	19	23	26	26	26	26	26	26
80	10	10	13	15	19	23	26	26	26	26	26	26
70	10	10	13	15	19	23	26	26	26	26	26	26
60	10	10	13	15	19	27	28	28	28	28	28	28
50	10	10	13	15	20	28	30	30	30	30	30	30
40	9	9	10	15	21	30	32	32	32	32	32	32
30	9	9	10	15	22	32	36	36	36	36	36	36

**Spark Map Tuning Basics** - The idea is that the idle and low speed area's are retarded to around 8-20deg, usually idle will be around 8-12deg, but this depends on your engine's design. If you set the first row in the RPM range as a little under your usual idle (e.g.600 if your engine idles at 800ish) and add some advance here, so if the engine stumbles into this area the slight increase in advance will help it to speed up a little so it doesn't stall. The cruising area of the map should have a reasonably high advance, (low to high 30's) as the mixture will be reasonably lean and therefore will give a slower burn. The overrun area can have an even greater advance, this will allow you to run lean in that section. At Wide Open Throttle (WOT) the spark map needs to be RPM based (analogous to centrifugal advance on an old style distributor) coming in at the right rate relative to engine RPM. Typically, you want it "all in" by about 2800-3200 RPMs for a street performance motor.

Note the optimum amount of total advance is not necessarily the most that doesn't cause detonation. For example, with a modern cylinder head design, you might get maximum power at 32°BTDC, but might not experience any detonation until 38°- 40°. However you will still want the advance to come in as quickly as possible (without knocking) up to 32°.

As the Kpa increases (load increase) the spark map should retard as the mixture will be richer and the chances of detonation will also increase with the load. When going into boost the advance table values will need to be lower than when out of boost (>100KPa = boost) and as the boost level increases the advance will need to decrease with it, as detonation is more likely. It has been said that 1deg of advance should be removed for every 2PSI of boost; this is simply a rough guide and lots of things can depend on how much to remove including compression ratio. Detonation Cans are a great option for

tuning in boost, use a piece of copper pipe flattened at one end with a flexible tube connected to it. Bolt the flattened end to the cylinder head. Get an old set of ear defenders and drill a hole into the side of them, push the other end or the tube into the hole you've just drilled in the defenders and you should be able to hear any detonation as it occurs.

***One thing to bear in mind is that altering the spark table WILL effect the AFR. So you will have to re-visit the VE table after tuning the spark table.***

If you experience detonation in your engine, then either:

\* Your mixture is too lean. Increase the numbers in the VE table at the point the engine detonates (or increase the Req\_Fuel if the detonation occurs at all points). Also make sure your fuel pump is operating well. It may be supplying enough fuel at idle, but not supplying enough when the demand rises. Use the oxygen sensor readings to determine if you are lean,

\* You have oil leakage into the combustion chamber (check the plugs for signs of oil). This could come past the rings or seals (possibly worn, or from something that was forgotten during assembly, or there are blocked drain back passages in the head, or the rings have been damaged by detonation or over-revving), a 'leaky' PVC system, or from a poor intake manifold gasket seal allowing oil into the runners (on push rod V-engines),

\* Your spark advance may come in too far and/or too fast. Edit the spark advance table to lower the rate at which advance is added. You may also need to limit the total advance. Most engines will not require more than  $\sim 36^\circ$  at WOT (possibly more for a flathead design, or a large open chamber, large piston dome design). Newer cylinder head designs and 4 valve/cylinders heads generally don't require a lot of advance,

\* You have spark plugs that are too hot (get a range or two colder), or they may be loose and over-heat due to poor thermal contact with the head),

\* Your thermostat is too hot (you can try as low as a 160°F thermostat for street use),

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Many thanks to Lance for giving us permission to edit and adapt his MS Manual for MSnS-Extra use.

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