MERLINS

EcuFLASH

VR4 & LEGNUM TT TUNING GUIDE

MITSUBISHI VR4 & LEGNUM turbo TUNING

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SECTION 1 – INTRODUCTION TO ECUFLASH TUNING

1.1-INTRODUCTION and ACKNOWLEDGMENTS

This tuning guide was written primarily for the VR4 and LEGNUM community and my own amusement and use. There was clearly a need for a comprehensive document that described what engine parameters EcuFLASH can tune , and how to do it. Sitting alongside EcuFLASH is an equally important and useful program, called EvoScan. This program is used to log what is going on inside the ECU. Pretty-much all the useful engine parameters can be logged and this write-up includes many references to it.

This tuning guide is not just my input though, it would not have been possible without the knowledge and generous contributions made by tuners and programmers in the EVO and VR4 community, especially those who regularly contribute to the forums of evelotutionm.net and Geekmapped.com.

The description of how the ECU detects knock and then what it does to combat the knock, is from jcsbanks disassembly of the knock routines and subsequent discussion on the EVO forums. Also, John did the disassembly on the Lean Spool routines and worked out how the whole Lean Spool thing works. My advice here is don't turn it off, but learn to use it effectively!

So, to anyone reading this, tuning the VR4 is fun, but it will take time to get all bases covered. Good luck to you all!

This is the stock VR4 engine bay with all the factory plumbing.

1.2-TUNING ABBREVIATIONS AND ACRONYMS

Any discussion of engine tuning is inevitably going to be riddled with abbreviations, acronyms and trade names. Some have been in common usage in the automotive world since its inception, while others have been inspired since the regular use of turbos in the 1980's. Familiarity with these terms helps the owner/tuner understand what is going on inside and around the engine and will be required to follow the manual.

Table 1	**ABREVIATIONS AND ACRONYMNS**
AFR	Air Fuel Ratio.
ATDC	After Top Dead Centre.
AUDM	Australian Domestic Market, also ADM.
BOV	Blow Off Valve, more correctly meaning an air re-circulation valve and required on engines fitted with a MAF to meet emissions.
BTDC	Before Top Dead Centre.
CAS	Crank Angle Sensor. Dual signal optical type on the inlet camshaft on EVO 1,2,3. Later EVOs had both a cam and a crankshaft sensor.
DIY	Do It Yourself.
EBC	Electronic Boost Controller.
ECU	Engine Control Unit.
EDM	European Domestic Market
EVOm	www.evolutionm.com.
HFC	High Flow Cat. Usually defined as 3" entry bore diameter or larger.
IAT	Intake Air Temperature.
IM	Inlet Manifold.
JDM	Japanese Domestic Market.
MAF	Mass Air Flow, usually referring to the MAF meter.
MBC	Manual Boost Control, may be either in-cabin or close to the turbo.
MIAT	Manifold Inlet Air Temp and/or the MIAT sensor.
MTBT	Minimum Timing for Best Torque.
NA	Normally Aspirated, an engine without turbo or supercharger.
NBO2	Narrow Band Oxygen Sensor.
PITA	Pain In The Arse. Says it all really.
PCV	Positive Crankcase Ventilation. A one-way valve opens on vacuum.
TBE	Turbo Back Exhaust, usually defined as a 3 inch exhaust system and catalytic converter.
ROM	Read Only Memory. Misused in this context as the ECU memory can be re-written, as is the case when the memory is re-flashed.
TDC	Top Dead Centre
TPS	Throttle Position Sensor.
USDM	United States Domestic Market.
WBO2	Wide Band Oxygen Sensor.
WOT	Wide Open Throttle.

1.3-REQUIRED EQUIPMENT

1. **EcuFLASH v1.42**: Earlier versions will not work with the required flashing cable.

2. **TACTRIX OpenPort2** flashing cable: This has a USB connector on the PC end and the correct OBD-II and flash connectors. It has in-built driver software which self-loads when the cable is connected to the laptop PC.

3. Laptop: You must have a laptop as EFI tuning is all about reading and manipulating data associated with the ECU and has to be capable of in-car operation for more than a few minutes. It thus follows that said laptop PC should have a good battery. Just about any post 2000 laptop running win-XP will do the job. The new mini net-book PCs with 7-9 inch screens for students are great for in-car tuning.

4. Power DC/AC inverter: Capable of powering your laptop from the 12 volt in-car cigarette lighter socket is a very useful addition.

5. **EvoScan** Logging Software: This application can use either the OpenPort2 cable, or the earlier 1.3 cable (which can read and log from the ECU but cannot flash the ECU). It also allows you to integrate data from your WBO2 with the data from your ECU port.

6. Wideband O2 meter (WBO2): Used to monitor the air Fuel Ratio in real-time, most have an output that can be used for logging. Not to be confused with the factory fitted narrow-band O2 sensor (NBO2). The NBO2 is used in conjunction with **EvoSCAN** to monitor fuel trims and is a vital tool when installing and tuning larger injectors. I use the **INNOVATE LM-1** as a general purpose WBO2 tuning tool and a **TechEdge 2CO** permanently wired into my EVO IX.

1.4-EcuFLASH INTRODUCTION

EcuFLASH is a free software program to support the tuning of MITSUBISHI and SUBARU ECUs and can be configured for multiple engine types with a correctly configured definition file.

It is free and you can download it from http://www.openecu.org

The program was written by Colby Boles and TACTRIX.

Regardless of whether you have a TACTRIX cable or not, you should read through the guide and familiarize yourself with the various capabilities of the EcuFLASH program. There is an amazing quantity of parameters that can be manipulated, but by no means should all items be altered. Indeed, part of the benefit of using the factory ECU is to retain most of the detailed factory settings.

1.5-PROGRAM INSTALLATION AND SETUP

Download the EcuFLASH program, save the application in a master EcuFLASH folder with the version number.

Launch the EcuFLASH installer application that you just downloaded. You can either let it install into **C:\Program Files\Open ECU\EcuFlash**, or you can set it to a folder of your choosing as per normal.

When finished installing, open the EcuFLASH folder, make a short-cut of the EcuFLASH exe file and set it into your desktop for easy access.

Now have a quick look at the definition file for your EVO. These files will be located at:
C:\Program Files\Open ECU\EcuFlash\rommetadata\mitsubishi\evo

Right click on the selected file and select **Open With > Notepad**

1.6-XML DEFINITION FILES

While a lot has been revealed of what is in the ROM, by no means have all been uncovered. For example, at the time of writing this revision, the parameters for ignition cranking have not been available in the various EVO forums. There are many other functions yet to be described or defined.

In addition, parameters (1D), tables (2D) and maps (3D) may have been found and described for some ROMs that are in wide use in the EVO community, but not for the more obscure vehicles. Definition files for these cars/ROMs are either poor or non-existent. This means you as the tuner will have to do a lot of the hard slog to winkle the main data from the ROM binary file. With perseverance, it can be done by closely examining known files with a hex editor and then searching the unknown ROM.

Definition files can be created or altered with a plain text editor, such as Windows NOTEPAD. When working on definition files, the file name extension must be xml.

The definition file has to follow a specific format to be valid and thus read properly and requires the operator to know the absolute hex address in the raw binary (BIN) code of the parameter to be added or modified.

There are a strict set of format rules for definition files to work properly, so the best approach is to copy a section containing a similar function, paste it into the file, then edit it to the new parameters. Note that the datum 'level=x' refers to the user level, where Level1=Developer, Level2=Advanced, Level3=Intermediate. No level command allows access to all user levels.

There is a good xml description, with rules, in Wikipedia.

Below is a stripped down section of definition file for an JDM EVO7, showing the essential elements for a valid definition file. For EcuFlash to read your ROM the xmlid, the internalidhex and the four data bytes at address F52 have to match. Note that EcuFlash likes hex data in lower case. HEX editors usually want upper case.

```
<rom>
        <romid>
                <xmlid>98640014</xmlid>
                <internalidaddress>f52</internalidaddress>
                <internalidhex>98640014</internalidhex>
                <make>Mitsubishi</make>
                <market>JDM</market>
                <model>Lancer</model>
                <submodel>Evo 7</submodel>
                <transmission>Manual</transmission>
                <year>2002</year>
                <flashmethod>mitsukernel</flashmethod>
                <memmodel>SH7052</memmodel>
        </romid>

<scaling name="Timing" units="degrees" toexpr="x" frexpr="x" format="%.0f" min="-61" max="61" inc="0.1" storagetype="int8" endian="big"/>

<scaling name="RPM" units="RPM" toexpr="x*1000/256" frexpr="x*256/1000" format="%.0f" min="0" max="11000" inc="50" storagetype="uint16" endian="big"/>

<scaling name="Load" units="g/S" toexpr="x*10/32" frexpr="x*32/10" format="%.0f" min="0" max="300" inc="1" storagetype="uint16" endian="big"/>

<table name="High Octane Ignition Map 1" category="IGNITION TIMING" address="3b85" type="3D" swapxy="true" scaling="Timing">
<table name="Load" address="503a" type="X Axis" elements="19" scaling="Load"/>
<table name="RPM" address="500a" type="Y Axis" elements="19" scaling="RPM"/>
</table>
</rom>
```

Following after all the romid stuff is the scaling data. These describe the size and format of the units being used. The scaling expression needs to be read by EcuFlash before the function it is called within.

Then come all the parameters, tables and maps. All the essential elements to make a valid definition are shown, the name, category, the binary address, type, and scaling used. Then follows the scaling used on the two axis, in this case Load and RPM, with the relevant address and element size and the scaling.

The </rom> bit at the end is required to close the file.

Note 1: toexpr="x/10" is a sample formula which converts the raw ROM data (decimal) value into suitable units for display on the EcuFlash window.

Note 2: frexpr="x*10" is the corresponding reciprocal formula to convert data entered in an EcuFlash window back into the ROM which the ECU will understand.

Note 3: format="%.1f" will give displayed values to 1 decimal place. %.0f will have no decimal places and will round off the displayed value.

Note 4: storagetype="uint8" means a one byte data variable (8 bits). storagetype="uint16" means a two byte data variable (16 bits).

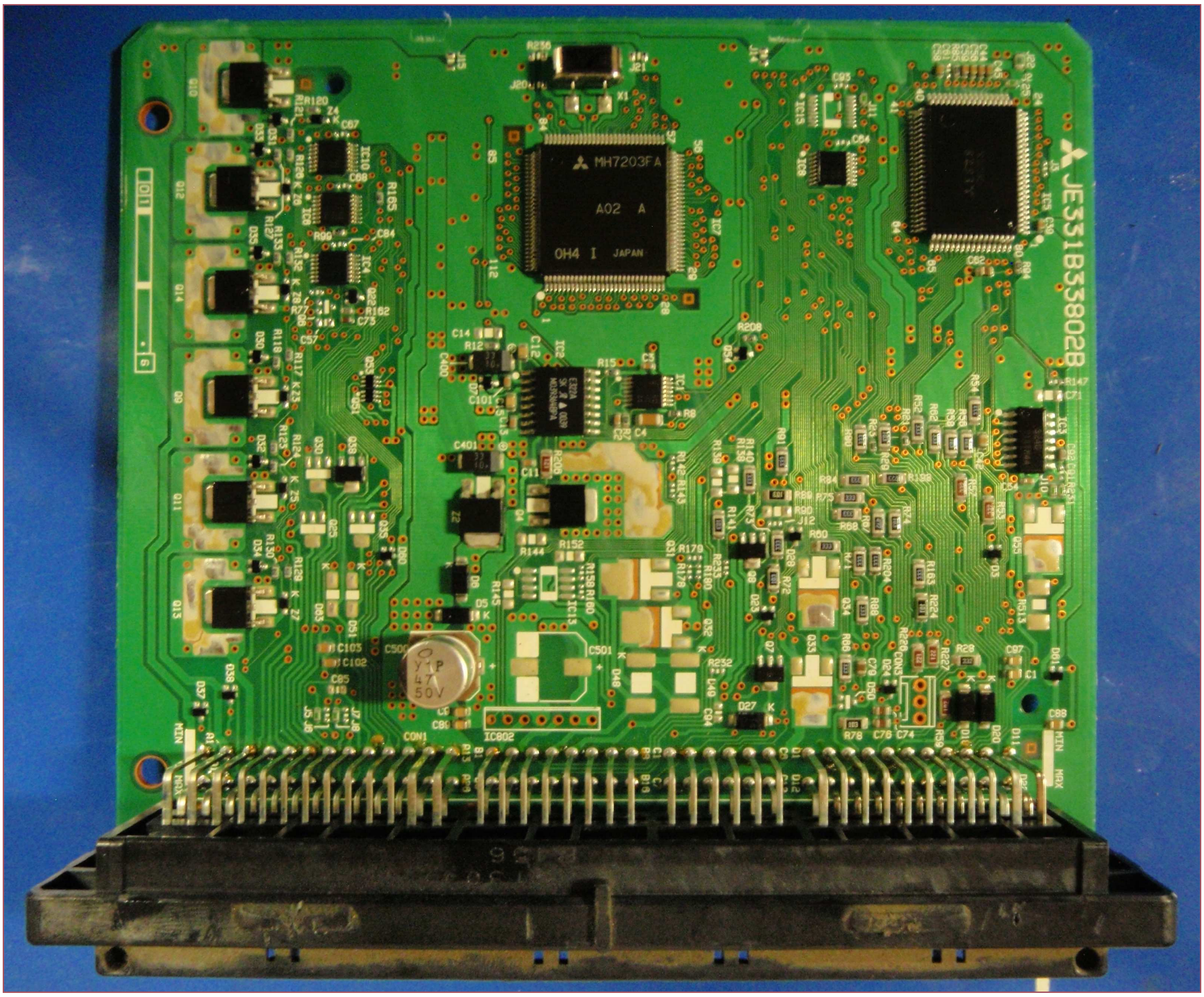
A fast and practical New Zealand LEGNUM is shown here.

1.7-EcuFLASH COMPATIBLE ECUs

At the time of writing, EcuFLASH V1.42 can only write to ECUs which use the Hitachi MH**7202** processor chip. Some ECUs have a 7203F or 7203FA processor chip, which can be read but not re-flashed by EcuFLASH. The processor chip is a flash-ROM chip, so there is hope that future versions of EcuFLASH will be able to do the job.

So, before proceeding, its best to check what is in the ECU. The ECU is located on the transmission tunnel behind the radio. It is secured by a screw on each side, so the centre console side panels will have to be removed to gain access to the ECU mounting screws and connectors.

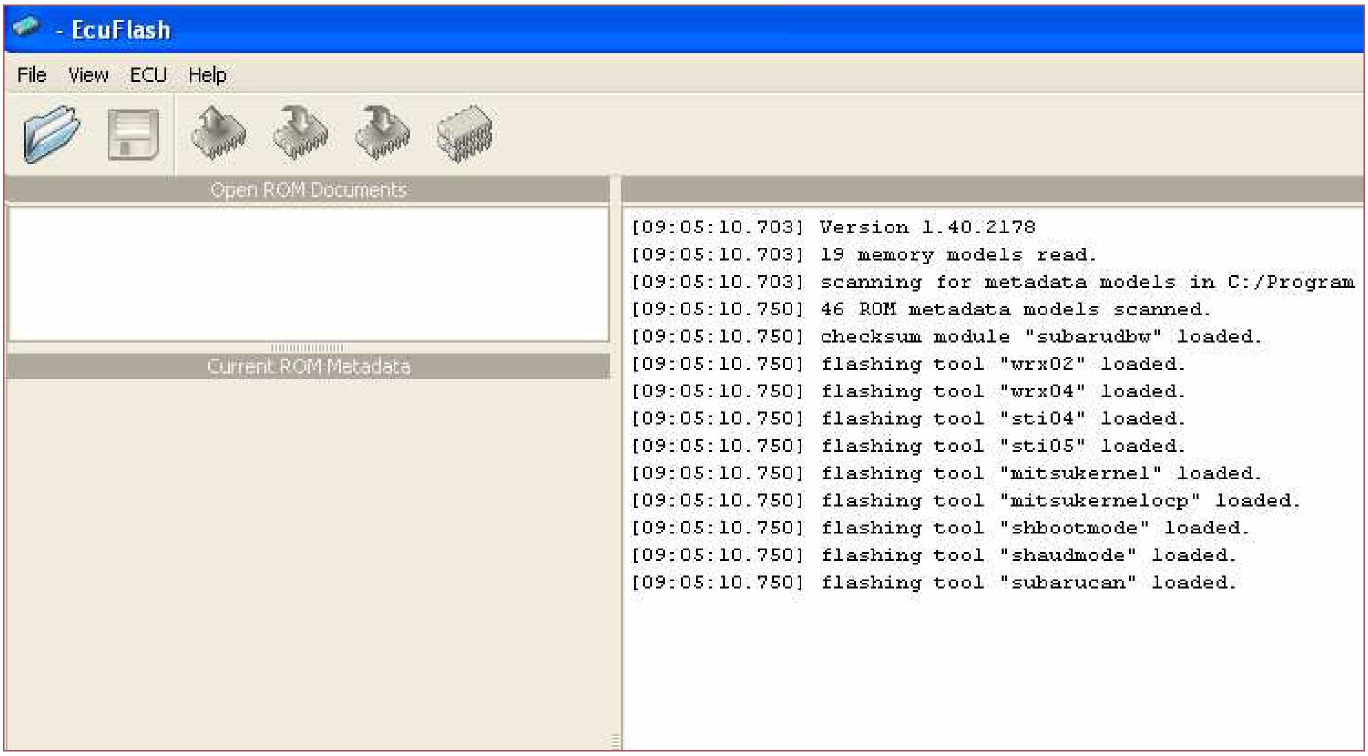
When you have the ECU in-hand, open the unit by sliding four thin metal tabs under the securing tabs. Safety single sided razor blades are good for this bit. When they are in place, pry or tap the connector panel out from the box. The processor board is soldered directly to the connector and can be removed quite easily from the plastic box. The processor chip is at top centre.



1.8-RUN EcuFLASH

Start the EcuFLASH program from the desktop icon you previously created. You will see The usual MS pull-down tabs, a Folder tab, a Save tab and four little integrated circuit icons, symbolizing the ECU, three with arrows and the fourth one doubled.

Figure 1: EcuFLASH – V1.40 OPENING VIEW



There are four preliminary steps to do before proceeding with connecting to the ECU for the first time.

1.9-SETTING THE USER LEVEL & DIRECTORY

To set the User Level, select:
File \ Options to get the window shown below.

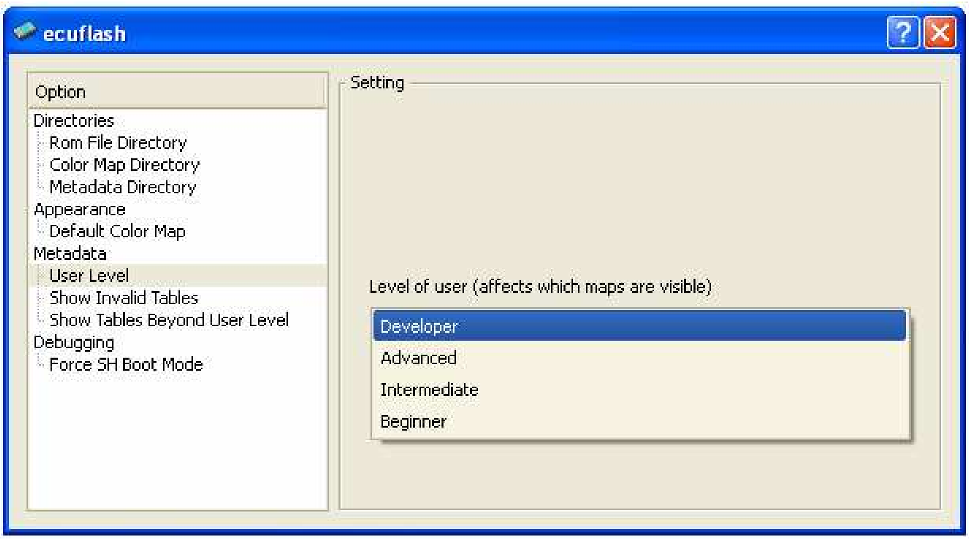
Then click on:
User Level \ Developer. This will allow you to gain access to all defined parameters.

To set the path to the ROM files for your ECU, click on:
Rom File Directory, then the file folder containing the desired ROM.

To set the path to the XML files for your ECU, click on:
Metadata Directory, then the file folder containing the required XML files.

Keep this window open for the moment.

Figure 2: EcuFLASH – USER LEVEL



1.10-SETTING THE DEFAULT COLOUR MAP

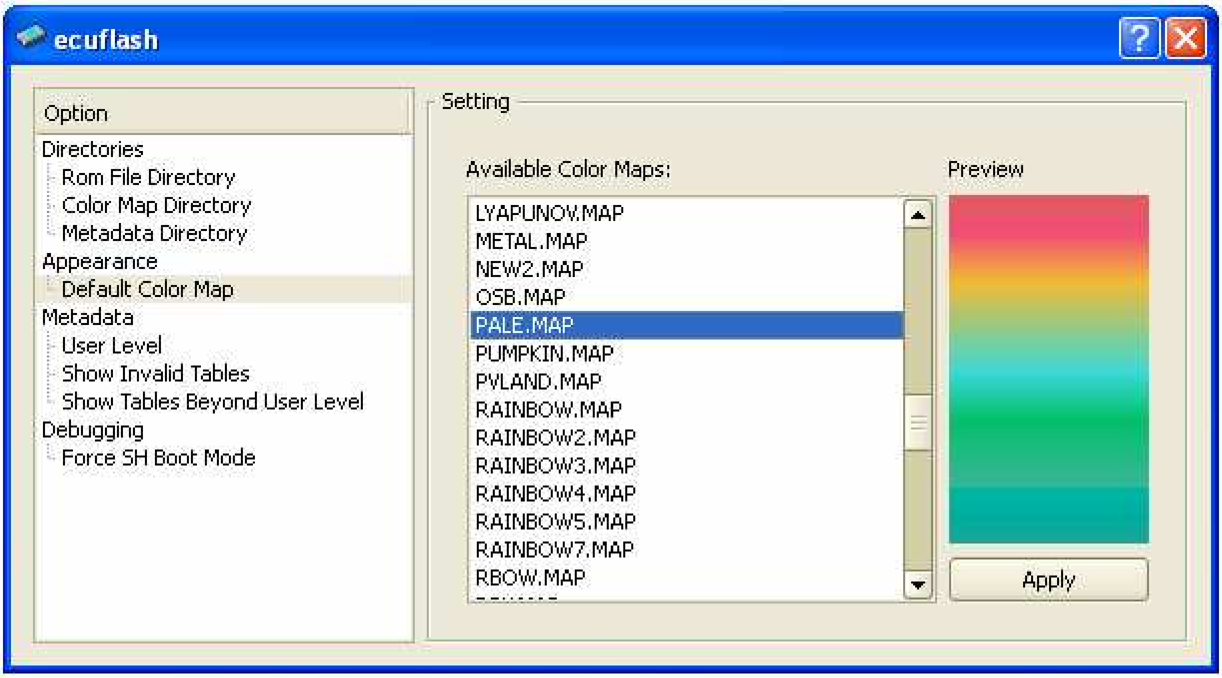
To set or change the COLOUR MAP style, select:
File \ Options

Then click on:
Default Color Map to get the window shown below.

Scroll through the selections and select whatever suites, as some colour styles display better than others or allow easier data viewing.

Click on:
Apply then close the window.

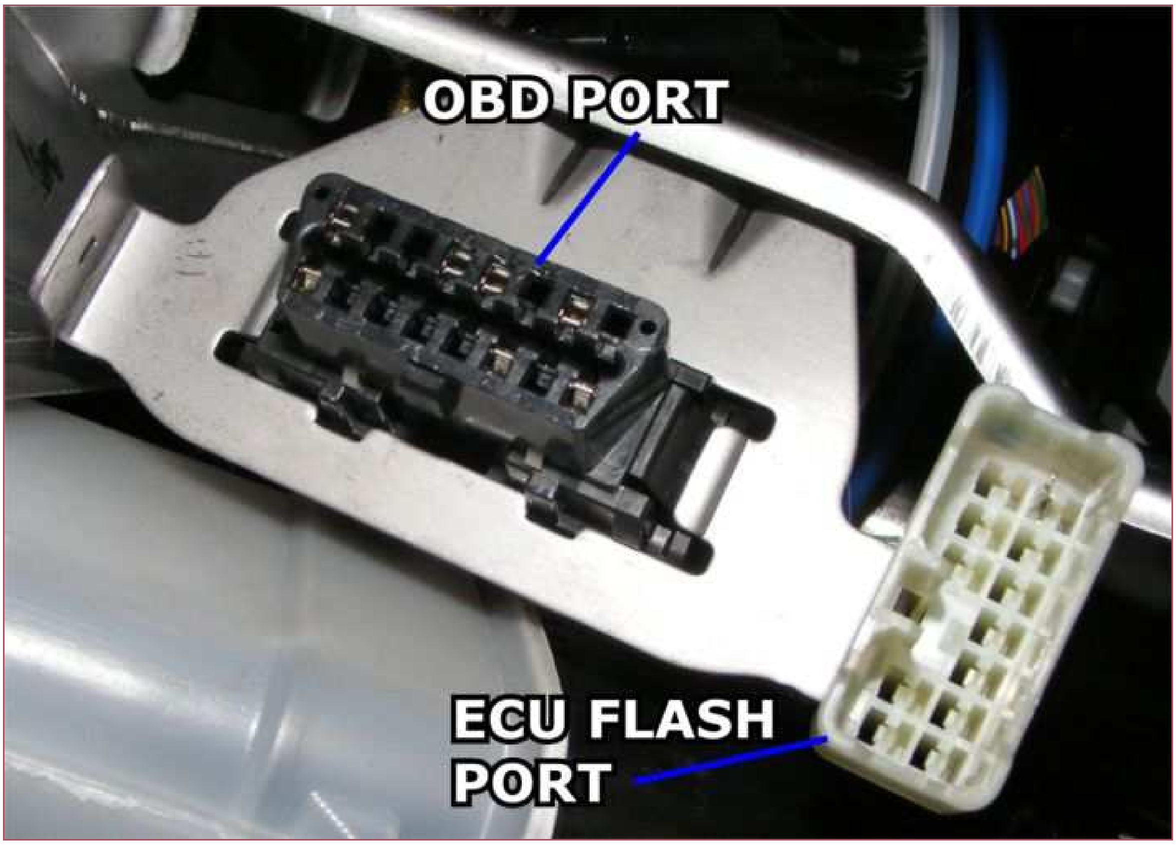
Figure 3: EcuFLASH – DEFAULT COLOUR MAP STYLE



1.11-CONNECTING to the ECU

Ok, you have your TACTRIX OpenPort2 cable, and have EcuFLASH up-and-running on your laptop. Take a quick look at the photo of the relevant connectors. Proceed to the VR4 and connect the TACTRIX cable large clear connector to the black OBD-II port and the smaller connector to the white re-flash port. The connectors are behind the dash facia, drivers side, adjacent to the centre tunnel. Just feel with your hand and plug the connectors into their receptacles. There is a latch on the white connector, requiring depression on removal. Pix from **Biggles** on MLR.

Figure 4: OBD-II PORT & ECU REFLASH PORT



Plug the USB end of the cable into your laptop, it seems to be a good practice to always use the same port to prevent USB driver conflicts.

The cable will talk to the laptop and proceed to install itself. Just follow the prompts and select **Proceed Anyway** when questioned about proceeding.

When the cable is installed and all is ready, the **Read from ECU** icon will light-up with a blue arrow.

1.12-ECU OPERATIONS

There are four ECU operations that can be selected:

Read from ECU – Reads the ECU (all of the flash-ROM) into EcuFLASH.

Write to ECU – Writes the whole of a binary/hex file to the ECU flash-ROM, then checks the write was good.

Test Write to ECU – Uploads the flashing kernel to the ECUs read/write memory (RAM) and sends data blocks to the RAM, thus confirming communications to the ECU. Flash-ROM, where the ECU routines, data tables and maps reside is not written to or changed.

Compare to ECU – Compares the ECU flash-ROM to the ROM currently select in EcuFLASH.

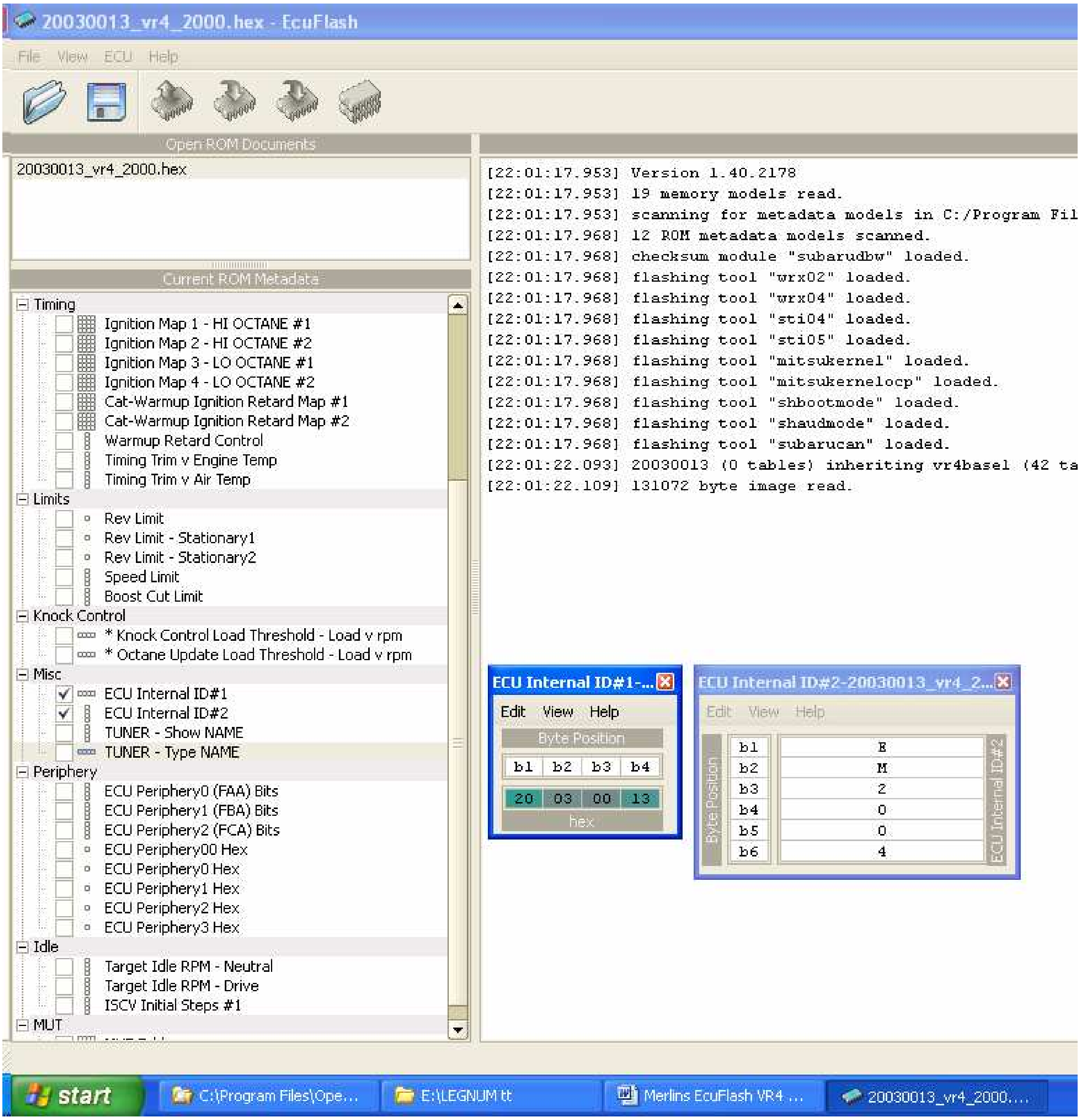
Assuming you want to proceed and read the ECU, turn the ignition key to RUN (not START!). Click on the **Read from ECU** function and then select the type of vehicle type to read. EcuFLASH will now proceed to download the ROM image from your ECU. When the read operation is completed, EcuFLASH will attempt to access the ROM, by reading the ROM identity code. If there is a matching XML definition file available in the Metadata directory, EcuFLASH will open the XML definition file and the ROMs contents can be examined with the menu bar. Two data items need to be examined and written down before proceeding further.

Figure 5: TACTRIX OPEN PORT 2 CABLE SET

1.13-READING THE ROM VERSION CODE

Shown here are the two ECU Internal ID fields, which should not be altered. If unfamiliar with your ROM identity, select **ROM Info**, and record the **Internal ID** number. This is the code or model number for the ROM for your type of VR4.

Figure 6: EcuFLASH – ROM VERSION CODE



1.14-EDITING FUNCTIONS and 3D GRAPH VIEWING

Select a map that you wish to view for editing.
Select View\View Graph.
The graph can be toggled on/off with the Alt+G keys.

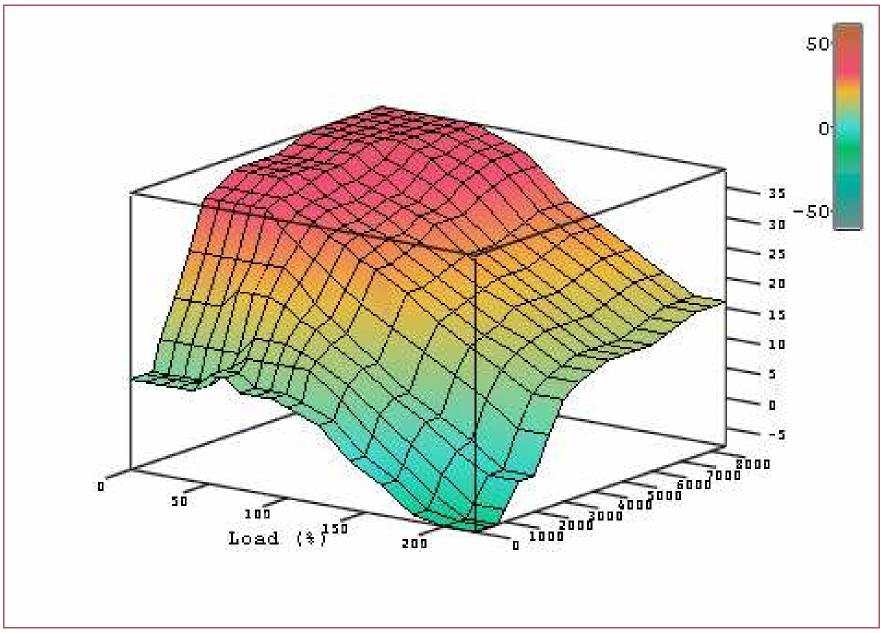
Use the **[** key to decrement map values.
Use the **]** key to increment map values.
Use the ← ↑ → ↓ keys to move around the map.

Other functions include:

Undo	Ctrl+Z
Redo	Ctrl+Y
Select All	Ctrl+A
Copy	Ctrl+C
Paste	Ctrl+V
Revert	Ctrl+R
Copy	Ctrl+C
Set Data	=
Add to Data	Alt++
Multiply Data	*
Interpolate Vertically	Alt+V
Interpolate Horizontally	Alt+H
Interpolate 2-D	Alt+B
Edit Map Definition	Ctrl+M

A sample MIVEC map is shown below in graphical view. It can be rotated etc by placing the mouse pointer near the graph, hold-down the left button and rotate as required.

Figure 7: EcuFLASH – GRAPHING EXAMPLE, modified HI OCT IGNITION



1.15-GETTING STARTED – PRELIMINARY TUNING

Next, if you have one, you should install the WBO2 properly on your EVO. Preferably, do not install the WBO2 sensor behind the Catalytic Converter, as this will give you erroneous (slightly leaner) AFR readings. The best position to place the sensor is in the down pipe 2 inches before the CAT flange in the three o'clock position where it won't knock against the transmission tunnel etc. Do not place the sensor in any position below horizontal, as condensation may form on the sensor and ultimately ruin it.

Next-up, you have to go out and log data from your VR4. This should include logs of warm-up running, idling, cruising, long straight up-hill runs in 3rd gear and 4^{th} gear, WOT, from 1500 rpm all the way to 7000 rpm. Keep logging parameters to the essential data, AFR, timing, load, TPS, RPM, Knock, boost (if possible), coolant temp, IAT, injector pulse width, and injector duty cycle and fuel trims. You should study and understand what the data means.

The first points of critical interest to check are the fuel trims and knock.

Fuel trims larger than ±5% should be rectified; the INJECTOR TUNING section has details on this.

Knock will need to be identified and assessed as real or phantom/false. False knock can now be dialed-out, thanks to the efforts of **jcsbanks** and our EVO community dis-assemblers and tuners! The KNOCK TUNING section has all the details.

Now read-on through SECTION 2 and see just what can be tuned. Remember; make small incremental and smooth changes to the tables.

1.16-NOTES for EXAMINING VR4 ROMS in HEX

1. The 3D maps on these ROMs are prefixed with the axis size, in hex notation
2. Ignition maps X=17, Y=19, prefix = F0 10 13 Y axis, hex13 = dec19
3. Fuel maps X=15, y=15, prefix = F0 10 0F X axis, hex0F = dec15
4. The full prefix for limp map = F0 10 05 Y axis, hex05 = dec05

SECTION 2 – FUEL TUNING

2.01-HOW THE VR4 ECU CALCULATES FUEL VALUES

The basic function of the ECU is to calculate the correct amount of fuel and ignition advance required by the engine at any rpm and load, within it's normal design operating range. To make these calculations it needs an accurate measure of how much load the engine is under.

The VR4s primary load sensor is the Mass Air Flow Meter (MAF). It is the ECUs biggest asset, but it can be a limiting factor to the engines ultimate performance when attempting to tune beyond the factory parameters. The MITSUBISHI air-flow meter utilizes the Karman-Vortex principal to measure the air-flow using ultra-sonic sound, which after processing outputs an alternating voltage (AC) proportional to the air-flow. The frequency of the MAF signal ranges from about 30Hz to 2600Hz, with very good resolution at low air-flow rates. This allows very precise AFR trimming at light engine loads.

The MAF makes a measurement of the mass of air entering the engine. At this point the measurement is un-corrected and requires manipulation from the following tables:

1. MAF SIZE.
2. AIR TEMP.
3. BAROMETRIC PRESSURE.

At this point load is calculated and is applied to lookup the fuel and ignition maps. Note that not all the compensations have been factored-in yet. The ECU now determines the mass of fuel required for a specific Air Fuel Ratio by checking:

4. MAF SMOOTHING.
5. BARRO + TEMP v RMP.
6. FUEL MAP.
7. INJECTOR SCALING.
8. INJECTOR LATENCY.

Now the conditional parameters can be included when required, such as:

9. ACCEL ENRICHMENT.
10. WARMUP ENRICHMENT.
11. CLOSED LOOP.
12. LEAN SPOOL.

Because of this, injectors and even the MAF itself can be up-graded to a larger size without requiring a major re-tune, as would be the case with a manifold absolute pressure (MAP) based load sensing, aka speed-density. The characteristics of the injectors are defined in ROM as the INJECTOR SCALING and the Injector BATTERY VOLTAGE LATENCY COMPENSATION value. Scaling relates the flow capacity of the injector, while the latency parameter is the time (in milli-seconds) for the injector to turn on. This parameter may be variously referred to as 'dead-time' or 'void blast-off time'. There are 4 fuel maps, two HI-OCTANE 3D maps and two LO-OCTANE 3D maps. The values in the maps are shown as desired final AFRs.

2.02-STOCK HI OCTANE VR4 FUEL MAP

There are two HI OCTANE FUEL maps and two LO OCTANE FUEL maps in the VR4 and LEGNUM-TT ECU. In all the ROMs I have examined, the HI OCTANE maps have been identical. With the two LO OCTANE FUEL maps, most of the map, including the idle and cruise areas have had the same data as the HI OCTANE maps. The difference is only apparent in the areas where the engine is under boost. This a very good tuning philosophy and helps us in our tuning work.

Note that the Load and RPM scaling is quite different to the ignition maps. If you plan on running boost levels of 18-20psi, better change the last load scale value to 220.

Figure 8: EcuFLASH – STOCK HI OCTANE FUEL MAP – 20030013

Fuel Map 1 - HI OCTANE #1-galant vr4_2000.hex

Edit View Help

Load (%)

RPM (RPM)	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
750	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	13.2	12.7	12.7	12.4	12.4
1000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	13.2	12.7	12.7	12.4	12.4
1250	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	13.2	12.7	12.7	12.4	12.4
1500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	13.2	12.7	12.7	12.4	12.4
2000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	13.2	12.7	12.7	11.8	11.8
2500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.7	12.7	11.8	11.8	11.1	11.1
3000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	12.7	12.4	11.4	11.1	10.8	10.8
4000	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.7	12.4	11.8	11.1	10.3	10.8	10.8
4500	12.7	12.7	12.7	13.3	13.3	13.8	13.8	13.8	12.7	11.8	11.4	10.7	10.3	10.8	10.8
5000	12.7	12.7	12.7	12.7	12.7	12.5	12.3	12.3	11.8	11.4	11.1	10.3	10.3	10.8	10.8
5500	12.7	12.7	12.7	12.7	12.7	12.5	12.3	11.8	11.1	10.7	10.3	10.2	10.3	10.8	10.8
6000	12.7	12.7	12.7	12.7	12.7	12.5	11.5	10.6	10.3	9.8	9.8	9.8	10.3	10.8	10.8
6500	12.7	12.7	12.7	12.7	12.7	12.5	11.5	10.6	10.3	9.8	9.8	9.8	10.3	10.8	10.8
7000	12.7	12.7	12.7	12.7	12.7	12.5	11.5	10.6	10.3	9.8	9.8	9.8	10.3	10.8	10.8
8000	12.7	12.7	12.7	12.7	12.7	12.5	11.5	10.6	10.3	9.8	9.8	9.8	10.3	10.8	10.8

AFR

Load 120 ≈ 05-07psi Load 140 ≈7-11psi Load 160 ≈11-15psi.

Load 180 ≈15-17psi Load 200 ≈17-19psi Load 220 ≈19-21psi.

2.03-STOCK LO OCTANE VR4 FUEL MAP

The LO OCTANE fuel map should have similar values for idle and cruise, with progressively richer values as the engine comes on boost.

The table scaling normally matches the HI OCTANE map, but does not have to be the same. The graphing function can be used with the fuel maps, but does not seem to be as useful as with ignition map graphing.

Figure 9: EcuFLASH – STOCK LO OCTANE FUEL MAP – 20030013

Fuel Map 3 - LO OCTANE #1-galant vr4_2000.hex

Edit View Help

Load (%) / RPM (RPM) / AFR

RPM	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
750	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1250	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
2000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	11.8	11.8	11.8
2500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	12.9	11.1	11.1	10.7	10.7	10.7
3000	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.8	11.8	11.1	10.7	10.7	10.7	10.7
4000	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.3	11.4	11.1	10.7	10.2	10.7	10.7
4500	12.5	12.5	12.5	12.5	12.5	13.3	13.3	13.3	12.3	11.4	11.1	10.3	10.2	10.7	10.7
5000	12.5	12.5	12.5	12.5	12.5	12.4	11.7	11.7	10.7	10.4	10.3	9.6	10.2	10.7	10.7
5500	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.5	9.8	9.6	9.6	9.6	10.2	10.7	10.7
6000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.1	9.7	9.6	9.6	9.6	10.2	10.7	10.7
6500	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.1	9.7	9.6	9.6	9.6	10.2	10.7	10.7
7000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.1	9.7	9.6	9.6	9.6	10.2	10.7	10.7
8000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.1	9.7	9.6	9.6	9.6	10.2	10.7	10.7

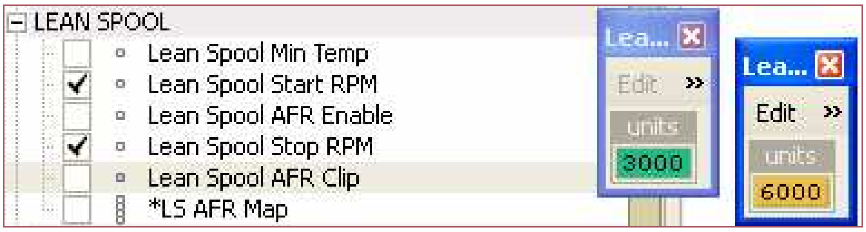
One curious aspect of the fuel maps when compared with an EVO map is the VR4 does not try to operate at stoch AFR above 2500 RPM. This may be to keep exhaust gas temperatures down when high speed cruising.

2.04-STOCK LEAN SPOOL SETTINGS

These are the main LEAN SPOOL parameters you will be tuning, the LEAN SPOOL AFR table, LEAN SPOOLSTART RPM and LEAN SPOOL STOP RPM.

Lean Spool operation can only operate between the start and stop RPM settings. If the start value is set to the stop value, or vice versa, Lean Spool is disabled. Lean Spool can also be disabled via the Periphery bits.

Figure 10: EcuFLASH – STOCK LS START RPM & LS STOP RPM – 20030013

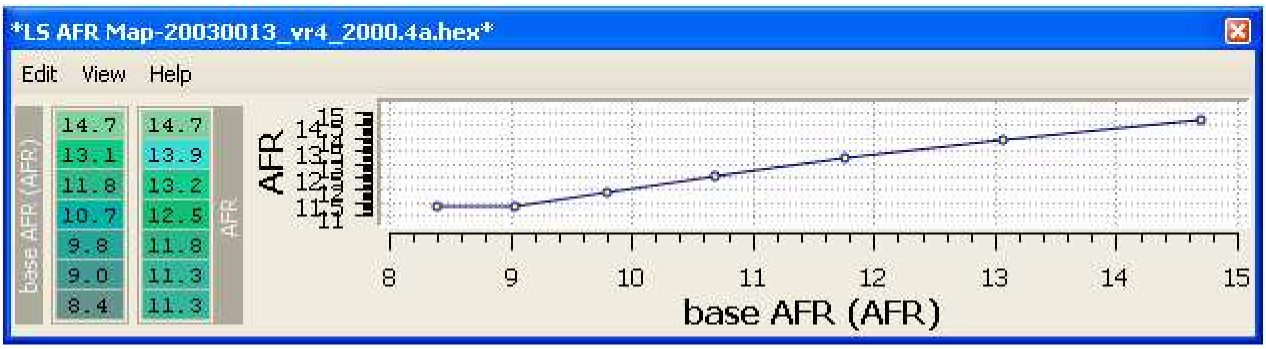


The LEAN SPOOL AFR table is the item which causes the measured AFR to be shifted to a leaner state than the fuel map. The two data sets in the table show how the AFR is shifted from the "base AFR" ie the fuel map, to the desired final AFR.

The idea is that the engine will happily tolerate a leaner mixture, provided the engine is rapidly accelerating and not lugging under high loads for any length of time, thus causing excessive heat soak in the engine. So there is a decay time table (not shown) which governs the time LEAN SPOOL will operate in each 500 RPM band. It is typically about 2 seconds/500 RPM on an EVO, VR4s are similar.

So, the fuel map is setup for thermal management, while the LEAN SPOOL table is setup to make the car quick on the road, without throwing excess fuel at the engine all the time. Only when it is needed!

Figure 11: EcuFLASH – STOCK LS AFR TABLE – 20030013



2.05-TUNED HI OCTANE VR4 FUEL MAP

This map was the result of road tuning, with the aid of det-cans, a wide-band air-fuel ratio meter and EvoScan for logging for knock etc. Final boost level was set at 17-18psi which means the ECU is into the highest load column. Fuel used was BP Ultimate 98, ambient temps about 18 degrees C. Minimal knock reported on EvoScan were subsequently eliminated with ignition tuning.

Further boost increments will require the 200 load scale changed to 220-250.

Figure 12: EcuFLASH – TUNED HI OCTANE FUEL MAP – VR4

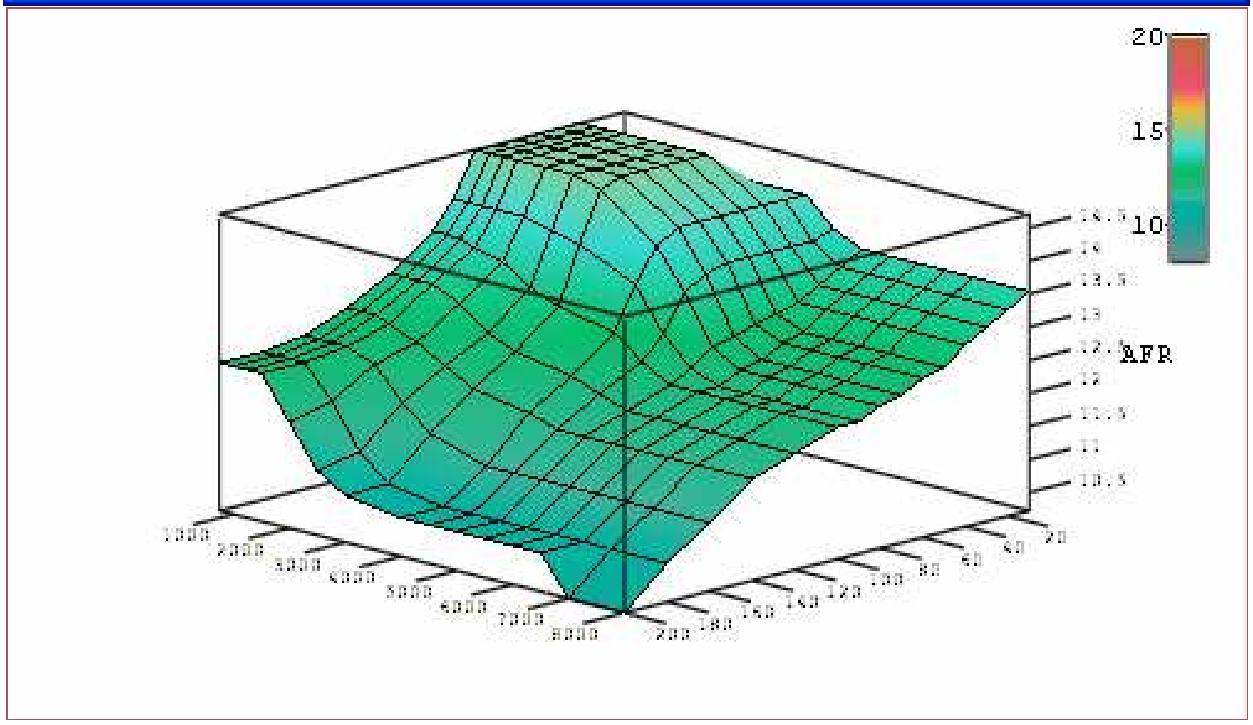
Fuel Map 1 - HI OCTANE #1-20030013_tune-4.hex

Edit View Help

Load (%)

RPM (RPM)	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
750	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.0	13.6	13.2	12.8	12.5	12.5	12.5
1000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.0	13.6	13.2	12.8	12.5	12.5	12.5
1250	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.0	13.6	13.2	12.8	12.5	12.5	12.5
1500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.0	13.5	13.2	12.7	12.5	12.5	12.5
2000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.0	13.4	13.0	12.5	12.4	12.0	11.8
2500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	13.9	13.2	12.6	12.3	11.9	11.3	11.2
3000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.6	13.8	13.0	12.5	12.1	11.5	10.9	10.9
4000	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.9	13.4	12.8	12.3	11.9	11.3	10.8	10.8
4500	13.7	13.6	13.6	13.6	13.6	13.6	13.5	13.3	12.8	12.5	12.1	11.8	11.3	10.8	10.8
5000	13.5	13.3	13.2	13.0	12.9	12.8	12.7	12.6	12.4	12.2	12.0	11.8	11.3	10.8	10.8
5500	13.5	13.3	13.2	13.0	12.7	12.6	12.5	12.4	12.2	12.2	12.0	11.8	11.3	10.8	10.8
6000	13.5	13.3	13.2	13.0	12.7	12.6	12.5	12.4	12.2	12.2	12.0	11.8	11.3	10.8	10.8
6500	13.5	13.3	13.2	13.0	12.7	12.6	12.5	12.4	12.2	12.2	12.0	11.8	11.3	10.8	10.8
7000	13.5	13.3	13.2	13.0	12.7	12.6	12.5	12.4	12.2	12.2	12.0	11.8	11.3	10.8	10.2
8000	13.5	13.3	13.2	13.0	12.7	12.6	12.5	12.4	12.2	12.2	12.0	11.8	11.3	10.8	10.2

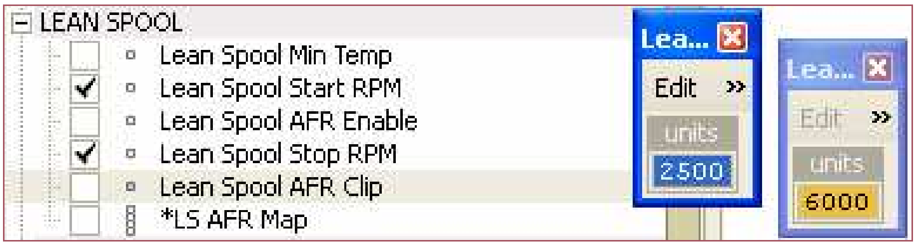
AFR



2.06-TUNED LEAN SPOOL SETTINGS

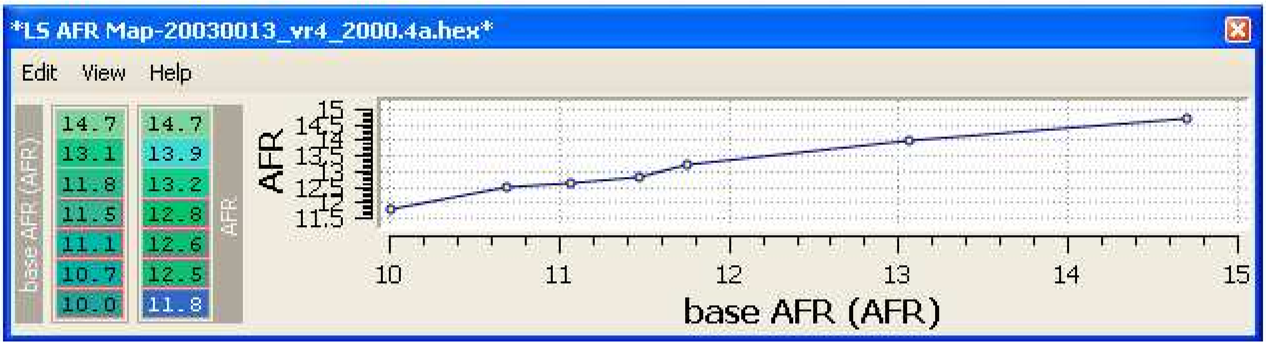
Here is the revised LEAN SPOOL START RPM settings I use on the VR4. This is to get the turbos' spooled a little earlier than stock.

Figure 13: EcuFLASH – TUNED LS START RPM & LS STOP RPM – 20030013



Here is the revised LEAN SPOOL AFR table I use with the VR4, it is similar to what I use with the EVO9. The filthy rich base settings have been revised upwards to the richest base fuel map settings I would expect to use, with fine tuning through the mid 12 AFR settings. It thus becomes easy to cross reference what you map to what to expect on the wide-band O2 sensor.

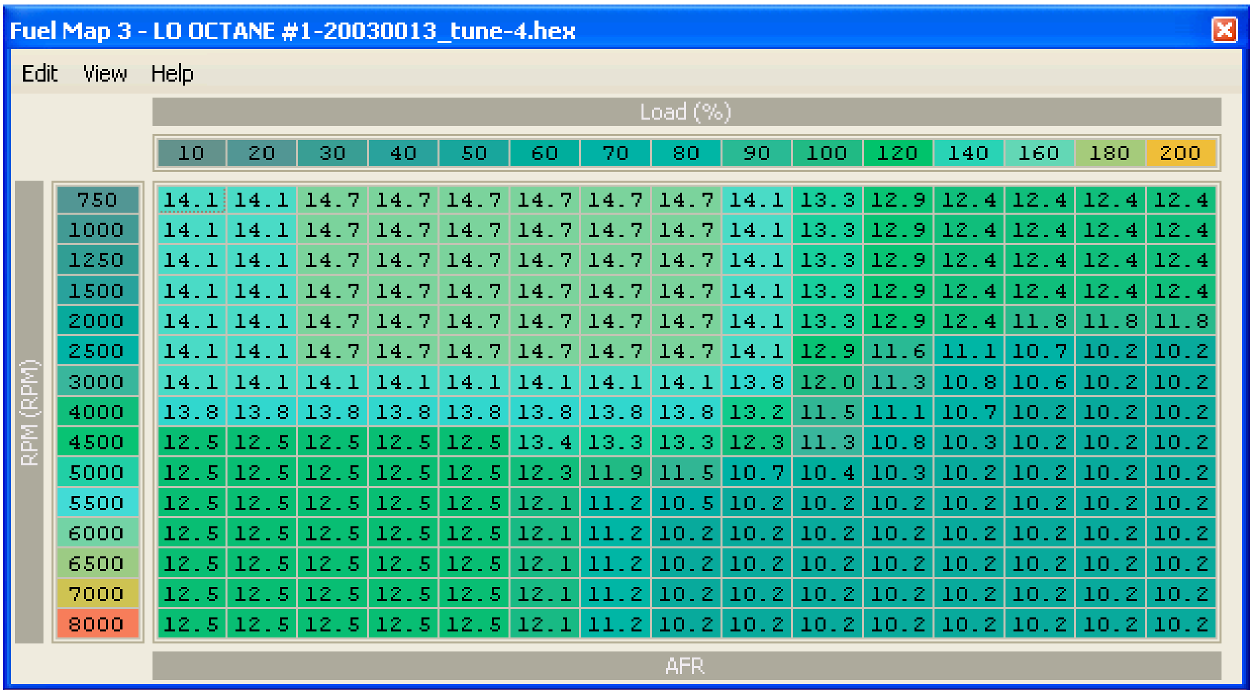
Figure 14: EcuFLASH – TUNED LS AFR TABLE – 20030013



2.07-TUNED LO OCTANE VR4 FUEL MAP

This map was the logical extension of the tuned HI OCTANE map, with a richer boost area while maintaining the low speed and cruise characteristics.

Figure 15: EcuFLASH – TUNED LO OCTANE FUEL MAP – VR4



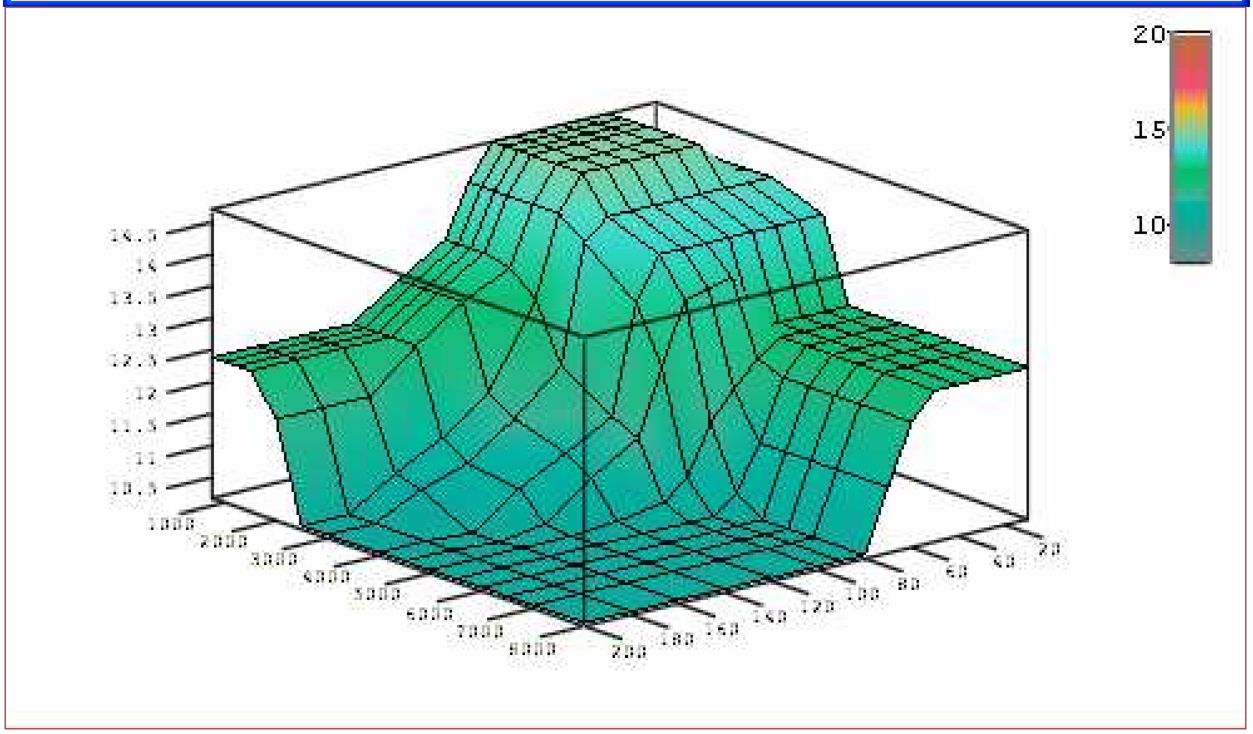
Fuel Map 3 - LO OCTANE #1-20030013_tune-4.hex

Edit View Help

Load (%)

RPM (RPM)	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
750	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1250	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
1500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	12.4	12.4	12.4
2000	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	13.3	12.9	12.4	11.8	11.8	11.8
2500	14.1	14.1	14.7	14.7	14.7	14.7	14.7	14.7	14.1	12.9	11.6	11.1	10.7	10.2	10.2
3000	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.8	12.0	11.3	10.8	10.6	10.2	10.2
4000	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.2	11.5	11.1	10.7	10.2	10.2	10.2
4500	12.5	12.5	12.5	12.5	12.5	13.4	13.3	13.3	12.3	11.3	10.8	10.3	10.2	10.2	10.2
5000	12.5	12.5	12.5	12.5	12.5	12.3	11.9	11.5	10.7	10.4	10.3	10.2	10.2	10.2	10.2
5500	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.5	10.2	10.2	10.2	10.2	10.2	10.2	10.2
6000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
6500	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
7000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
8000	12.5	12.5	12.5	12.5	12.5	12.1	11.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2

AFR

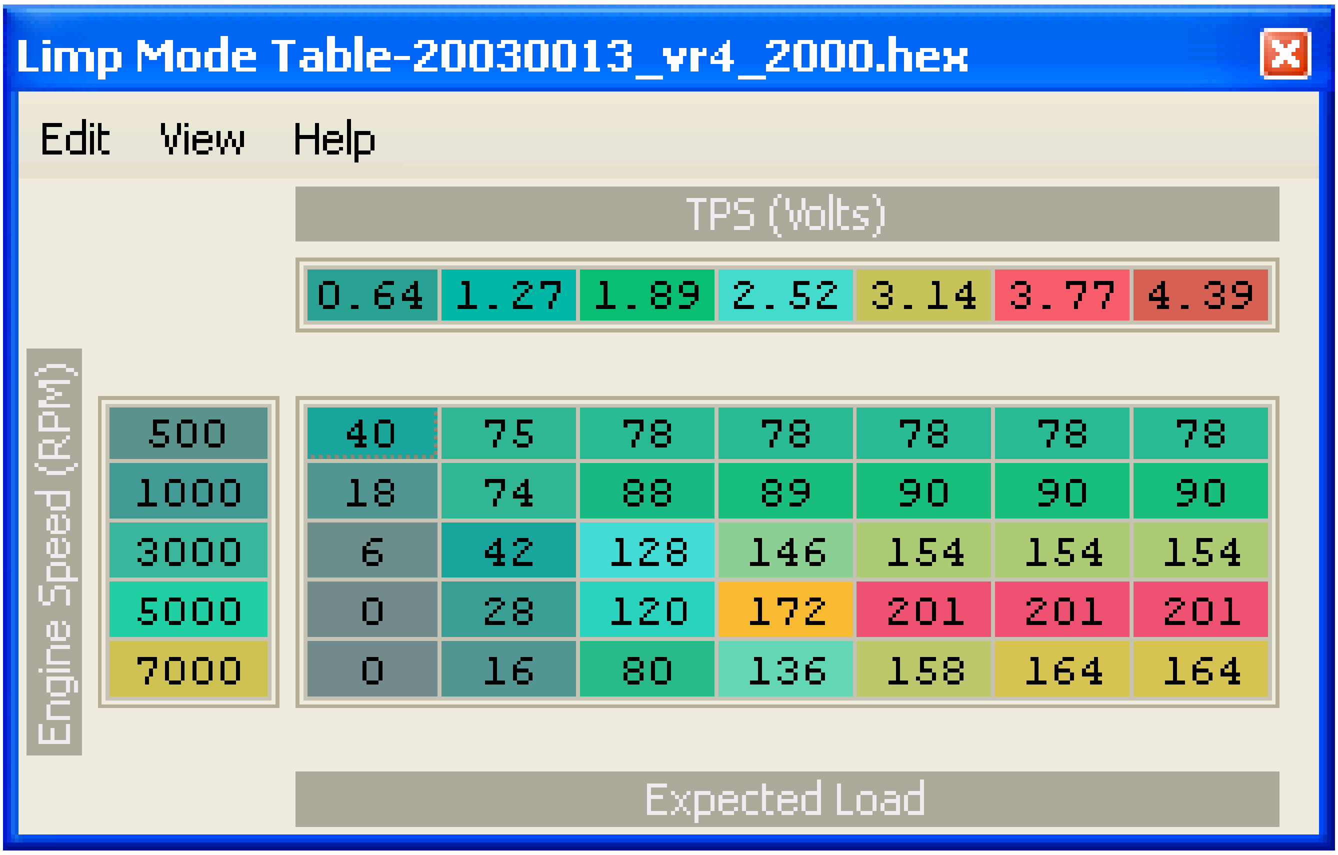


2.08-FUEL_TPS v RPM LIMP HOME LOAD TABLE

If the MAF fails, the VR4 has a limp home capability, using just the throttle position sensor and the engine RPM to generate a simulated load value.

This type of system is known as "alpha-N" fuel mapping.

Figure 16: EcuFLASH – TPS v RPM LIMP HOME LOAD MAP - 20030013


Limp Mode Table-20030013_vr4_2000.hex

Edit View Help

Engine Speed (RPM) \ TPS (Volts)	0.64	1.27	1.89	2.52	3.14	3.77	4.39
500	40	75	78	78	78	78	78
1000	18	74	88	89	90	90	90
3000	6	42	128	146	154	154	154
5000	0	28	120	172	201	201	201
7000	0	16	80	136	158	164	164

Expected Load

There are likely to be RPM and BOOST limits applied under this condition as well, but they have not been found/defined as yet.

This map would not normally be altered from the stock parameters.

SECTION 3 – IGNITION TUNING

3.01-IGNITION TUNING INTRODUCTION

There are two HI OCTANE IGNITION maps and two LO OCTANE IGNITION maps in the VR4 and LEGNUM-TT ECU. In all the ROMs I have examined, the two HI OCTANE maps have been identical.

In the two LO OCTANE IGNITION maps the idle and cruise areas have had the same data as the HI OCTANE maps. The difference is only apparent in the areas where the engine is under boost. This a good tuning philosophy and helps us in our tuning work, as well as ensuring the engine has similar characteristics in normal non-boost driving.

It is a safe bet that the ignition maps were factory set for "premium" fuel, which in Japan is usually 100 RON. That being the case, they will need to be run on BP Ultimate 98 octane as a minimum spec fuel. When run on 98 RON, the engine will likely show some detonation. EvoSCAN should always be reporting some **low** (1-3) level of knock. A count of three will result in reduced timing of 1 degree! So the car should be logged under power to check for detonation prior to any ignition map tuning.

It is important to appreciate that the VR4 ECU is constantly testing for an improvement in fuel via the knock detector. If there is no knock detected when operating above the OCTANE UPDATE THRESHOLD, the ECU will increase the octane number and try to run fully on the HI OCTANE map. Thus, for a VR4 in Australia, using 95 RON fuel, the ECU will have pulled between 2-6 degrees to combat the knock until it is only seeing about 1-2 counts. Thus the level of performance will suffer considerably. The good news is that the ECU will give back the lost timing when presented with high octane fuel. Note also that old fuel goes stale and looses some of its octane rating!

Fill the tank with fresh fuel of the correct octane rating before any tuning involving ignition timing.

One thing you will immediately notice if a timing light is used on the VR4 is that at idle, the timing is not stable, but is constantly shifting about by an apparently varying number of degrees. This is normal, as Mitsubishi use an active ignition timing routing to control idle speed, which sits on top of the idle stepper-motor control. See the idle stability section for details.

3.02-STOCK HI OCTANE VR4 IGNITION MAP

For VR4s run on pump gasoline between 91 and 93 RON, tuners typically spend the time to chase out the knock so they can get stable operating conditions and get on with chasing HP with increased boost and other modifications.

If you don't want to risk getting ambitious, my thinking is to run the car on BP 98, run the **stock** factory HI OCTANE map and let the ECU do its thing via the knock sensor. And - using 100 octane race fuel in the tank on track-days if available.

Figure 17: EcuFLASH – STOCK HI OCTANE IGNITION MAP – 20030013

Ignition Map 1 - HI OCTANE #1-20030013_vr4_2000.hex

Edit View Help

Load (%)

RPM (RPM)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	400
0	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
500	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
750	7	7	7	7	7	10	12	12	12	12	12	8	3	-1	-5	-8	-8
1000	12	12	12	12	12	12	15	15	15	14	13	10	6	2	-2	-6	-6
1500	18	18	18	18	21	21	21	20	18	17	15	12	8	5	1	-2	-2
2000	25	25	25	25	25	25	25	23	20	18	16	12	8	5	2	-2	-2
2500	33	33	33	33	33	30	28	26	24	22	20	17	14	11	8	4	4
3000	34	34	34	34	34	32	31	29	28	26	25	22	18	15	12	9	9
3500	36	36	36	36	34	33	32	30	29	27	25	22	19	16	14	11	11
4000	36	36	36	36	35	33	32	30	29	28	26	23	20	17	15	12	12
4500	36	36	36	36	36	34	32	31	30	28	27	24	21	19	16	13	13
5000	36	36	36	36	36	34	33	32	31	30	29	25	22	19	16	13	13
5500	37	37	37	37	37	35	34	32	31	30	29	25	22	19	16	13	13
6000	38	38	38	38	38	36	35	34	33	31	29	25	22	19	16	13	13
6500	38	38	38	38	38	38	37	36	34	33	31	26	23	20	17	14	14
7000	38	38	38	38	38	38	37	36	35	34	32	27	24	21	18	15	15
7500	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16
8000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16
20000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16

degrees

3.03-STOCK LO OCTANE IGNITION MAP

When the ECU initially detects detonation, it will retard timing by preset number of degrees depending on the knock count and the conditions that the knock occurred. At the same time, the "octane number" that the ECU has stored is reduced. If detonation continues to occur, then the ECU will interpolate between the HI and LO OCTANE maps, with a calculation using the octane number. Supposedly, the ECU never actually gets to operate fully on the LO OCTANE map though.

The ECU will then continue to operate proportionally between the two maps, until an absence of knock is noted in a boost condition (when operating above the OCTANE UPDATE THRESHOLD), at which point the octane number is progressively increased and operation rapidly reverts back to the HI OCTANE map, or close to it.

Should detonation still occur the ECU will reduce the boost level to the minimum possible level by fully closing the boost control solenoid. For further reading on this topic, refer to the section on KNOCK CONTROL.

There are two LO OCTANE IGNITION MAPS, usually with the same values. I usually **don't change** the LO OCTANE IGNITION maps.

Figure 18: EcuFLASH – STOCK LO OCTANE IGNITION MAP – 20030013

Ignition Map 4 - LO OCTANE #2-20030013_vr4_2000.hex

Edit View Help

Load (%)

RPM (RPM)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	400
0	7	7	7	7	7	10	8	6	1	-4	-6	-8	-8	-8	-8	-8	-8
500	7	7	7	7	7	10	8	6	1	-4	-6	-8	-8	-8	-8	-8	-8
750	7	7	7	7	7	10	10	7	2	-3	-5	-8	-8	-8	-8	-8	-8
1000	12	12	12	12	12	12	12	11	8	2	-2	-4	-6	-8	-8	-8	-8
1500	18	18	18	18	21	21	18	16	11	7	4	-2	-5	-7	-8	-8	-8
2000	25	25	25	25	25	25	21	18	15	11	8	3	-1	-5	-7	-8	-8
2500	33	33	33	33	33	30	26	23	19	16	12	5	1	-3	-6	-8	-8
3000	34	34	34	34	34	31	29	24	19	16	13	7	3	0	-3	-6	-6
3500	36	36	36	36	34	33	30	24	19	16	13	8	5	2	0	-2	-2
4000	36	36	36	36	35	33	30	24	20	17	15	11	8	6	4	1	1
4500	36	36	36	36	36	34	30	24	20	19	16	11	8	6	4	2	2
5000	36	36	36	36	36	34	30	27	25	23	21	16	12	9	6	3	3
5500	37	37	37	37	37	35	33	30	26	24	21	16	12	9	7	4	4
6000	38	38	38	38	38	36	35	31	28	24	21	16	12	9	7	4	4
6500	38	38	38	38	38	38	37	34	28	24	21	17	14	11	8	5	5
7000	38	38	38	38	38	38	37	34	30	25	22	18	15	12	8	5	5
7500	38	38	38	38	38	38	38	35	31	26	23	19	16	13	9	6	6
8000	38	38	38	38	38	38	38	35	31	26	23	19	16	13	9	6	6
20000	38	38	38	38	38	38	38	35	31	26	23	19	16	13	9	6	6

degrees

3.04-KNOCK and the KNOCK SENSOR

Here is a short description of knock and the knock sensor.

An ideal combustion process behaves in the following manner:

1. The air fuel mixture is brought into the combustion chamber. Ideally this mixture should have around 12.5:1 AFR to extract maximum power from gasoline. Given that the EVO engine is about 17 years old, crappy CA gas, and high boost, this ideal is pretty hard to achieve w/o running water or methanol injection. As stated before most amateur tuners that I know run between 11.5-11:1 AFR on an EVO.

2. The intake and exhaust valves close and the spark plug fires. On an EVO 8 a spark plug fires at around 18-21° BTDC by 7000 rpm. On an EVO 9 there is less timing advance with the spark plug firing around 14-16° BTDC by 7000 rpm. Why less timing advance on the EVO 9 than the EVO 8? In part, it is because the EVO 9 is blessed with a better cooled and better flowing cylinder head than the EVO 8. The EVO 9 can run leaner AFRs. Leaner AFRs burn faster up to 12.5:1. Beyond that they burn slower. A faster burning mixture does not require as much timing advance as a slower burning one. I am not saying that the EVO 9 has a leaner AFR from the factory. Far from it. What I am saying is that it has the potential to run leaner AFRs and consequently less timing advance.

3. After the spark is fired the burning of the mixture proceeds. It begins at the spark plug and progresses in an orderly fashion across the combustion chamber. It is as if you took a pebble and threw it in a pond and watched the ripples progress outward from where the pebble fell. The burn should be complete with no remaining air-fuel mixture by the end of the combustion process.

In reality combustion sometimes does not progress in an orderly and smooth fashion. Sometimes the air-fuel mixture spontaneously combusts after the spark plug is fired but before the flame front reaches the mixture. This is known as detonation or knock. Why does that happen? Too much pressure and too much heat combined with the lack of enough octane in the mixture to resist self-combustion. Think of octane as the ability of gasoline to resist self-combustion under pressure and heat. The higher the octane the less likely the gasoline will self-combust under high boost and heat that the EVO is known to generate.

When a car knocks, it causes a very sharp pressure spike that is outside the normal shape of a pressure curve during normal combustion. The pressure spike creates a force in the combustion chamber. The structure of the engine pings/rings in reaction to the force generated from the pressure spike. That is where the knock sensor steps in.

The knock sensor is usually connected to the back or side of the engine block. It is nothing more than a piezo microphone. It converts engine vibrations into a corresponding electrical signal for the ECU. The ECU filters and amplifies that signal and decides if any spiking signal in the background noise is knock. If it is, the ECU retards the timing in order to save the engine from further detonation and possible damage. The knock sensing system is reactive and not pro-active. The timing pull happens after knock is detected and pulls timing to prevent further damage. It does not prevent knock, it tries to limit it after it has happened.

The data stream that the ECU sends to the OBD-II port is commonly known as KNOCKSUM The loggers that we use have the ability to log KNOCKSUM. The higher the knocksum the more timing will get pulled, the lower the knocksum the less timing will get pulled.

So what sort of damage does knock cause? If left unchecked, knock can break the spark plugs insulator, break the compression rings and smash the ring lands around the pistons. Knock can also be very abrasive to the crown of the piston. Pistons on an engine that is suffering from excessive knock will look like as if it has been sandblasted and will show small pits in the top of the piston. Finally, excessive knock will cause a premature failure of your rod bearings resulting in the very distinctive rod knock sound.

Having said the above about the dangers of knock do not be surprised to learn that almost all cars knock. As long as the knock is occasional and moderate cars can run for thousands of miles with little to no problems. While mild detonation is not an optimum situation for engine operation, it does not guarantee engine failure.

3.05-USING KNOCKSUM via EVOSCAN to TUNE OUT KNOCK

So how do we tune out the knock?

The ECU spits out the OBD-II port a parameter known as KNOCKSUM This parameter, with ignition timing and RPM are the most important to log with EcoScan when tuning your Mitsubishi. EvoScan tells us that this parameter can vary from 0 to 36 with 36 as the maximum knock count that the ECU can register.

When tuning the engine it is advisable to tune timing, fuel, and boost without triggering more than 1-2 occasional counts of knock, three at the most. We know for a fact that 3 knock counts pull 1° of timing. I would therefore tune for 1 to 2 occasional and sporadic counts of knock, three at most. Anything above that is unacceptable. Here is my take on knock:

1. All cars knock on occasion. I have logged an EVO that knocked the first log and then gave me three knock free WOT runs. Generally speaking, the first WOT log that you do tends to be knock prone. You have to do at least three back-to-back logs to make sure that knock is consistent. I do not worry about an occasional log that has a single knock it. If the knock is transient and does not repeat, I usually ignore it.

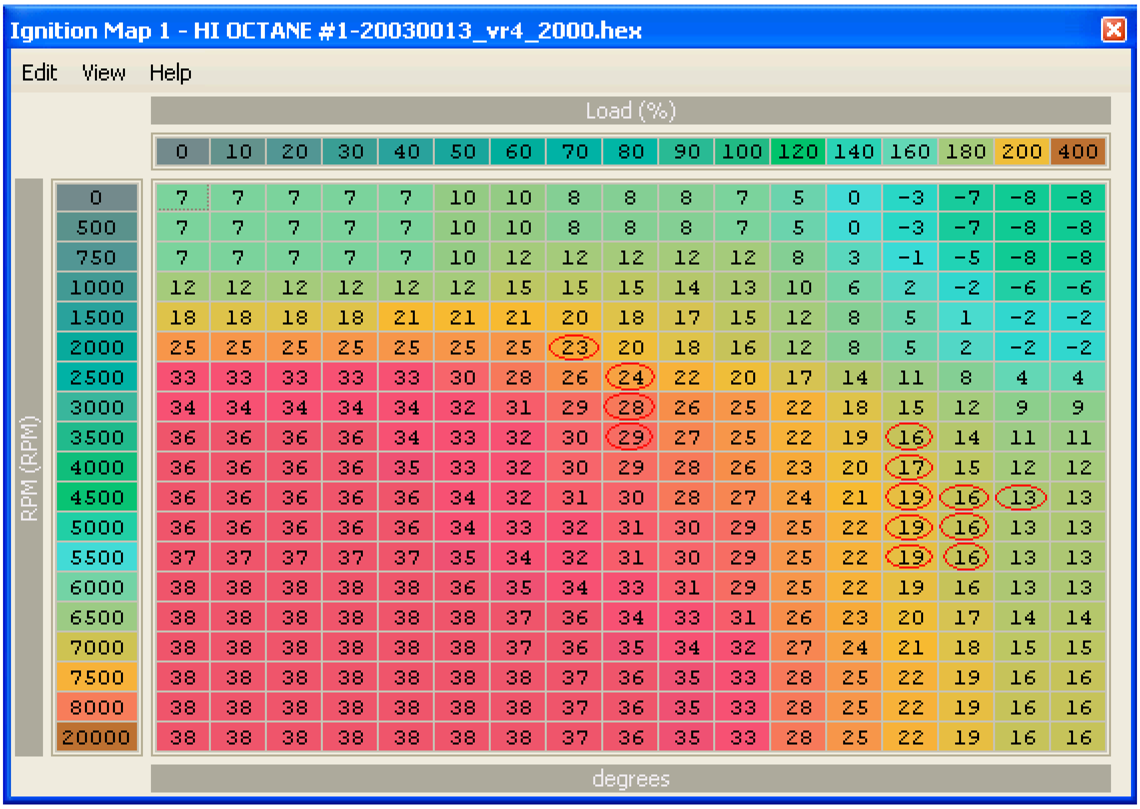
2. Knock is a problem when it is consistent and repetitive, i.e., it happens every log and at the same point in the rpm range. That is the kind of knock to worry about and work hard to eliminate.

So, we have made several power pulls on the VR4/Legnum we are tuning and an examination of the resulting EvoScan log files has revealed more than 2 counts of knock and the knock is consistent and repetitive. What should I do to eliminate it?

3.06-VR4 IGNITION MAP with KNOCK

This is the stock VR4 ignition map showing in red the cells where knock occurred, when running 15-16psi of boost. Multiple power pulls were logged using EvoScan and later analyzed using excel.

Figure 19: EcuFLASH – KNOCK DETECTED, HI OCTANE IGNITION MAP – 20030013


Ignition Map 1 - HI OCTANE #1-20030013_vr4_2000.hex

Edit View Help

Load (%) / RPM (RPM) / degrees

RPM \ Load	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	400
0	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
500	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
750	7	7	7	7	7	10	12	12	12	12	12	8	3	-1	-5	-8	-8
1000	12	12	12	12	12	12	15	15	15	14	13	10	6	2	-2	-6	-6
1500	18	18	18	18	21	21	21	20	18	17	15	12	8	5	1	-2	-2
2000	25	25	25	25	25	25	25	23	20	18	16	12	8	5	2	-2	-2
2500	33	33	33	33	33	30	28	26	24	22	20	17	14	11	8	4	4
3000	34	34	34	34	34	32	31	29	28	26	25	22	18	15	12	9	9
3500	36	36	36	36	34	33	32	30	29	27	25	22	19	16	14	11	11
4000	36	36	36	36	35	33	32	30	29	28	26	23	20	17	15	12	12
4500	36	36	36	36	36	34	32	31	30	28	27	24	21	19	16	13	13
5000	36	36	36	36	36	34	33	32	31	30	29	25	22	19	16	13	13
5500	37	37	37	37	37	35	34	32	31	30	29	25	22	19	16	13	13
6000	38	38	38	38	38	36	35	34	33	31	29	25	22	19	16	13	13
6500	38	38	38	38	38	38	37	36	34	33	31	26	23	20	17	14	14
7000	38	38	38	38	38	38	37	36	35	34	32	27	24	21	18	15	15
7500	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16
8000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16
20000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16

The knock levels were as follows:

3.07-TUNED HI OCTANE VR4 IGNITION MAP

This VR4 running 15psi boost consistently registered knock counts of 4-12 between 3500 RPM and 5500RPM, which resulted 1-3 degrees of timing being pulled by the ECU and a slight reduction in the ECU octane number.

So what is the ECU telling us to do to combat the knock?

We know from MTBT (minimum timing best torque) theory that we should advance the timing until we either stop making power or we see the onset of knock. In this case we clearly see the onset of knock. So what we have to do is pull 2-3° of timing to combat the knock in that rpm range.

Here is a revised ignition map, with 1-3 degrees pulled from the areas where consistent knock occurred. In addition, the highest load scaling cell has been changed from a relatively useless 400 to a far more useful 240.

Figure 20: EcuFLASH – TUNED HI OCTANE IGNITION MAP – 20030013

Ignition Map 1 - HI OCTANE #1-20030013_vr4_2000.4a.hex*

Edit View Help

Load (%)

RPM (RPM)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	240
0	7	7	7	7	7	10	10	8	8	8	7	5	0	0	0	0	0
500	7	7	7	7	7	10	10	8	8	8	7	5	0	0	0	0	0
750	7	7	7	7	7	10	12	12	12	12	12	8	3	0	0	0	0
1000	12	12	12	12	12	12	15	15	15	14	13	10	6	2	0	0	0
1500	18	18	18	18	21	21	21	20	18	17	15	12	8	5	2	0	0
2000	25	25	25	25	25	25	25	22	20	18	16	13	9	6	3	1	0
2500	33	33	33	33	33	30	28	25	23	22	20	17	14	11	8	5	2
3000	34	34	34	34	34	32	31	29	27	26	24	21	17	14	12	9	6
3500	36	36	36	36	34	33	32	30	28	27	25	22	18	15	13	10	8
4000	36	36	36	36	35	33	32	30	29	28	26	23	19	16	14	11	9
4500	36	36	36	36	36	34	32	31	30	28	27	24	20	17	15	12	10
5000	36	36	36	36	36	34	33	32	31	30	29	25	21	18	15	12	10
5500	37	37	37	37	37	35	34	32	31	30	29	25	22	19	15	12	11
6000	38	38	38	38	38	36	35	34	33	31	29	25	22	19	15	12	11
6500	38	38	38	38	38	38	37	36	34	33	31	26	23	20	16	13	12
7000	38	38	38	38	38	38	37	36	35	34	32	27	24	21	17	14	13
7500	38	38	38	38	38	38	38	37	36	35	33	28	25	22	18	15	14
8000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	18	15	14
20000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	18	15	14

degrees

3.08-ELIMINATING SHIFT KNOCK

The following HI-OCTANE map is from **jcsbanks** FQ340 EVO9 and has been included to show some clever tuning. The engine is run on 98RON fuel.

This map is altered from the JDM GSR by retarding 1 degree at 6000-6500, and flattening some timing at 120-220% from 3000-4500 RPM to get rid of lift off detonation. At 240 load or higher apart from at 6000-6500 RPM it runs stock timing.

Figure 21: EcuFLASH – HI OCTANE IGNITION MAP – FQ340 (jcsbanks) EVO 9

High Octane Ignition Map 2-EVO9 JM8857v7.hex

Edit

Engine Load (%)

RPM (RPM)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300
0	5	5	5	5	5	10	15	17	15	7	5	2	-1	-4	-7	-10	-10	-10	-10	-10	-10
500	5	5	5	5	5	10	15	17	15	7	5	2	-1	-4	-7	-10	-10	-10	-10	-10	-10
750	5	5	5	5	5	10	15	17	15	7	5	2	-1	-4	-7	-10	-10	-10	-10	-10	-10
1000	5	5	5	5	15	15	20	20	16	11	7	4	1	-2	-5	-8	-10	-10	-10	-10	-10
1250	15	15	15	15	15	25	23	22	20	17	15	12	9	6	3	0	-3	-6	-9	-10	-10
1500	25	25	25	25	25	25	24	24	23	19	16	14	11	8	5	2	-1	-4	-7	-10	-10
2000	35	35	35	35	35	32	32	28	24	24	20	15	12	9	6	3	0	-3	-6	-9	-10
2500	40	40	40	40	35	35	32	29	24	24	23	20	15	11	8	4	1	-2	-5	-8	-10
3000	40	40	40	40	35	33	32	30	28	27	23	18	14	9	5	2	1	1	-2	-5	-8
3500	40	40	40	40	35	30	30	27	26	25	25	21	15	10	7	5	5	5	2	-1	-4
4000	40	40	40	40	35	30	30	27	26	25	25	21	16	12	9	6	5	5	2	-1	-4
4500	40	40	40	40	35	30	30	27	26	25	25	21	17	13	10	7	6	6	3	0	-3
5000	40	40	40	40	35	30	30	27	26	25	25	25	21	17	14	11	9	6	3	0	-3
5500	40	40	40	40	35	32	32	31	29	28	26	25	21	18	15	12	10	7	4	1	-2
6000	40	40	40	40	35	34	32	31	30	29	28	25	20	18	15	12	10	7	4	1	-2
6500	40	40	40	40	38	37	35	34	34	33	30	27	23	20	16	14	11	8	5	2	-1
7000	40	40	40	40	38	37	36	35	34	34	33	29	24	21	17	16	13	10	7	5	1
7500	40	40	40	40	38	37	36	35	34	34	33	29	24	21	18	17	14	11	8	5	2
11000	40	40	40	40	38	37	36	35	34	34	33	29	24	21	18	17	14	11	8	5	2

3.09-IGNITION MAPS AND HIGH BOOST

If you are planning on running boost levels over 17-18psi, then the “400” load column values should be reduced, and the 400 scaling set to reflect the actual final airflow. For example, if using 20psi boost, set the 400 load scale cell to 240, and tune the timing accordingly for no knock.

3.10-STOCK CAT WARMUP IGNITION RETARD MAP

When the engine is warming up, there is another timing function enabled to get the emissions systems catalytic converters operating efficiently as quickly as possible. This is to reduce NOX and to speed-up closed loop operation. To get the cats heated quickly, another timing map is used where the cell values are subtracted from the main hi-octane map. This map is commonly referred to as the CAT WARMUP RETARD MAP.

There are two of these maps with the VR4 and they usually have the same values. In any case, make your changes to both the cat warm-up maps. The retarded ignition timing is frequently a cause of complaint from drivers when their engine is cold, but is easily fixed by reducing the values or even zeroing them out, though this is not necessary. In any case though, zeroing the cells at 1000rpm and 1250rpm would result in better idle stability. Especially when using big cams.

Figure 22: EcuFLASH – STOCK CAT WARMUP RETARD IGNITION MAP – 20030013

Cat-Warmup Ignition Retard Map #1-20030013_vr4_2000.hex

Edit View Help

Load (%)

RPM (RPM)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	400
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1000	0	0	-5	-5	-5	-2	-3	0	0	0	0	0	0	0	0	0	0
1500	0	0	-8	-8	-11	-11	-11	-5	0	0	0	0	0	0	0	0	0
2000	0	0	-8	-8	-13	-15	-15	-10	0	0	0	0	0	0	0	0	0
2500	0	0	-8	-8	-13	-15	-18	-10	0	0	0	0	0	0	0	0	0
3000	0	0	0	-4	-6	-8	-11	-10	0	0	0	0	0	0	0	0	0
3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

units

Note that if you re-scale the ignition RPM scale for better resolution, then you are also changing the RPM scale on the CAT WARM-UP MAPS. This can really bugger things up if you forget to zero off the top three rows, as you will be retarding while trying to accelerate.

SECTION 4 – LIMITS TUNING

4.01-WARNING ON CHANGING the LIMITS

Here is the usual warning on changing the limit parameters.

"All changes made at your risk" There, that aught to cover it!

4.02-LIMITS - SPEED

The Japanese domestic market cars are factory speed limited to 184kph, with a large speed difference to when normal operation is resumed. This is a dumb idea, as you could be unable to negotiate a corner while the engine is off without the drive traction while the vehicle is slowing down. I have set the limit to something (moderately) sensible, based on the track I attend. Adjust as required.

Figure 23: EcuFLASH – SPEED LIMIT – REVISED

The ON value is the speed at which limiting is triggered.

The OFF value is the speed at which normal ECU operation is resumed.

4.03-LIMITS - BOOST / AIRFLOW

The factory ECU tune has a set of parameters, called AIRFLOW LIMIT, which is directly related to the calibrated output from the MAF. Once the ECU senses the AFM is at the AIRFLOW LIMIT as shown in the table below, it will cut fuel to protect the engine. This is referred to as the boost cut function, but is more accurately called Air Flow Cut.

Its effect on the car is dramatic. Acceleration ceases and you get jerked back and forth as the engine quits and cuts back in again in rapid succession. With the usual exclamation of ”WTF was that?”

Once the MAF reads below the AIRFLOW LIMIT value, the ECU will inject fuel once again. If the values of AIRFLOW LIMIT are set at maximum, to eliminate the boost cut function, there is no over boost protection, which is not good idea. The table below will provide a rough guide as to what the boost level is for a given load. The actual pressure will vary with gearing/temp/altitude and the rate of load change.

Table 2 ROUGH GUIDE TO LOAD v BOOST LEVEL – VR4/LEGNUM-TT

LOAD	120	140	160	180	200	220	240	260	280	300
BOOST RANGE	4.5 7.5	7.5 11.0	11 15	15 17	17 19	19 21	21 23	23 25	25	

Figure 24: EcuFLASH – STOCK AIRFLOW BOOST LIMIT V RPM – 20030013

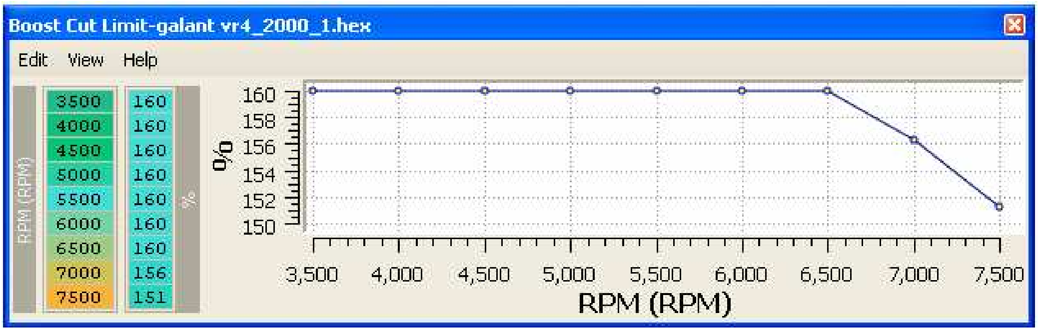
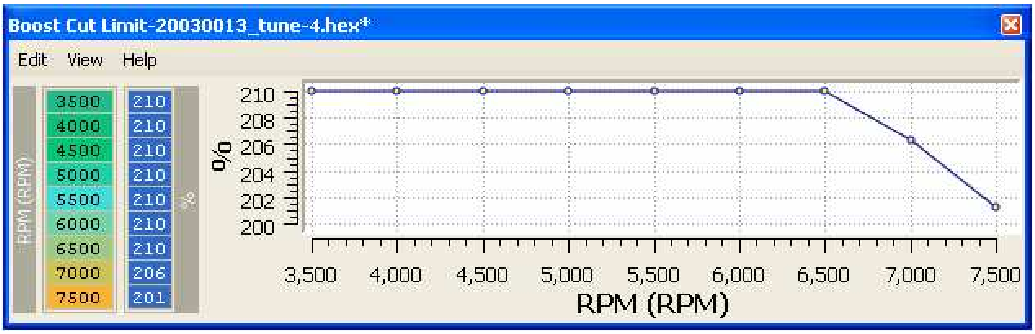


Figure 25: EcuFLASH – TUNED for 17-18psi AIRFLOW BOOST LIMIT V RPM – VR4



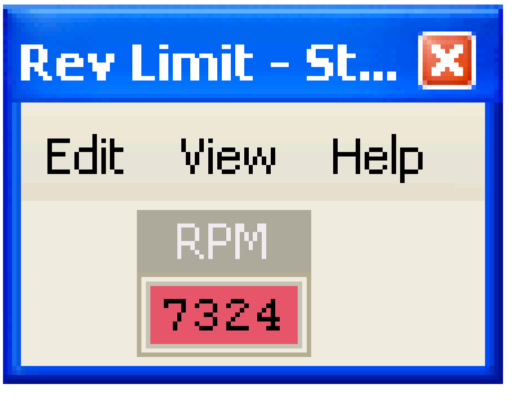
4.04-LIMITS - REV LIMIT

The REV LIMIT is a hard fuel-cut. Leave it alone unless the motor is specially built with forged rods and pistons etc. Remember maximum torque is around 4000rpm with standard cams, so that's where you want up-shifts to land for max acceleration.

Figure 26: EcuFLASH – REV LIMITs – std VR4

The SATIONARY REV LIMIT is a function that is available on the VR4 ROM, but is set at the factory to a value higher than the master rev-limit.

Figure 27: EcuFLASH – REV LIMIT - STATIONARY – std VR4



4.05-LIMITS – MAX KNOCK RETARD LIMIT

When the ECU encounters knock, its first and most immediately noticeable affect is to reduce the ignition timing to combat the knock. The maximum value of retard is set to 12.6°, which is what would happen with 36 counts of knock. This effectively puts you at the low octane fuel map settings, but the timing pull is applied across the whole map.

This can be reduced a bit for race applications.

Figure 28: EcuFLASH – MAX KNOCK RETARD LIMIT - std VR4

Figure 29: EcuFLASH – MAX KNOCK RETARD LIMIT - tuned VR4

SECTION 5 – START & IDLE PARAMETER TUNING

5.01-INTRODUCTION

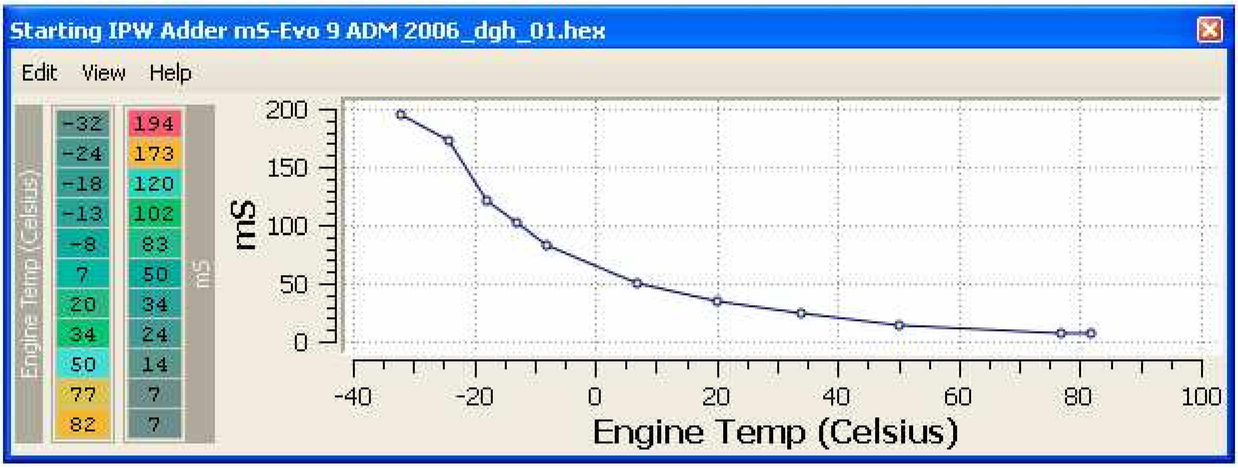
These parameters should only need altering if you have changed to alcohol fuel, or installed bigger cams, or some other mod that is upsetting the MAF.

5.02-START - STARTING IPW v TEMP

An engine will require a large STARTING IPW from the injectors when cold, it's function is to prime the engine by wetting the inlet manifold, thus providing extra fuel at starting due to poor fuel atomization. The table values are added to the latency values, thus directly adding the table to the final IPW. The table only applies when the engine speed is below 438 rpm.

These parameters will not need altering, unless the engine is run on alcohol/blend fuel, in which case more fuel is likely to be required. If larger injectors are used (on pump fuel) the parameters may need to be reduced to prevent flooding.

Figure 30: EcuFLASH – STARTING IPW ADDER v TEMP - EVO 9



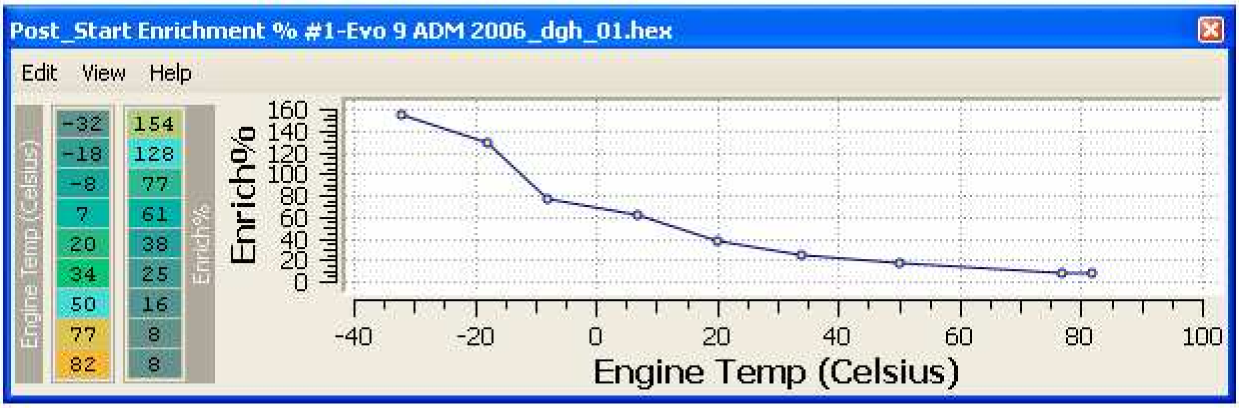
If you intend using E85 fuel, then the values from 20 through to -32 need to be progressively increased. Use the following as a starting point:
7,7,15,30,50,70,90,110,135,175,200.

When larger injectors are used, the IPW values will need to be altered based on the new injector scaling. Use the following formula to some initial values:
New Cranking primer IPW = old IPW x [old injector scale / new injector scale]
In addition, the values from 7ºC through to -32ºC will need progressively larger corrections.

5.03-START – POST START ENRICHMENT % v TEMP

An engine will require enrichment for a few seconds after starting, particularly when cold. This extra fuel is progressively decreased to zero enrichment at a rate usually based on injection cycles. The table is for enrichment of the current FUEL MAP value. Eg an expected 38% enrichment at 20°C and only 8% increase at operating temperature.

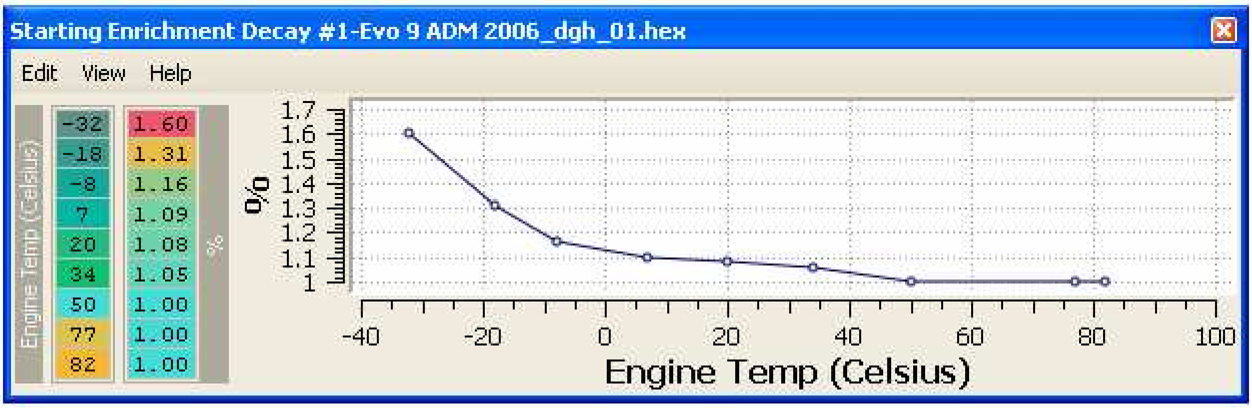
Figure 31: EcuFLASH – POST START ENRICHMENT % v TEMP - EVO 9



5.04-START – POST START ENRICHMENT DECAY v TEMP

This table controls the enrichment decay rate. Supposedly.

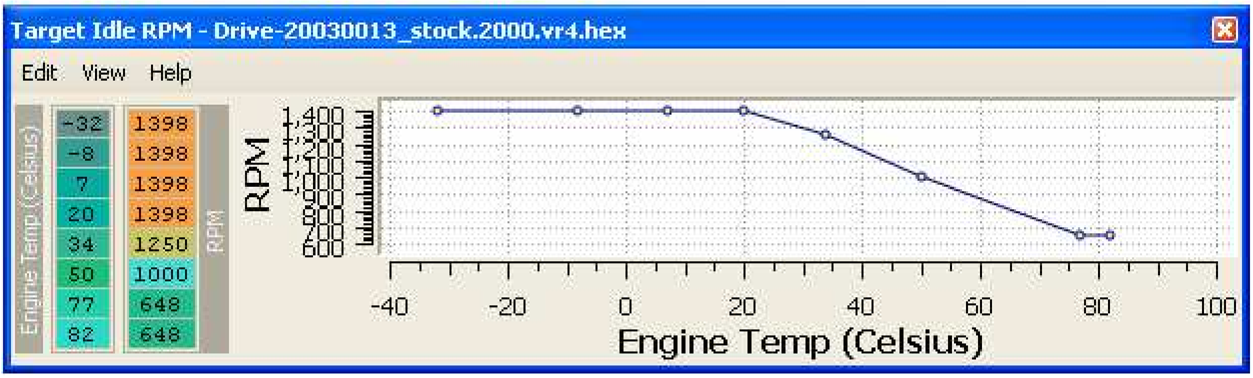
Figure 32: EcuFLASH – POST START ENRICH DECAY v TEMP - EVO 9



5.05-IDLE CONTROL- TARGET RPM v TEMP

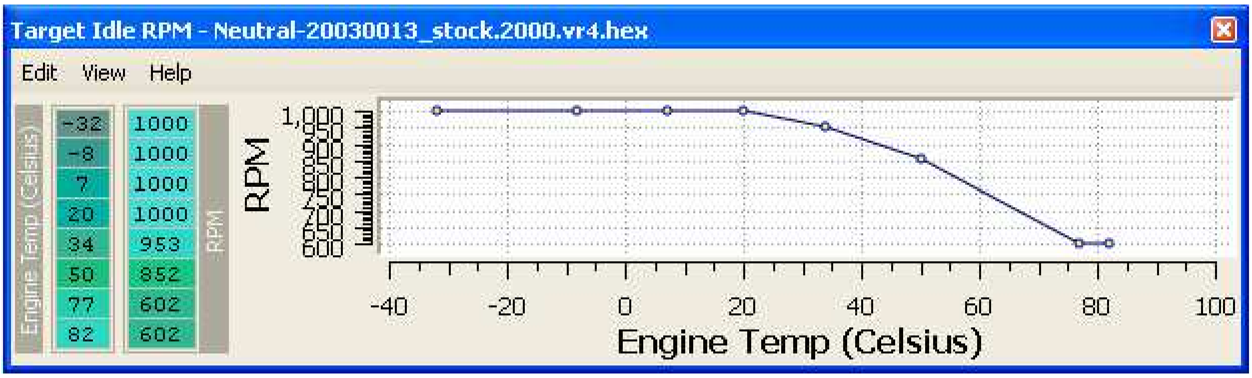
This is the desired, or target idle RPM when the vehicle is moving (Drive) against engine temperature.

Figure 33: EcuFLASH – TARGET IDLE v TEMP IN DRIVE – VR4



This is the desired, or target idle RPM when the vehicle is stationary (Neutral), against engine temperature. This table may require adjustment when using bigger cams.

Figure 34: EcuFLASH – TARGET IDLE RPM v TEMP IN NEUTRAL – VR4

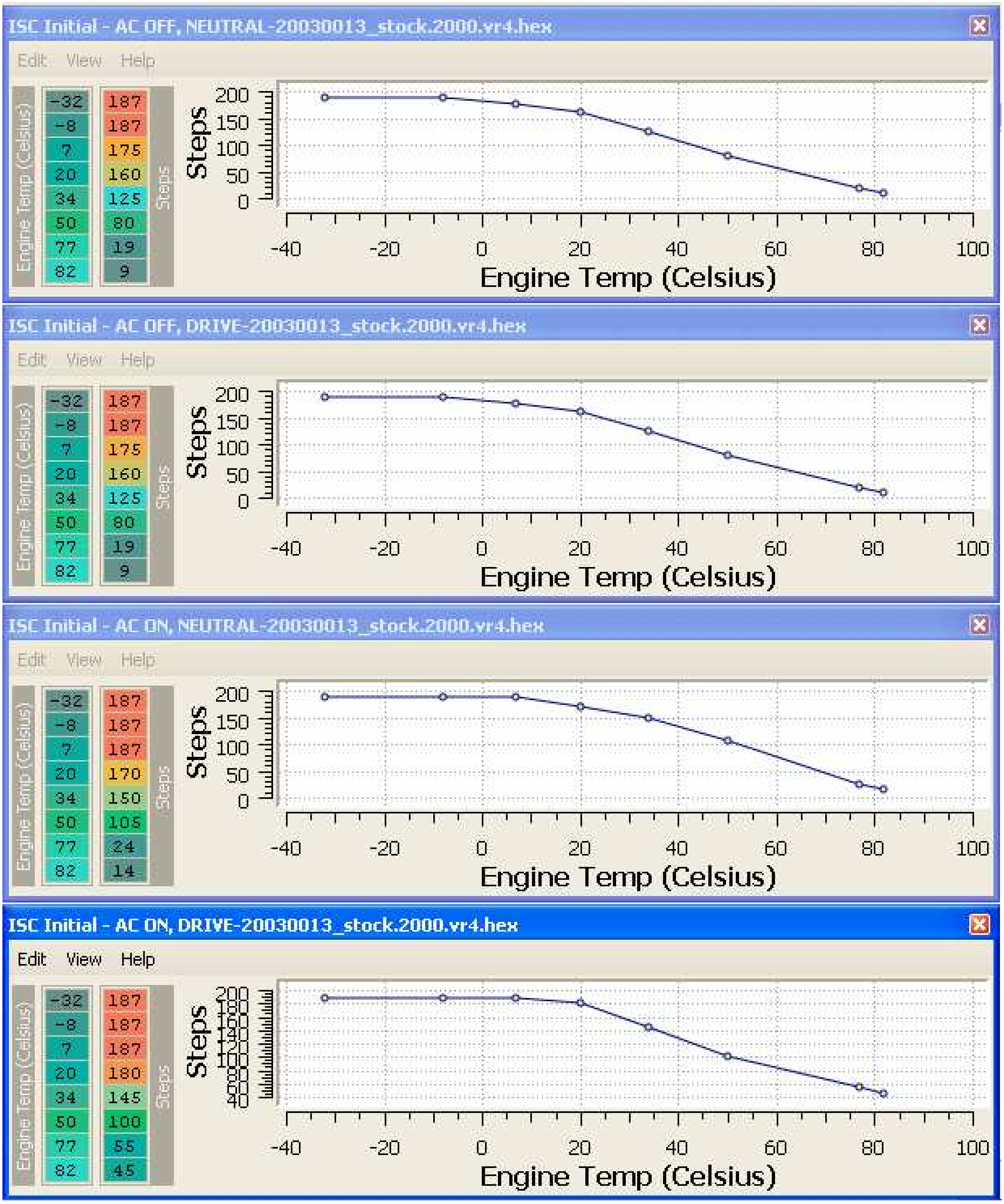


When changes are made to these two parameters, some adjustment is usually made to the ISC stepper-motor initial settings, so the engine does not overshoot the desired RPM, nor take a long time to settle at the desired RPM. The error between the preset initial steps and the required steps can be observed by logging the idle parameters with EvoScan, examining the resulting log with Excel, then reading the ISC error in the log. Do the log for a full warm-up cycle.

5.06-IDLE CONTROL – INITIAL STEPPERMOTOR POSITION

These four tables provide the initial idle stepper motor target position to quickly get the engine idling at the target RPM. If the target RPM is changed significantly, then these should be tweaked to compensate. Otherwise, idle response will be slow.

Figure 35: EcuFLASH – ISC INITIAL STEPS v TEMP – VR4



5.07-IDLE CONTROL - TIMING at IDLE & IDLE STABILITY

The Mitsubishi engineers have not setup this function as a table (as was expected), but have implemented an aggressive idle control strategy using ignition timing adjustment. This is a code based embedded algorithm with two adjustable parameters. The idle stepper motor is used to get the air flow in the right range for the desired idle speed, but the timing algorithm adjustment is used to dynamically keep the idle at the set/desired speed.

So, if you were wondering why your idle ignition timing is bopping all over the place, this is the reason.

Two ROM variables have been found pertaining to idle stability v timing control. The first is a sensitivity variable (EVO=128, VR4=121), and the second a maximum timing adjustment limit variable (defaults are EVO7 GTA=±8°, EVO9/VR4 = ±3°).

The general equation for the timing adjustment is:

$$\text{DeltaTiming} = x/64 * (y / 500 * \text{TargetIdle} - 0.256 * \text{CurrentEngineSpeed})$$

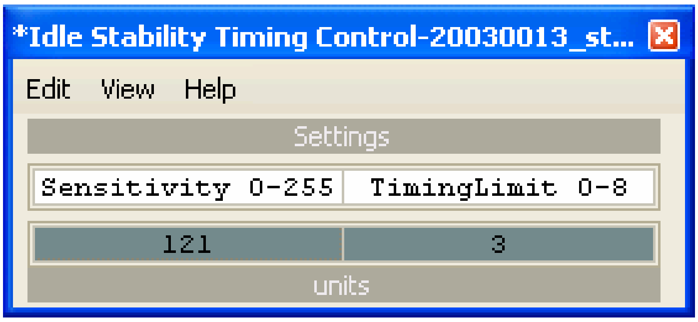
Where:
x = the sensitivity.
y = the limit.

To illustrate this, if the TargetIdle=800 but the CurrentEnginSpeed=950, then the resulting DeltaTiming would be -7.2° from the ignition map. It is aggressive and very effective.

If the TIMING LIMIT valve is (temporarily) set to zero, the base timing can be verified with a timing light as the ECU would then run the 5 or whatever is set in the idle area of the map without all the fritzing around.

In practice though, most tuners will not have any reason to alter the way this works. Its just nice to know how it works! This parameter has not been defined in the XML.

Figure 36: EcuFLASH – IDLE STABILITY TIMING CONTROL – VR4



SECTION 6 – FALSE KNOCK TUNING

6.01-FALSE KNOCK TUNING - KNOCKSUM & OCTANE NUMBER

KNOCKSUM and OCTANE NUMBER are the parameters which combine to give the final ignition timing value, operating temperature corrections aside.

KNOCKSUM is generated by the ECU, from the input from the knock sensor and it has several tables and variables that can be manipulated to subtly alter the final KNOCK SUM result. This has particular relevance to the tuning fraternity, as some engines exhibit what has been described as "phantom" or "false" knock. This becomes even more important when engine internals, like forged pistons, are added to the equation. It has been reported that some aftermarket clutches can have an effect on false knock as well as general engine aging.

OCTANE NUMBER controls the interpolation between the HI-OCTANE and LO-OCTANE fuel and ignition maps and is a dynamic number stored in memory. The OCTANE NUMBER starts off at a value of 255, for 100%. HI-OCTANE map operation. The maximum value is not quite an arbitrary number, as its value would have an affect on the driving time it would take to transit from fully Hi to fully LO-OCTANE map operation for a given rate of knock.

The following equation describes the method for deriving the new ignition timing from the two timing maps:

$$(((255 - \text{octane\#}) \times \text{LO-MAP}) + (\text{octane\#} \times \text{HI-MAP})) \div 255$$

Using a LO-MAP value of 10° and a HI-MAP value of 20°, with an octane number of 128 will yield a ignition timing value of 15, a 50% shift. With the same map values, and an octane number of 250, ie 5 counts have been deducted, this yields an ignition timing value of 19.8°. Only a 2% shift, so the shift from the HI-MAP to the LO-MAP is gradual.

If the KNOCKSUM is greater than 5 then the OCTANE NUMBER will be decreased by 1 on a timer.

If the KNOCKSUM is 4 or 5 then the OCTANE NUMBER is left alone.

If the KNOCKSUM is less than 4, then the OCTANE NUMBER will be increased by 1 on a timer. However, OCTANE NUMBER will not increment until the engine coolant temperature is above a preset value.

In the short term, the timing will be reduced directly, based on the KNOCKSUM. Disassembly of the code has revealed that each knock count will reduce the timing by approximately 0.34 of a degree, thus a knock count of three will result in 1° of timing pulled from the ignition map.

It has been reported that the octane number recovers to normal or near normal, quite quickly if the engine experiences knock-free operation above the KNOCK TRHESHOLD, which is a LOAD v RPM table. If it sees no knock, it will adjust the octane number back quickly.

This is good news, as it allows for rapid recovery by adding some better fuel or octane enhancer product if a dud batch of fuel has been supplied.

The ECU holds the current OCTANE NUMBER when the ignition is switched off. If for example, a dyno session produced a number of knocks and you want to get the OCTANE NUMBER quickly back to 100%, the ECU will have to be disconnected.

Additionally, OCTANE NUMBER is reported to have an affect on the boost control settings, though no details are available as yet.

When the OCTANE NUMBER = 0, the ECU use 100% of the low octane map.

However, your timing will be less than the LO-OCTANE map, as the ECU is still pulling timing. In the short term, knock control is still pulling 1° of timing per 3 knock counts. So, if you have maxed your KNOCKSUM out to 36 counts of knock, you will be running 12° less timing than the ignition maps call. Thus the LO-OCTANE map acts as a long-term timing adjustment.

If false knock has reduced your OCTANE NUMBER to zero, KNOCKSUM can continue to pull timing to the MAXIMUM RETARD value. This has been set on most ECUs to -10º. This parameter is starting to appear on some definition files.

So, to sum-up, you want to end-up with a tune that works with the knock sensor and gives 0-2 knock counts to prevent timing being pulled and running 100% on your HI-OCTANE ignition map.

6.02-FALSE KNOCK TUNING – KNOCKBASE

KNOCKBASE is the term used to describe the dynamic average noise threshold. When an incoming signal spike from the knock sensor/filter/amplifier system exceeds this level, it is regarded as knock.

The KNOCKBASE level is derived from the knock sensor signal level, after filtering, and then being passed through a dual gain amplifier. The knock sensor amplifier system can switch from gain=x3 to gain=x1. This is used to give the system a high dynamic range and possibly to prevent input signal overload. The amplifier operates at high gain on low level signals. The resulting level as read by the internal analog to digital converter is then multiplied by the KNOCK MULTIPLIER value and the single/triple gain adders applied.

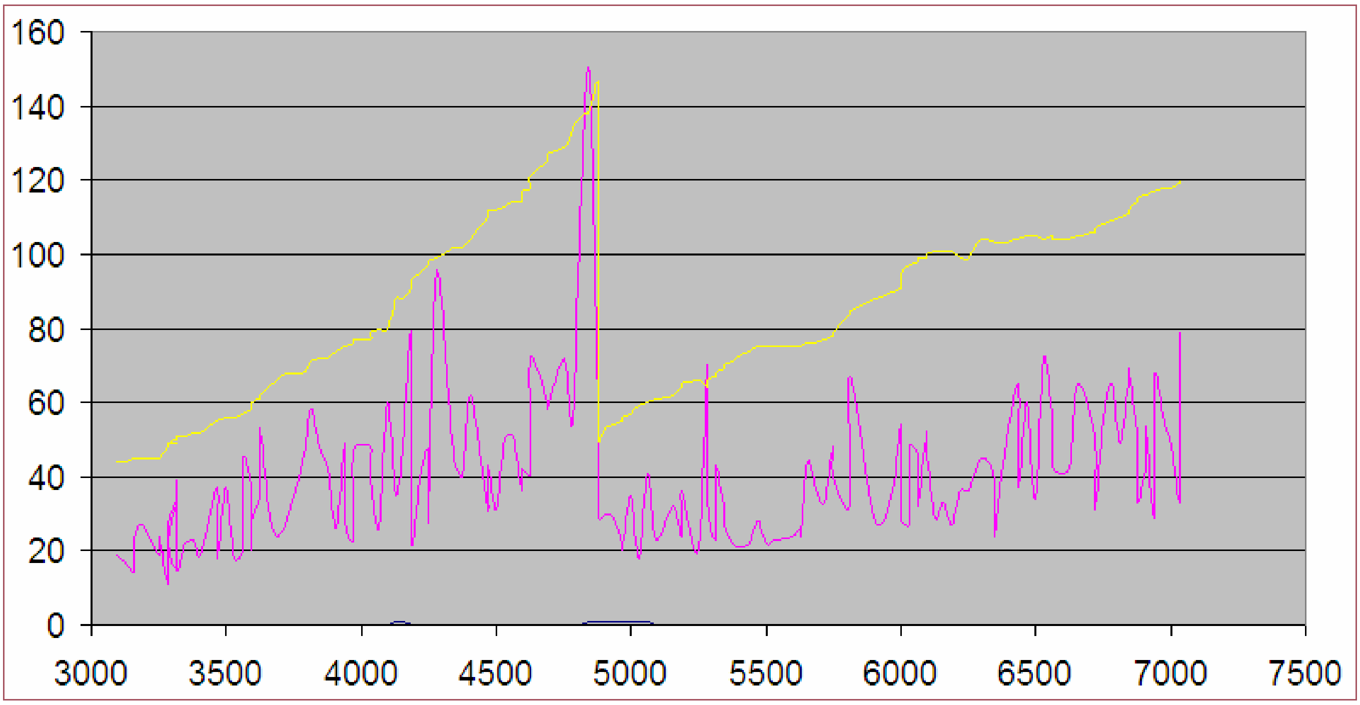
The multiplier is used to multiply the difference between the present filtered knock ADC and the long term average knock ADC, and the result is divided by the long term average knock ADC.

This is a dynamic noise reference level in effect, which has the ability to learn the engines noise v rpm characteristics.

To update KNOCKBASE, the ECU takes the old value and multiplies it by 7, adds the latest knock free noise level, then divides by 8. So it takes 8 ignition events to fully update the KNOCKBASE.

The figure below shows a logged power pull from 3000rpm to 7000rpm. The yellow line is the ECU generated KNOCKBASE, that the multipliers adjust. The pink line is the knock sensor signal after the filter and switched-gain amplifier. The gain transition point can be seen at about 4800rpm. Where the pink knock sensor signal "pokes" through the yellow curve you get a knock count, which is added to the current KNOCKSUM value.

Figure 37: KNOCKBASE & KNOCK EVENT - jcsbanks



The main point of this graph is to show the sudden drop in KNOCKBASE and KNOCKFILTADC in the middle of the full throttle pull from 3000 to 7000 RPM.

The gain is suddenly divided by 3. The CPU changes an output port that switches the gain on the knock amplifier in the ECU before it reaches the CPU. This switch is triggered by KNOCKBASE reaching about 140.

The level/gain change is so the amplifier and analog to digital converter have headroom to see big spikes and to help signal to noise ratio in a very volatile raw signal. It's switching is slick and comprehensively controlled by the ECU.

Recent versions of EvoScan can log KNOCKBASE at MUT6B and KNOCKFILTADC at MUT6A.

6.03-FALSE KNOCK TUNING – REAL or FALSE KNOCK?

The knock events that you have logged have to be assessed as to whether they are real knock or false knock. There are several ways this can be done. A very useful tool to assist with knock and ignition tuning is a set of "DET-CANS".

Start by closely examining your log to see where the knock occurs and if the knock is random or repetitive and predictable. If you have DET-CANS, use them to help confirm suspected real detonation. It should be pointed out however that as the ECU aggressively fights to reduce detonation, you may only fleetingly hear the event. Especially if there is a lot of other engine related noise.

Real detonation will respond to reducing the ignition timing and/or increasing the fuels octane rating. Light-tune engines having to run on fuel with an octane rating less than 98RON will benefit from reducing the timing of the cells where knock occurs by 1-2 degrees.

False knock can have many mechanical causes that can be rectified without diving into the ECU. Some examples as follows:

1. Valve-lash adjusters. These can and should be replaced if they are the problem. Use electronic DET-CANS to diagnose the problem.
2. Plumbing rattles, intercooler, exhaust, whatever. Somewhat harder to find sometimes. Use electronic DET-CANS to diagnose the problem.
3. Forged pistons and piston slap. Some combinations cause a problem, others don't. Tough one, short of changing the pistons, better to fix with the ECU. Note that you can hear piston slap with good electronic DET-CANS.
4. Balance shafts removed. Affects some cars, not others. Fix via the ECU.
5. Clutch rattle. Some twin-plate clutches have been reported as causing a problem. Difficult to diagnose.

6.04-FALSE KNOCK TUNING – DET-CANS

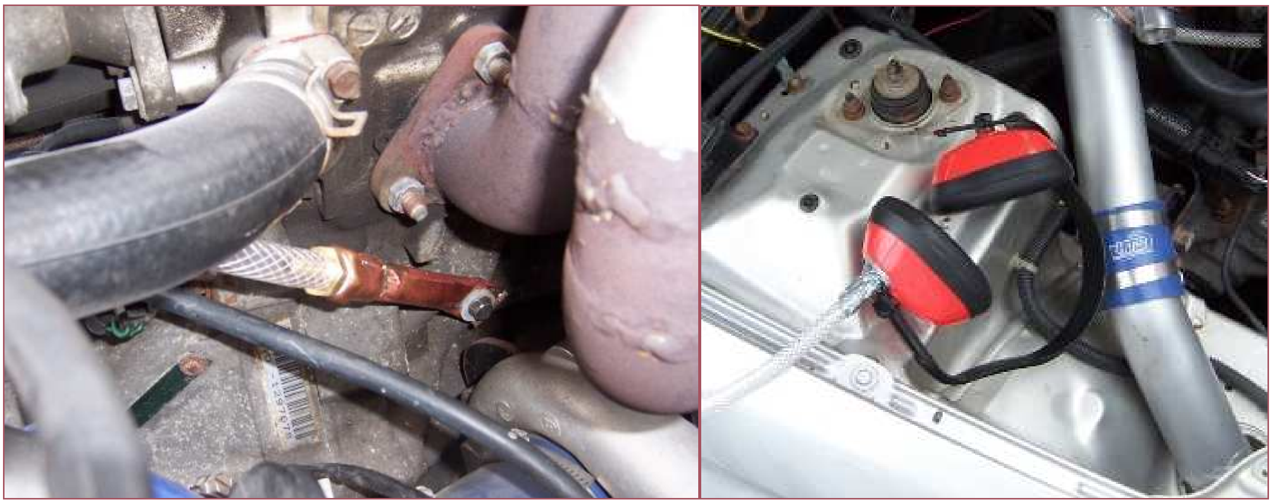
As mentioned before, DET-CANS can be of great assistance in resolving knock and/or KNOCKSUM.

These may be either a simple hose to a pair of ear-muffs or a full microphone /amplifier/headset affair. They can be purchased or built by the home tuner.

There is a caveat when using DET-CANS on the EVO ECU. The ECU works aggressively to save the engine from damaging detonation by immediately pulling timing. The net result of this is a detonation episode may only last for 5 to 10 counts before being knocked on the head, so-to-speak. So you may not even hear it with the DET-CANS. You should certainly hear any prolonged real detonation though.

Figure 38: KNOCK TUNING, ELECTRONIC DET-CANS

Figure 39: KNOCK TUNING, PASSIVE DET-CANS



6.05-FALSE KNOCK TUNING – ELIMINATING FALSE KNOCK

The knock events that you have logged have been assessed as false knock, so how do we get rid of the problem?

There are three ECU functions that can be altered:

1. The LOAD THRESHOLD v RPM table.
2. The MULTIPLIER table (EVO9) or MULTIPLIER LOW/MID/HIGH for EVO 7-8.
3. The ADDER tables.

6.06-FALSE KNOCK TUNING – ADJUSTING LOAD THRESHOLD

Note that the low rpm table cell all have a load value of 159.4. Because the load scaling is 5/8x, the maximum decimal value that can be put in the table is 255*5/8=159.4. This means that KNOCKSUM cannot be disabled at loads above 160.

This is probably a good idea but it also means that Mitsubishi don't particularly care if the engine rattles below 2000rpm. In other words you wont loose your OCTANE NUMBER just because of a crappy hill start that got the engine detonating a bit.

The LOAD THRESHOLD v RPM table values can be raised to say 100, if the false knock was at 90 (for a given rpm). If the value is raised, it will eliminate that false knock condition, at the expense of having no knock protection below load 100 at that rpm.

Figure 40: KNOCK TUNING, LOAD THRESHOLD V RPM - EVO 9

500	1000	1500	2000	2500	3000	3500	4000	4500	5000
159.4	159.4	159.4	159.4	60.0	70.0	70.0	70.0	70.0	80.0

This may be an acceptable solution in some instances. Certainly there are tuners who have done this and got a good result and cured their problem, but there is a better way forward.

6.07-FALSE KNOCK TUNING – ADJUSTING MULTIPLIER

The MULTIPLIER v RPM table provides a way to alter the KNOCKBASE profile, thus telling the ECU there is more engine noise at this load/rpm point, without loosing knock control.

Figure 41: KNOCK TUNING, KNOCK MULTIPLIER V RPM - EVO 9

jcsbanks

"I would think of this as a KNOCKBASE predictor - ie the adaptive system is retrospective since it can only influence the KNOCKBASE upwards after the heavily filtered and slightly delayed (the digital filtering used adds a delay) noise level has increased. However, the right programming of the multiplier (and/or adder) by RPM will give a combination of adaptive and predictive.

The multipliers increase the KNOCKBASE, so if you increase the multiplier for a given RPM by x%, then you increase KNOCKBASE by x% also. To recap, KNOCKBASE is the level that the knock sensor noise has to exceed after each spark plug fires to cause that combustion event to register as knock and increase the KNOCKSUM. It will do this for every combustion event, so a small breach can quickly build to a big KNOCKSUM, so a small but persistent breach of KNOCKBASE will give big problems. If you think about how it is designed, it makes sense that if this was real knock and not going away quickly with KNOCKSUMs applied to the ignition timing that it would be appropriate to get aggressive with it quickly to prevent engine damage. By use of the OCTANE NUMBER, the ECU will always aim to have KNOCKSUMs of 5 or less in the long term."

Table 3 TYPICAL VR4 MULTIPLIER PARAMETERS

BAND	RPM	STOCK	+10%	+15%	+20%
LOW	0-3800	13	14	15	16
MID	3800-4800	18	20	21	22
HIGH	4800-8000	20	22	23	24

Somewhat encouraging to note that at the time of writing, nobody has reported having to raise the multiplier by more than 20% to clear false knock!

6.08-KNOCK CONTROL

KNOCKSUM and OCTANE NUMBER are the parameters which combine to give the final ignition timing value, operating temperature corrections aside.

OCTANE NUMBER controls the interpolation between the hi-octane and lo-octane fuel and ignition maps and is a dynamic number stored in memory with a maximum value of 255.

KNOCKSUM is generated by the ECU, from the input from the knock sensor and it has several tables and variables that can be manipulated to subtly alter the final KNOCK SUM result. This has particular relevance to the tuning fraternity, as some engines exhibit what has been described as “phantom” or “false” knock. This becomes even more important when engine internals, like forged pistons, are added to the equation. It has been reported that some aftermarket clutches can have an effect on false knock as well as general engine aging.

KNOCKBASE is the term used to describe the dynamic average noise threshold. When an incoming signal spike from the knock sensor/filter/amplifier system exceeds this level, it is regarded as knock.

The KNOCKBASE level is derived from the knock sensor signal level, after filtering, and then being passed through a dual gain amplifier. The knock sensor amplifier system can switch from gain=x3 to gain=x1. This is used to give the system a high dynamic range and possibly to prevent input signal overload. The amplifier operates at triple gain on low level signals. The resulting level as read by the internal analog to digital converter is then multiplied by the KNOCK MULTIPLIER value and the single/triple gain adders applied. This is a dynamic noise reference level in effect, which has the ability to learn the engines noise v rpm characteristics.

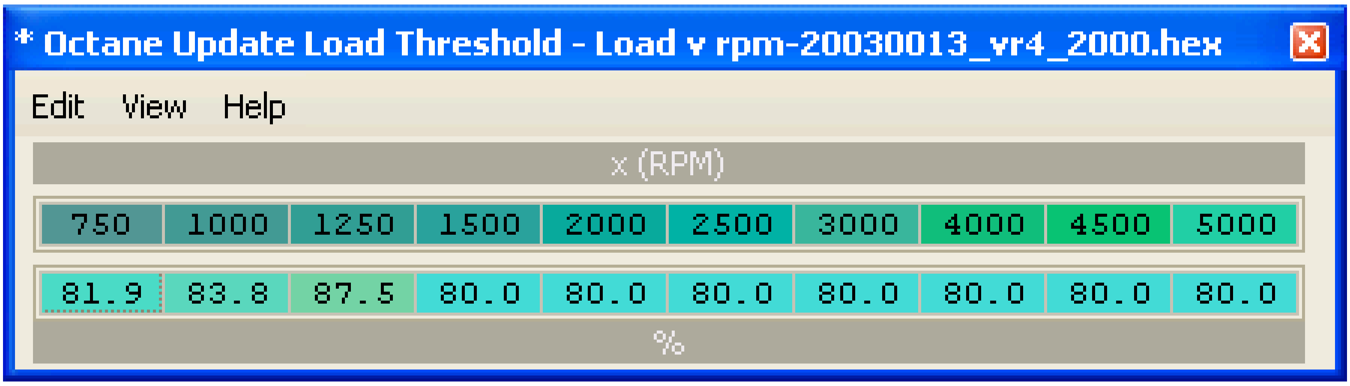
A typical knock sensors specifications:

VOLTAGE OUTPUT:	27mV ±10mV/g.
FREQUENCY RESPONSE:	1kHz to 18kHz, ±15% linearity.
LOAD RESISTANCE:	100kΩ.
OPERATING TEMPERATURE:	-40°C to +150°C.

6.09-KNOCK CONTROL – OCTANE UPDATE THRESHOLD

The engine has to operate above the OCTANE UPDATE THRESHOLD, knock-free, before the octane number will be incremented. These settings work well and there is little point in altering them. It is however useful to know where to run the engine in order to quickly recover the best possible OCTANE NUMBER.

Figure 42: EcuFLASH – OCTANE UPDATE LOAD THRESHOLD – VR4

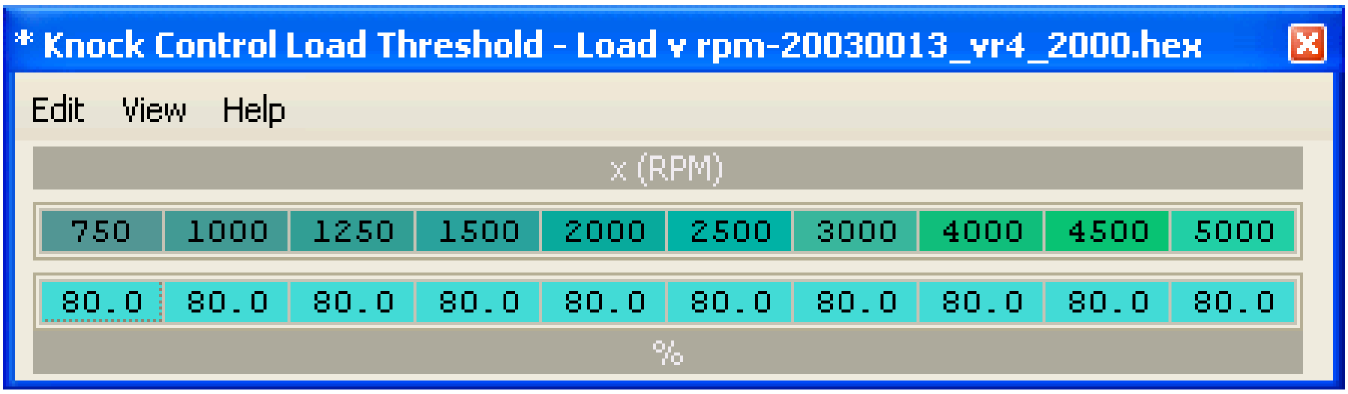


750	1000	1250	1500	2000	2500	3000	4000	4500	5000
81.9	83.8	87.5	80.0	80.0	80.0	80.0	80.0	80.0	80.0

6.10-KNOCK CONTROL – LOAD v RPM THRESHOLD

This table sets the load and rpm point where the knock control becomes fully active. On some ECUs it appears to be active below, but at most half as sensitive.

Figure 43: EcuFLASH – KNOCK CONTROL, LOAD V RPM THRESHOLD – VR4



750	1000	1250	1500	2000	2500	3000	4000	4500	5000
80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0

Tuners have been able to eliminate false knock that occurred at load = 100 and rpm = 2700 by raising the threshold at that rpm point.

SECTION 7 – PERIPHERY BIT TUNING

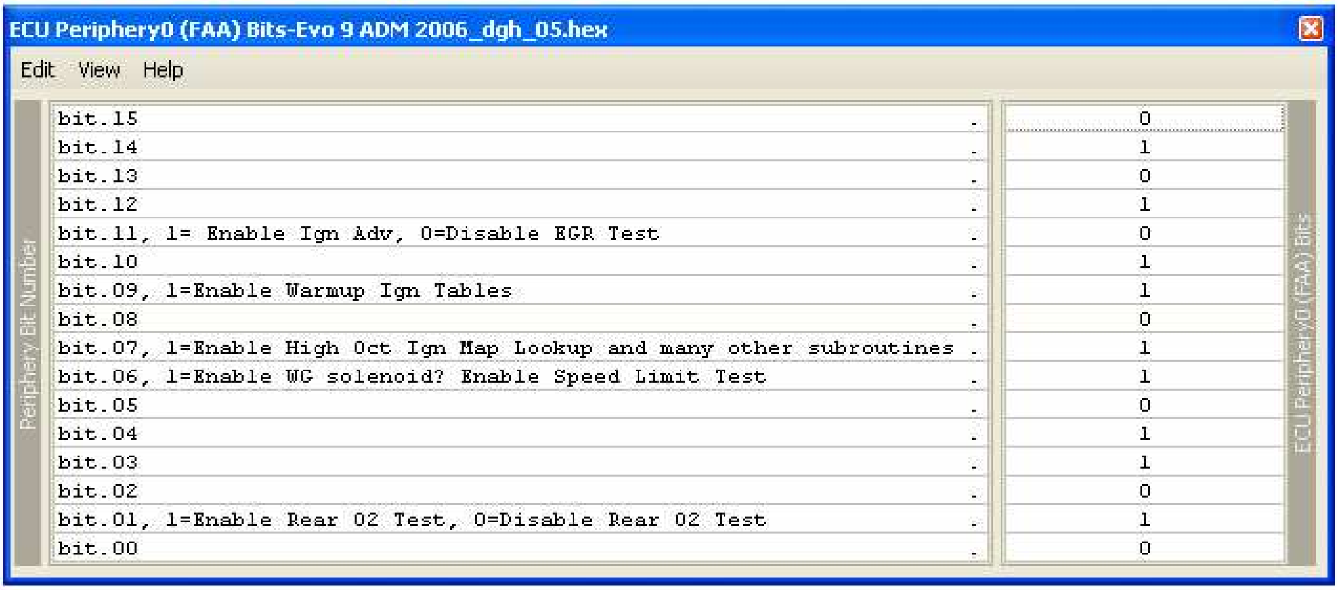
7.01-PERIPHERY BITS INTRODUCTION

There are six sets of sixteen bit data parameters, called the Periphery bits, which are mainly single bit controls to enable or disable functions/attributes/tests/fault codes. The data can be presented in raw hex format, or as bits with some explanatory text if the function is known (and the xml file up-dated). Not all the bits have been defined, **mrfred, jcsbanks, Mattjin, acamus** and others are continuing to work on identifying parameters as and when they can.

The usual arrangement is a 0 will disable the function, a 1 will enable it. Some bits control several functions at the one time. Some are used in conjunction with another bit as an “or” function for the parameter.

7.-02-PERIPHERY 0 - BIT PARAMETERS

Figure 44: EcuFLASH – PERIPHERY0, DATA BITS - EVO 9



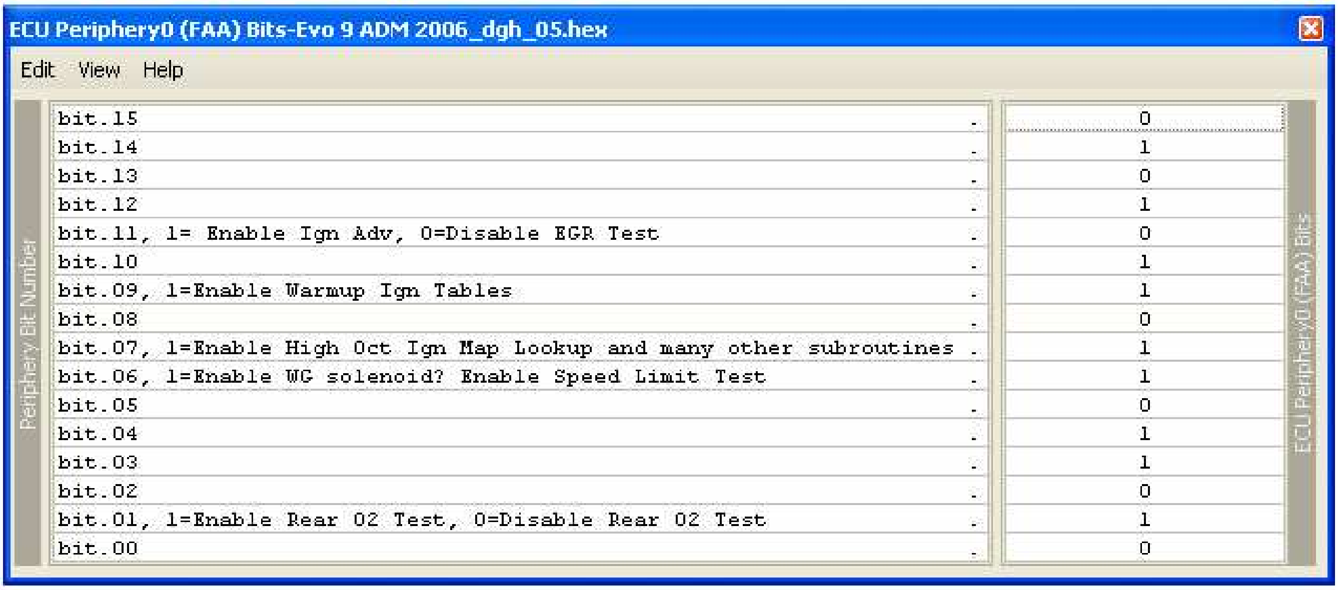
bit.15	0
bit.14	1
bit.13	0
bit.12	1
bit.11, 1= Enable Ign Adv, 0=Disable EGR Test	0
bit.10	1
bit.09, 1=Enable Warmup Ign Tables	1
bit.08	0
bit.07, 1=Enable High Oct Ign Map Lookup and many other subroutines	1
bit.06, 1=Enable WG solenoid? Enable Speed Limit Test	1
bit.05	0
bit.04	1
bit.03	1
bit.02	0
bit.01, 1=Enable Rear O2 Test, 0=Disable Rear O2 Test	1
bit.00	0

Periphery0 seems to be the most useful at the moment. I have edited my definition files to better present the current data lists. Periphery bits can also be edited/changed entering a new hex value into the table. The factory set hex value should be 56DA for an EVO 9.

If you are using a high-flow front pipe, you may be getting some rear O2 sensor fault indications on the CEL indicator. While it is possible to circumvent this by adding a spacer to the rear O2 sensor, this may then cause the sensor to rub on the under-body. Setting Periphery0 bit 01 to zero and Periphery 2 bit 01 to zero will unfortunately NOT disable the rear O2 test completely and the ECU will still throw a CEL. To date, the only other fix is **mrfred** & **tephra**s rear O2 simulator.

7.-03-PERIPHERY 1 - BIT PARAMETERS

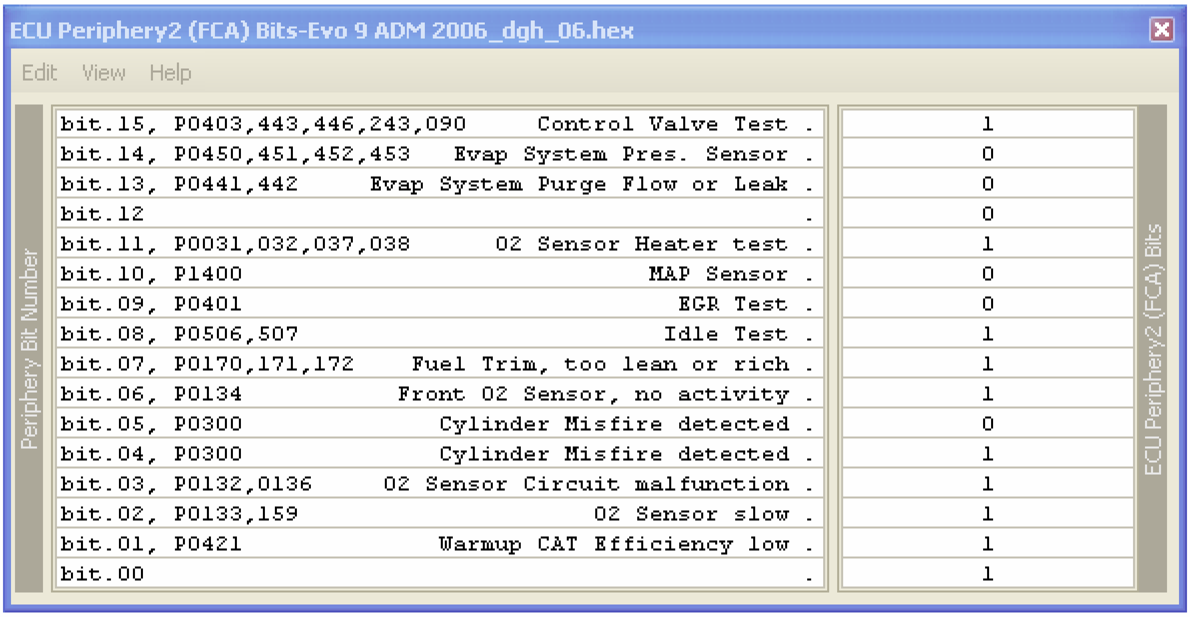
Figure 45: EcuFLASH – PERIPHERY1, DATA BITS - EVO 9



Periphery Bit Number	ECU Periphery0 (FAA) Bits
bit.15 .	0
bit.14 .	1
bit.13 .	0
bit.12 .	1
bit.11, 1= Enable Ign Adv, 0=Disable EGR Test .	0
bit.10 .	1
bit.09, 1=Enable Warmup Ign Tables .	1
bit.08 .	0
bit.07, 1=Enable High Oct Ign Map Lookup and many other subroutines .	1
bit.06, 1=Enable WG solenoid? Enable Speed Limit Test .	1
bit.05 .	0
bit.04 .	1
bit.03 .	1
bit.02 .	0
bit.01, 1=Enable Rear O2 Test, 0=Disable Rear O2 Test .	1
bit.00 .	0

7.-04-PERIPHERY 2 - BIT PARAMETERS

Figure 46: EcuFLASH – PERIPHERY2, DATA BITS - EVO 9



ECU Periphery2 (FCA) Bits-Evo 9 ADM 2006_dgh_06.hex

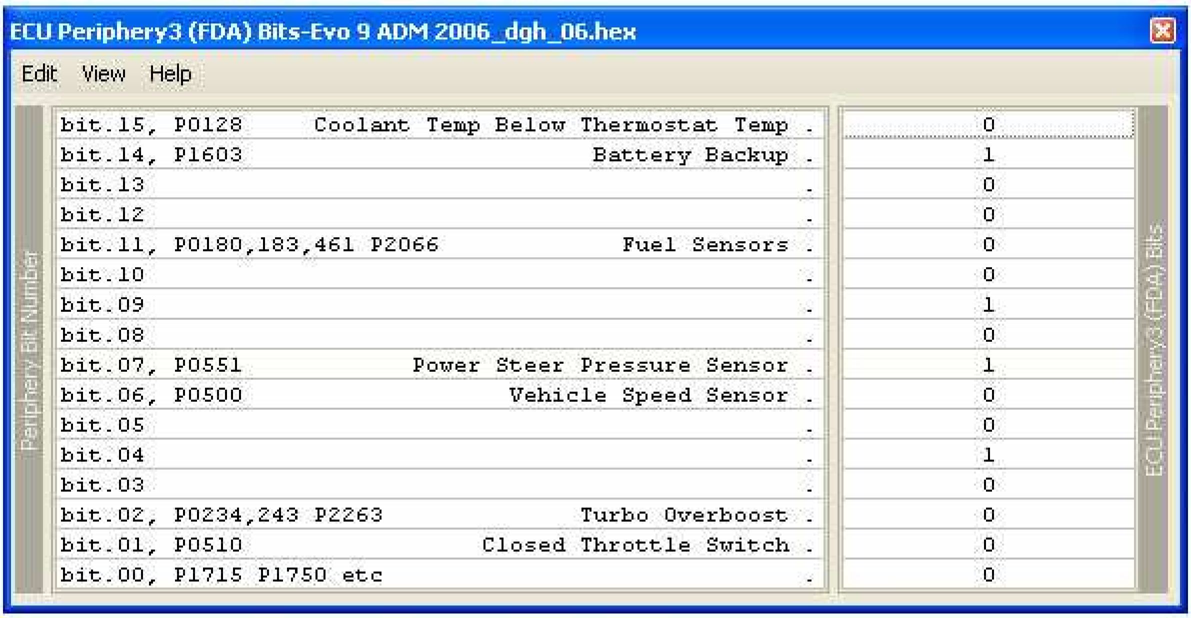
Edit View Help

Periphery Bit Number	ECU Periphery2 (FCA) Bits
bit.15, P0403,443,446,243,090 Control Valve Test .	1
bit.14, P0450,451,452,453 Evap System Pres. Sensor .	0
bit.13, P0441,442 Evap System Purge Flow or Leak .	0
bit.12 .	0
bit.11, P0031,032,037,038 O2 Sensor Heater test .	1
bit.10, P1400 MAP Sensor .	0
bit.09, P0401 EGR Test .	0
bit.08, P0506,507 Idle Test .	1
bit.07, P0170,171,172 Fuel Trim, too lean or rich .	1
bit.06, P0134 Front O2 Sensor, no activity .	1
bit.05, P0300 Cylinder Misfire detected .	0
bit.04, P0300 Cylinder Misfire detected .	1
bit.03, P0132,0136 O2 Sensor Circuit malfunction .	1
bit.02, P0133,159 O2 Sensor slow .	1
bit.01, P0421 Warmup CAT Efficiency low .	1
bit.00 .	1

To kill the P0300 code, set Periphery2, bits 4 and 5, to 0.

7.-05-PERIPHERY 3 - BIT PARAMETERS

Figure 47: EcuFLASH – PERIPHERY3, DATA BITS - EVO 9



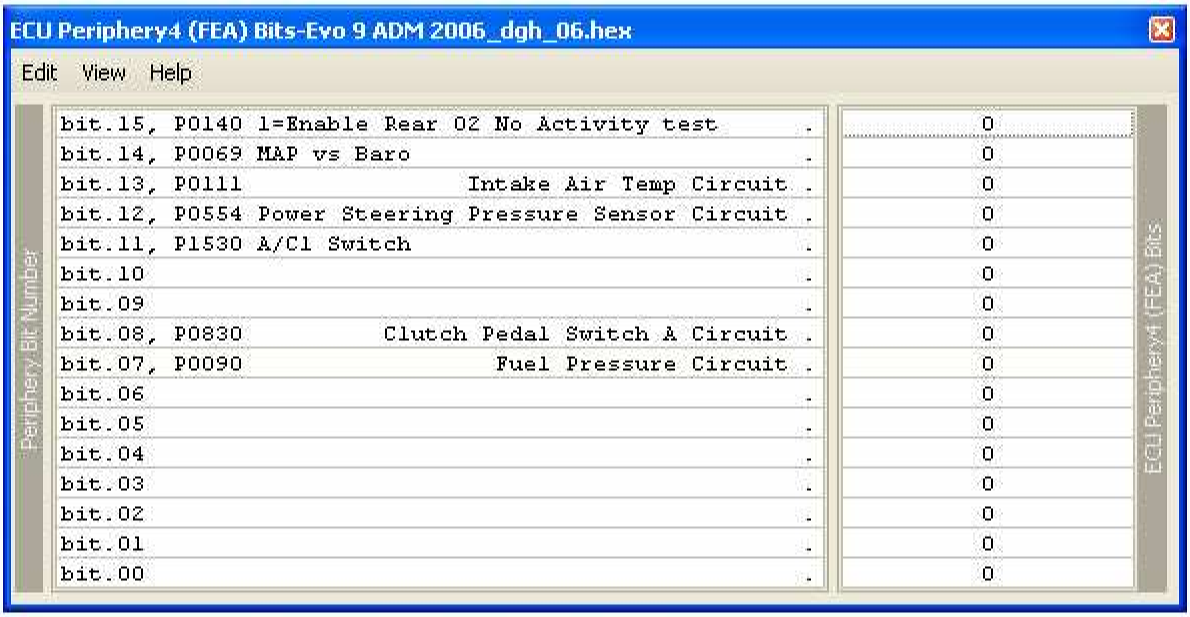
ECU Periphery3 (FDA) Bits-Evo 9 ADM 2006_dgh_06.hex

Edit View Help

Periphery Bit Number	ECU Periphery3 (FDA) Bits
bit.15, P0128 Coolant Temp Below Thermostat Temp .	0
bit.14, P1603 Battery Backup .	1
bit.13 .	0
bit.12 .	0
bit.11, P0180,183,461 P2066 Fuel Sensors .	0
bit.10 .	0
bit.09 .	1
bit.08 .	0
bit.07, P0551 Power Steer Pressure Sensor .	1
bit.06, P0500 Vehicle Speed Sensor .	0
bit.05 .	0
bit.04 .	1
bit.03 .	0
bit.02, P0234,243 P2263 Turbo Overboost .	0
bit.01, P0510 Closed Throttle Switch .	0
bit.00, P1715 P1750 etc .	0

7.-06-PERIPHERY 4 - BIT PARAMETERS

Figure 48: EcuFLASH – PERIPHERY4, DATA BITS - EVO 9



SECTION 8 – INJECTOR TUNING

8.01-INJECTOR SETUP INTRODUCTION

The stock injectors on the VR4 and LEGNUM TT are DENSO units rated at 410cc/min. Generally speaking, the stock injectors will give you adequate fuel flow with a TBE, a better hot-side intercooler pipe and 15-17 lbs of boost by redline. Once you get cams, then it is advisable to get bigger injectors. If you fit a pair of TD04 turbos, or raise the boost above 18psi, then definitely get bigger injectors.

When you install bigger injectors, you will have to scale them properly and use the correct injector voltage latency, otherwise your car will idle poorly and stall on occasion, run rich and generally behave poorly.

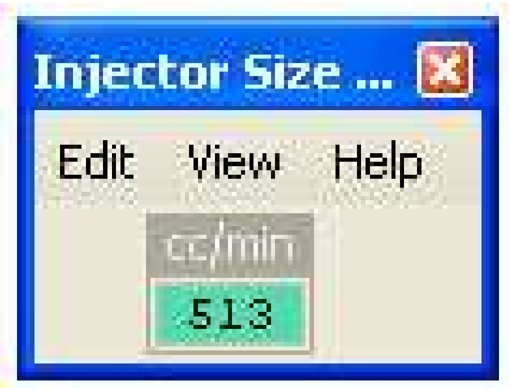
The simplest injector upgrade path is to use the 560cc/min injectors from the EVO 9. These injectors should be ok for power to 300kW and the scaling and latency data is known.

So how do you go about scaling your new injectors? The two injector parameters need to be changed, SCALING and LATENCY.

8.02-INJECTORS – INJECTOR SIZE SCALING

INJECTOR SIZE SCALING is used by the ECU to calculate the required IPW and will have a specific value for every type of injector that may be used.

Figure 49: EcuFLASH – INJECTOR SIZE SCALING - EVO 9



8.03-INJECTORS - LATENCY

The figures shown below are for three different injectors, the stock VR4, the EVO7 and the EVO9. These last two are your best choice for an upgrade. When upgrading the injectors, only change the latency values. Don't change the battery volt values.

Figure 50: EcuFLASH – INJECTOR LATENCY V BATTERY VOLTS – VR4

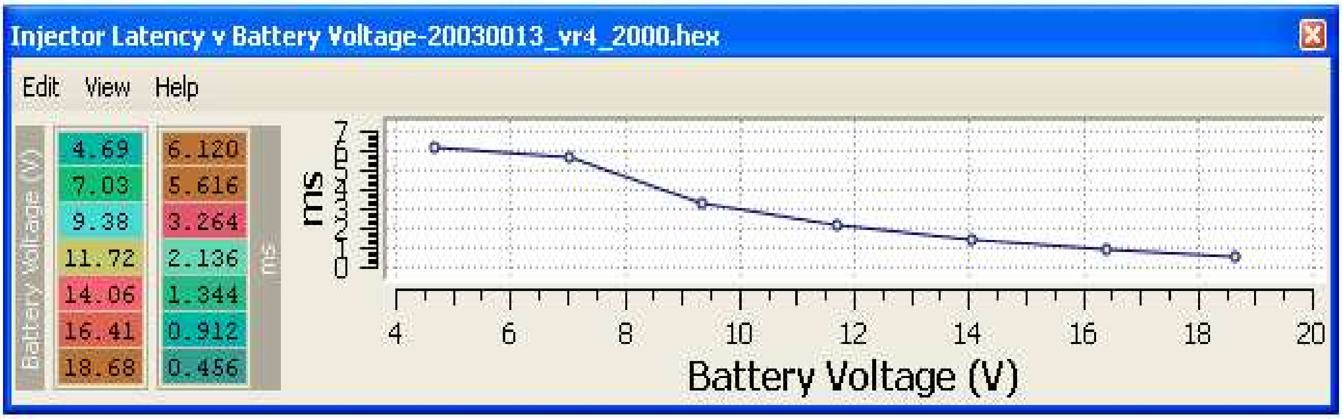


Figure 51: EcuFLASH – INJECTOR LATENCY V BATTERY VOLTS - EVO7

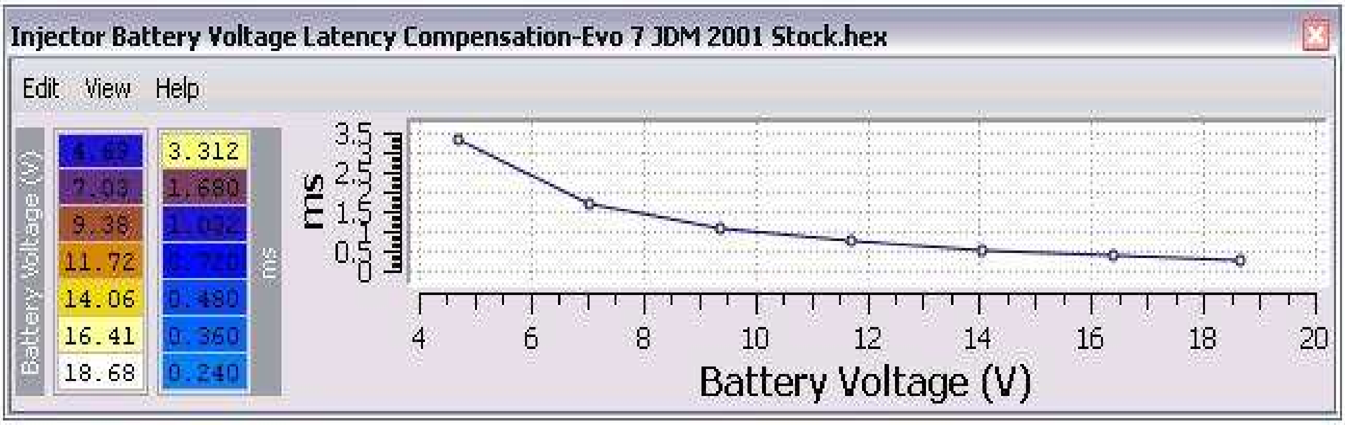
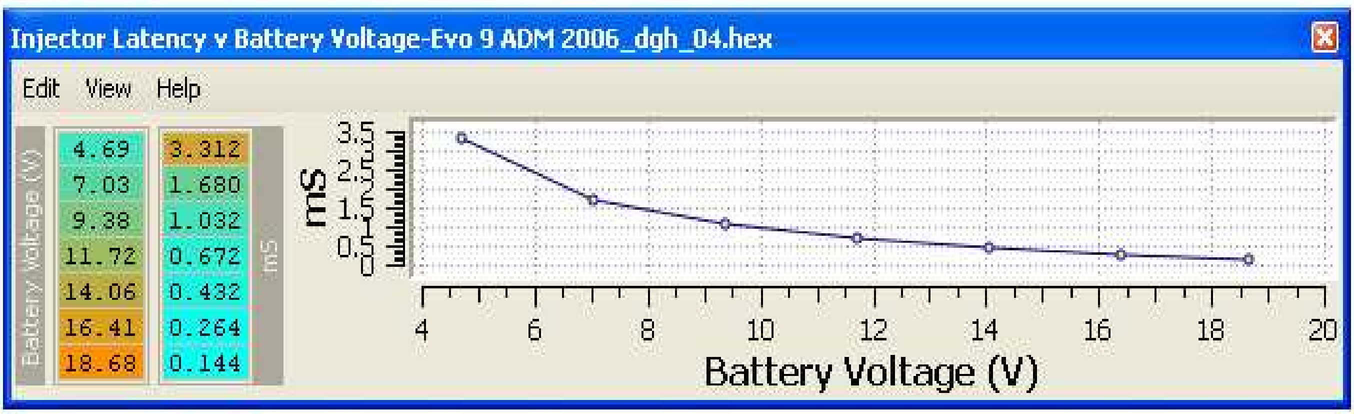


Figure 52: EcuFLASH – INJECTOR LATENCY V BATTERY VOLTS - EVO9



8.04-VERIFYING FUEL TRIMS on NEW INJECTORS

When installing larger injectors, use the following procedure:

Start and warm-up the engine.

Log fuel trims at idle and cruise for 15-20 minutes, using EvoScan.

If both trims are roughly the same, but positive, then you need to lower your injector scaling number.

If both trims are roughly the same, but negative, then you need to raise your injector scaling number.

If idle trim is more positive than cruise trim, or +, then you need to increase the dead-time / latency value.

If the idle trim is less positive than the cruise trim, or -, you need to decrease the dead-time / latency value.

The desired result is to have both the LTFT and the STFT at less than ±3%.

Note 1:The CRANKING IPW and POST START ENRICHMENT tables may require some adjustment, especially if using ethanol blend fuel. Alcohol fuels will need these table values raised 10-20% typically.

Note 2: 02 feedback is STFT and what the car is doing, at that very moment, to keep everything happy. LTFT is what the car has learned over time, to keep the car as close to stoic as possible. So if LTFT is at +12 and 02 feedback/STFT is at +3, then the car is adding +15% at that very moment to try and maintain stoic.

Note 3: LTFT range is ±12.5%. STFT range is ±25%.

Note 4: The trims also reset every time you re-flash the ECU. Otherwise, trims can be reset by disconnection the ECU from the harness.

SECTION 9 – ALS TUNING FOR POPS & BANGS

9.01-ALS TUNING – JUST the POS and BANGS PLEASE!

The VR4 and LEGNUM do not have the full ALS hardware as found on some EVOs, nor is the necessary routines in the ROM coding. However if you just want some pop-bang and flame action on throttle off, the requirements are easy. Simply do the IGNITION MAP alteration and increase the MAX RETARD LIMIT value to -15°. Instant pops and bangs! You could also try adding fuel in the corresponding load/rpm fuel map cells, say set the values to 10.0 instead of the usual 14.7.

9.02-ALS TUNING – MAXIMUM IGNITION RETARD SETTING

This parameter is factory set at -5° on the EVO7 and -10° on the EVO9 and VR4. This needs to be set at -15° to -20° for the best ALS effect.

The value is stored in ROM as a hex number, where -10° = CB = 203. Increment the hex value to get more retard. The retard value is raised by about 1/3 of a degree per increment. If the XML definition file for your ROM does weird things to the value when you try to alter the retard, try the adding the segment shown below to get this display shown. With this setup, the hex value can be incremented and you will see the decimal value change accordingly.

Figure 53: ALS TUNING, MAXIMUM IGNITION RETARD SETTING

Not all ROM definition files have the IGNITION MAX RETARD parameter defined, so you may have to add the following to your XML file. Also, the scaling has not been accurately de-coded, so I have worked-up an interim dual scaling and display the value in its raw hex state and in the expected negative degrees of timing. To alter the value, use the **[** and **]** keys on the hex number. The expected decimal value will increment or decrement in response as you change the hex value.

Also note that the address entered in the XML for the hex entry is incremented by one, so it is only showing a hex byte, not a word. This is to limit the maximum entry to hex FF / decimal 255. The frexpr formula in the decimal scaling is not exactly correct, as it does not work with signed integers. Just enter the value without the negative sign.

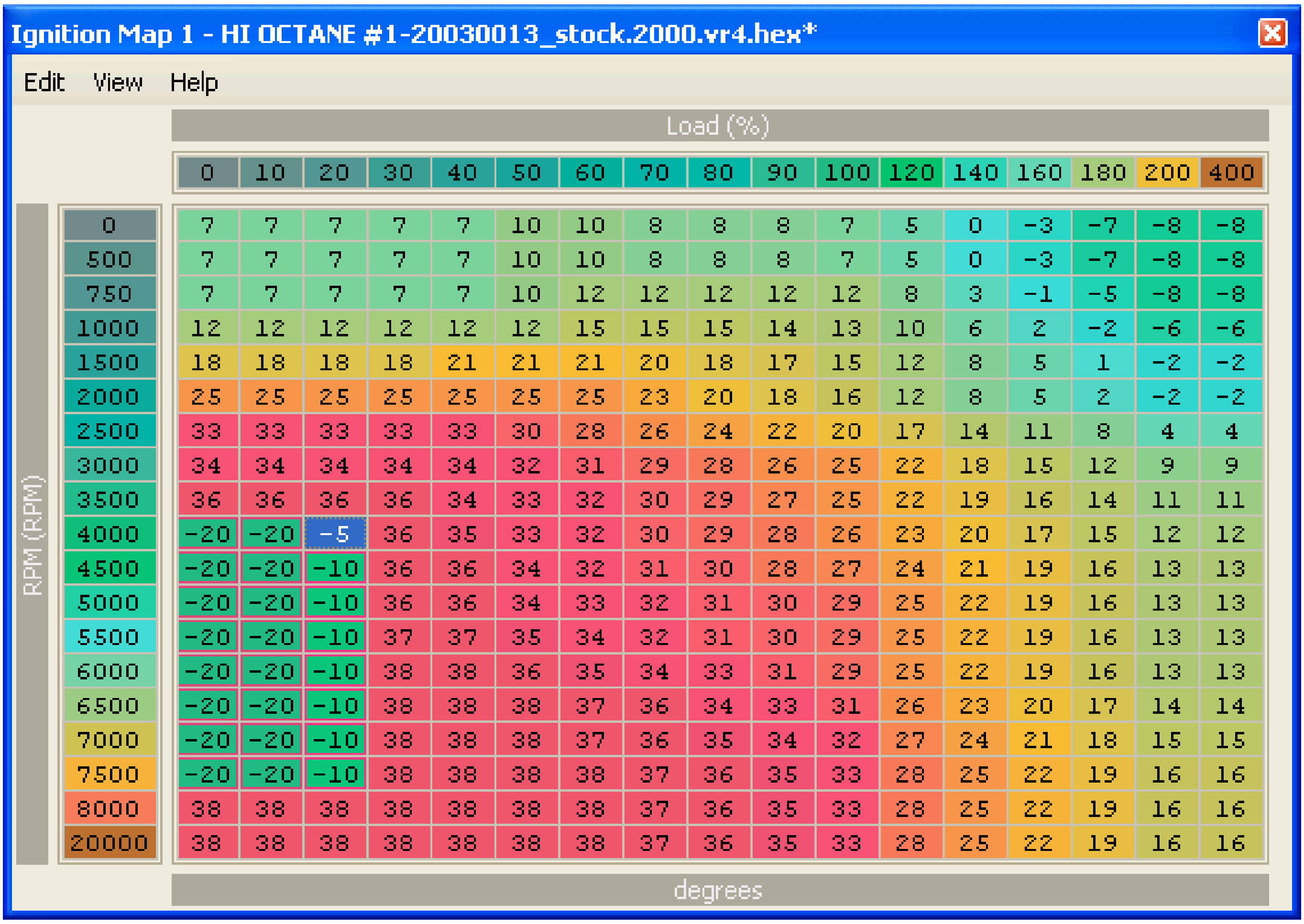
```
<scaling name="Retarduint16" units="MAX Retard Degrees - dec" toexpr="-(10+(x-203)/3)" frexpr="(x-10)*3+203" format="%.1f" min="-200" max="255" inc="0.3" storagetype="uint16" endian="big"/>

<scaling name="RetardHex8" units="MAX Retard Degrees - hex" toexpr="x" frexpr="x" format="%02X" min="0" max="255" inc="1" storagetype="uint8" endian="big"/>

<table name="Ignition Retard Max Degrees - dec" category="Timing" address="133e" type="1D" scaling="Retarduint16"/>

<table name="Ignition Retard Max Degrees - hex" category="Timing" address="133f" type="1D" scaling="RetardHex8"/>
```

9.03-ALS TUNING – RETARDING the IGNITION MAP

The ignition map shown below has been modified for either full ALS or for simple pops and bangs on throttle off when over 3000rpm.

The selection of 3000rpm was based on an EVO9 traveling at 110kph in 6th gear, so the system will not be pulling timing when cruising on the freeway. This is done to prevent excessive exhaust temperature rise and to keep the car driving nicely.

Figure 54: ALS TUNING, RETARDING THE IGNITION MAP – VR4



RPM \ Load (%)	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	400
0	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
500	7	7	7	7	7	10	10	8	8	8	7	5	0	-3	-7	-8	-8
750	7	7	7	7	7	10	12	12	12	12	12	8	3	-1	-5	-8	-8
1000	12	12	12	12	12	12	15	15	15	14	13	10	6	2	-2	-6	-6
1500	18	18	18	18	21	21	21	20	18	17	15	12	8	5	1	-2	-2
2000	25	25	25	25	25	25	25	23	20	18	16	12	8	5	2	-2	-2
2500	33	33	33	33	33	30	28	26	24	22	20	17	14	11	8	4	4
3000	34	34	34	34	34	32	31	29	28	26	25	22	18	15	12	9	9
3500	36	36	36	36	34	33	32	30	29	27	25	22	19	16	14	11	11
4000	-20	-20	-5	36	35	33	32	30	29	28	26	23	20	17	15	12	12
4500	-20	-20	-10	36	36	34	32	31	30	28	27	24	21	19	16	13	13
5000	-20	-20	-10	36	36	34	33	32	31	30	29	25	22	19	16	13	13
5500	-20	-20	-10	37	37	35	34	32	31	30	29	25	22	19	16	13	13
6000	-20	-20	-10	38	38	36	35	34	33	31	29	25	22	19	16	13	13
6500	-20	-20	-10	38	38	38	37	36	34	33	31	26	23	20	17	14	14
7000	-20	-20	-10	38	38	38	37	36	35	34	32	27	24	21	18	15	15
7500	-20	-20	-10	38	38	38	38	37	36	35	33	28	25	22	19	16	16
8000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16
20000	38	38	38	38	38	38	38	37	36	35	33	28	25	22	19	16	16

Note that the MAX IGNITION RETARD parameter needs to be altered to get timing retard more than -10° for the VR4.

SECTION 10 – BREATHING MODIFICATIONS for POWER

10.01-ITEMS TO UPGRADE

There are several significant points of airflow restriction on the stock VR4/LEGNUM, specifically the intercooler, hot side pipe, front exhaust and the CATs. These items will need to be upgraded if power levels much over 200kWatw are desired.
Here is a short summary of the VR4's plumbing that can or should be upgraded.

1. AIRBOX: If something good is available, see photo
2. INTAKE MAF-TURBO: Only if changing the airbox, see photo
3. HOT SIDE PIPE: Spend the effort to get this upgraded
4. INTERCOOLER: Required if boost exceeds 16psi, use EVO 7-9
5. COLD SIDE PIPE: Yes, if you can find a good setup, see photo
6. THROTTLE BODY: Leave stock
7. INLET MANIFOLD: Leave stock
8. EXHAUST MANIFOLD: Leave stock
9. TURBOS: TDO4, if you are really keen and have an intercooler.
10. DUMP PIPE: If you can find them
11. FRONT EXHAUST: 2.5 - 3 inch is a good upgrade
12. CAT: 3 inch is the right upgrade
13. REAR EXHAUST: 2.5 – 3 inch is a good upgrade

Here is a very good example of VR4 breathing and cooling system upgrades.
Pix from **ume18R** on OZVR4.

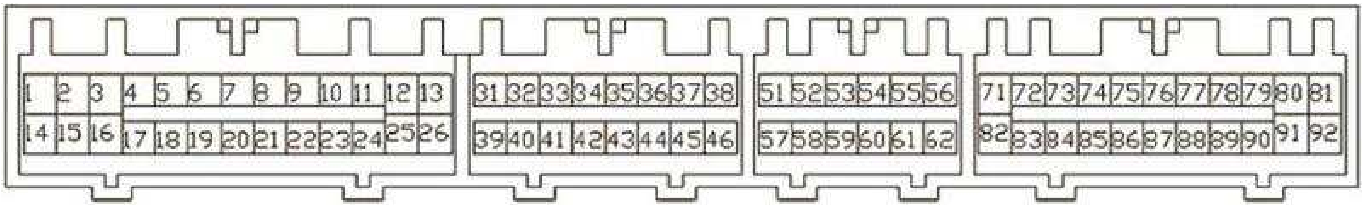
APPENDIX 1: VR4 TECHNICAL DETAILS

8th generation Galant:	VR4 (EC5A/EC5W)
Production:	1996–2002
Body style:	4-door sedan (VR4), 5 door wagon (LEGNUM tt)
Layout:	Front engine, 4WD
Engine:	2498 cc DOHC 24v V6, twin-turbo, waste-spark
Configuration:	DOHC 24v V type 6 cylinder
Engine Code:	6A13TT
Bore/stroke/capacity:	81.0 × 80.8 mm, 2498 cc
Compression ratio:	8.5:1
Turbo:	TD03 x2
Fuelling:	ECI-MULTI, premium unleaded fuel
Peak power:	206 kW (280 PS) @ 5500 rpm
Peak torque:	367 N/m (271 ft/lb) @ 4000 rpm
Transmission:	Four-wheel drive, 5-speed semi-auto, 5-speed manual
Length:	4680 mm
Width:	1760 mm
Height:	1420 mm
Wheelbase:	2635 mm
Curb weight:	1520 kg
Fuel tank:	60 L
Wheels/tyres:	225/50 R16 91V

APPENDIX 2: ECU PIN DESCRIPTIONS AND WIRING NOTES

A2.1: EVO 4-5-6-7-8 & VR4 ECU PIN CONFIGURATIONS

Figure 55: ECU WIRE SIDE VIEW - EVO 4-8 & RVR-LEGNUM tt



A2.2: VR4 ECU PIN FUNCTION & WIRE COLOUR

Table 4 VR4 ECU PIN FUNCTION & WIRE COLOUR

Pin	Function	Colour	Pin	Function	Colour
1	INJECTOR 1	B-R	71	STARTER signal *	
2	INJECTOR 3	Y-R	72	AIR TEMP Sensor	R-L
3	INJECTOR 5	Y-L	73		
4	ISC Motor pin A1	G-B	74		
5	ISC Motor pin B1	G-W	75	LAMBDA – Rear	W
6	EGR Solenoid *	L-B	76	LAMBDA - Front	W
7	VACUME Solenoid *	B-W	77		
8	A/C COMP Relay *	G	78	KNOCK Sensor	W
9			79	DIAGNOSTICS	G-W
10	IGNITION COIL PACK 1*	R-L	80	BACKUP 12V supply	R-B
11	IGNITION COIL PACK 3*	R-B	81	+5V to sensors	G-Y
12	12V Switched power	R	82	IGNITION SWITCH	B-R
13	CHASSIS GROUND	B	83	WATER TEMP Sensor	Y-G
14	INJECTOR 2	Y	84	THROTTLE POS Sensor	Y-B
15	INJECTOR 4	L-Y	85	BARROMETRIC Sensor	G-W
16	INJECTOR 6	Y-G	86	VEHICLE SPEED Sensor	W-G
17	ISC Motor pin A2	G-R	87	CRUISE AUTO	Y-R
18	ISC Motor pin B2	B-Y	88	CAM Sensor	R-W
19	MAF RESET signal	G-L	89	CRANK Sensor	G-R
20			90	AIR FLOW Sensor	W-L
21	RAD FAN Speed, PWM	L-W	91	CHASSIS GROUND	B
22	FUEL PUMP *	W-R	92	SENSOR GROUND	B
23	IGNITION COIL PACK 2	L			
24	PURGE SOLENOID	L			
25	12V Switched power	R			
26	CHASSIS GROUND	B			
31	TCL VENT SOLENOID	R-B			
32	TCL SOLENOID	G-B			
33					
34					
35			51		
36	ECU CHECK ENG LAMP	R-W	52		
37	PWR STEER pressure sw	Y	53	AUTO ECU TCL	B
38	ECU RELAY	W	54	ALTERNATOR	B-R
39			55	ALTERNATOR	Y-B
40			56	DIAGNOSTICS pin 1	GrR
41			57	AIRCON PRESSURE SW	L-W
42			58	TACHO	W
43	VACUME SOLENOID	Y-O	59	AUTO ECU TCL	W
44			60	O2 sensor heater	
45	AICON FAN RELAY HI	G-R	61	IMMOBILIZER	Y
46			62	DIAGNOSTICS pin 7	R-W

APPENDIX 3: MISCELLANEOUS USEFUL TUNING DATA

A3.01: AIR-FUEL RATIO OPERATIONAL APPROXIMATIONS

06:1	Rich run limit.
09:1	Low power with black haze.
11.5:1	Rich best torque at WOT.
12.5:1	Safe best power at WOT.
13.2:1	Lean best torque at WOT.
14.7:1	Stociometric ideal burn AFR for gasoline.
15.5:1	Lean light load, cruise/part throttle.
16.2:1	Best economy, cruise/part throttle.
18:1	Lean run limit.

A3.02: PRESSURE CONVERSIONS

1 bar = 100	kPa
1 bar = 1000	mbar
1 bar = 750	mm of Hg
1 bar = 29.53	inch of Hg
1 bar = 14.503	psi

1”Hg = 0.4912	psi
1”Hg = 3.3864	kPa
1”Hg = 33.864	mbar

1psi = 2.036	“Hg
1psi = 6.8947	kPa

$1kg/cm^2$ = 14.223	psi
$1kg/cm^2$ = 99.06	kPa

APPENDIX 4:

Table 5 VR4 TUNING WORK-SHEET	
CLIENT:	
CONTACT DETAILS:	
MODEL:	YEAR:
TRANSMISSION:	REGISTRATION:
ROM CODE:	XML FILE:
ROM SAVED:	XML BASE:
HI OCTANE FUEL MAP:	
HI OCTANE IGNITION MAP:	
KNOCK:	
LO OCTANE FUEL MAP:	
LO OCTANE IGNITION MAP:	
BOOST CUT LIMIT:	
INJECTORS:	INTERCOOLER:
SPEED LIMIT:	TURBO:
REV LIMIT:	BOV:
CAT WARMUP RETARD MAP:	FUEL:
IDLE:	AIR TEMP – AMBIENT:
BOOST:	AIR TEMP - MANIFOLD:
BREATHING MODIFICATIONS:	

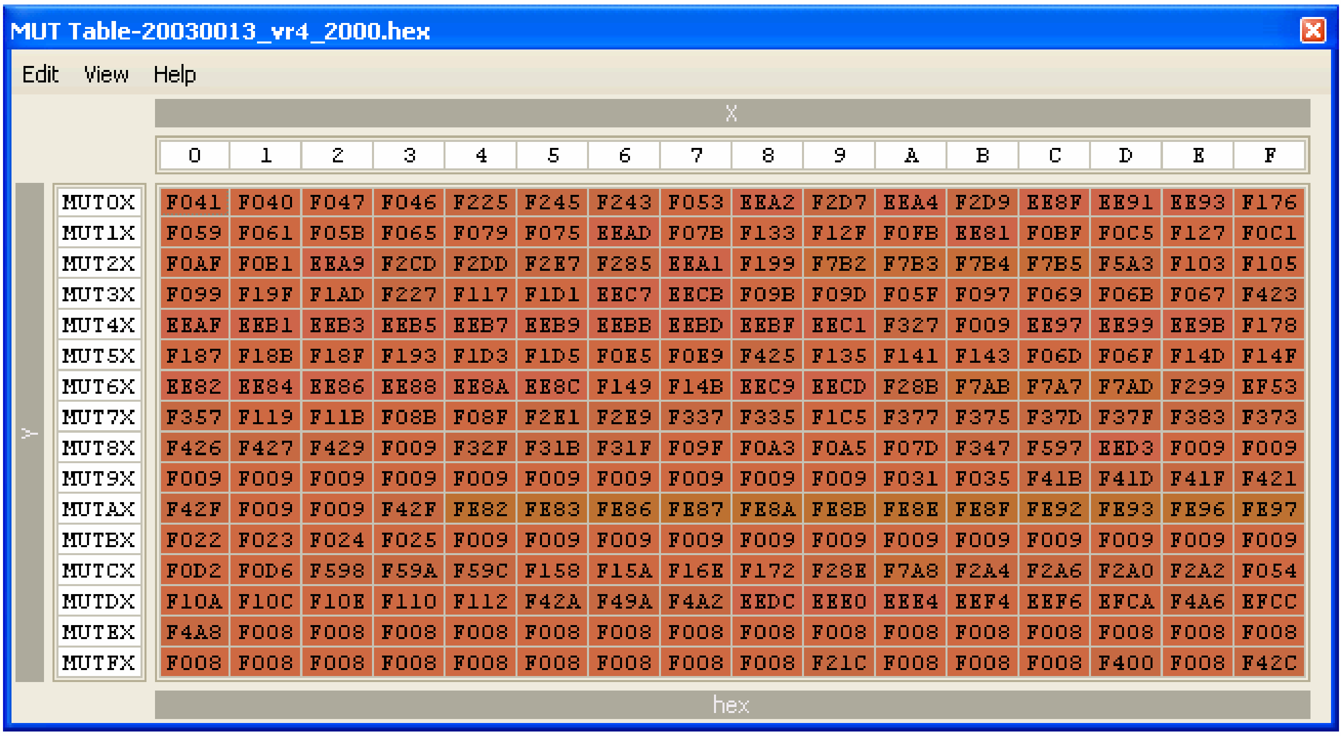
APPENDIX 5: 2-BYTE LOGGING & MUT TABLE SETUP

Enter the HEX addresses from the table for your ROM into the MUT TABLE to enable 2-byte logging of LOAD, RPM and AIRFLOW.

They are entered on the top line of the table, starting at the left. Data is to be entered in the usual way for HEX, eg 0x6b12. EvoScan is already setup to log the following 2-byte data:

LOAD at MUT 00 and MUT 01.
RPM at MUT 02 and MUT 03.
AIRFLOW at MUT 04 and MUT 05.

Figure 56: MUT TABLE – VR4 20030013



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
MUT0X	F041	F040	F047	F046	F225	F245	F243	F053	EEA2	F2D7	EEA4	F2D9	EE8F	EE91	EE93	F176
MUT1X	F059	F061	F05B	F065	F079	F075	EEAD	F07B	F133	F12F	F0FB	EE81	F0BF	F0C5	F127	F0C1
MUT2X	F0AF	F0B1	EEA9	F2CD	F2DD	F2E7	F285	EEA1	F199	F7B2	F7B3	F7B4	F7B5	F5A3	F103	F105
MUT3X	F099	F19F	F1AD	F227	F117	F1D1	EEC7	EECB	F09B	F09D	F05F	F097	F069	F06B	F067	F423
MUT4X	EEAF	EEB1	EEB3	EEB5	EEB7	EEB9	EEBB	EEBD	EEBF	EEC1	F327	F009	EE97	EE99	EE9B	F178
MUT5X	F187	F18B	F18F	F193	F1D3	F1D5	F0E5	F0E9	F425	F135	F141	F143	F06D	F06F	F14D	F14F
MUT6X	EE82	EE84	EE86	EE88	EE8A	EE8C	F149	F14B	EEC9	EECD	F28B	F7AB	F7A7	F7AD	F299	EF53
MUT7X	F357	F119	F11B	F08B	F08F	F2E1	F2E9	F337	F335	F1C5	F377	F375	F37D	F37F	F383	F373
MUT8X	F426	F427	F429	F009	F32F	F31B	F31F	F09F	F0A3	F0A5	F07D	F347	F597	EED3	F009	F009
MUT9X	F009	F009	F009	F009	F009	F009	F009	F009	F009	F009	F031	F035	F41B	F41D	F41F	F421
MUTAX	F42F	F009	F009	F42F	FE82	FE83	FE86	FE87	FE8A	FE8B	FE8E	FE8F	FE92	FE93	FE96	FE97
MUTBX	F022	F023	F024	F025	F009	F009	F009	F009	F009	F009	F009	F009	F009	F009	F009	F009
MUTCX	F0D2	F0D6	F598	F59A	F59C	F158	F15A	F16E	F172	F28E	F7A8	F2A4	F2A6	F2A0	F2A2	F054
MUTDX	F10A	F10C	F10E	F110	F112	F42A	F49A	F4A2	EEDC	EEE0	EEE4	EEF4	EEF6	EFCA	F4A6	EFCC
MUTEX	F4A8	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008	F008
MUTFX	F008	F008	F008	F008	F008	F008	F008	F008	F008	F21C	F008	F008	F008	F400	F008	F42C

Table 6 2-BYTE MUT ADDRESS – VR4 ROMS

20030010, 11, 12, 13 2byte load MUT 00 = F008 MUT 01 = F009 2byte RPM MUT 02 = F0A8 MUT 03 = F0A9 2byte AirFlow* MUT 04 = MUT 05 = MUT 3D TABLE ADDRESS = 2FAD0	23810003, 04 2byte load MUT 00 = MUT 01 = 2byte RPM MUT 02 = MUT 03 = 2byte AirFlow MUT 04 = MUT 05 = MUT 3D TABLE ADDRESS = 2FAD0			

APPENDIX 6: INTAKE HARDPIPES & IDLE CONTROL ISSUES

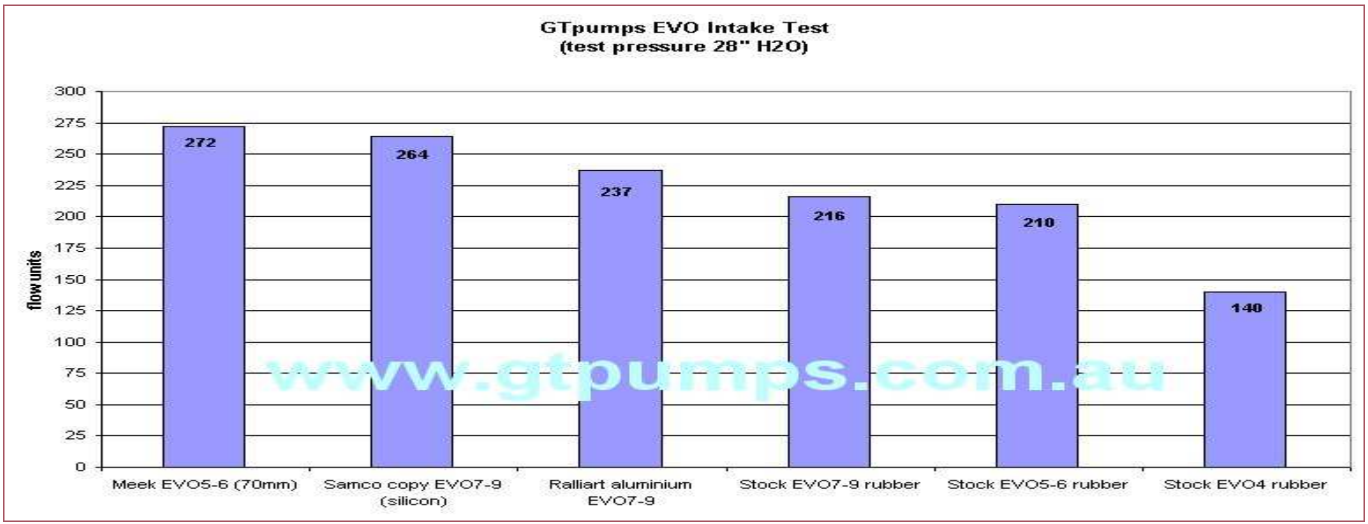
Many people report having idle control issues after installing a "hard" suction pipe between the MAF and the turbo inlet. The problems are exacerbated with the addition of big cams. These problems are usually rough and unsteady idle, cutting out at idle or cutting out when coming to a stop. Another problem is an inability to correctly scale new/larger injectors. In an attempt to get some stability, tuners have raised the idle target speed, but this can cause other problems.

One related issue is when the MAF (at idle) gives a airflow signal of 52Hz or higher. When this happens, the LONG TERM FUEL TRIM LOW will not operate. What you should do, before installing the new hard-pipe, is to use EvoScan to check what your idle airflow Hz signal is doing. Stock units will typically run between 25-35 Hz when warmed-up. Check it again after installing the new hard-pipe. If it is erratic, or over 52Hz, you can expect to have some problems.

Not all up-graded or hot-rodded intake pipes cause problems. I have a PLAZMAMAN silicon unit on my EVO9, which gives the same idle airflow Hz figures as the stock convoluted rubber item. This silicon unit and the stock rubber unit, probably work satisfactorily due to a lack of self-resonance (low Q) in the pipe. Aluminium intake pipes, by their very nature, will have a higher Q at self resonance. Some problem hard-pipes have been cured by the addition of a silicon coupling from the MAF to the pipe.

Not surprisingly, not all intake pipes flow the same rate for a given pressure drop.
A number of units were flow-bench tested at GT PUMPS (Sydney Australia) with some interesting results. The graph below shows the results.

Figure 57: GT-PUMPS EVO INTAKE PIPE TEST RESULTS



Keep in mind that altering the MAF scaling is more a fix for fuel trim issues, though it may be of some benefit when using a hard-pipe.

APPENDIX 7: OBDII CONNECTOR & CLEARING FAULT CODES

A7.01-OBD-II CODE INTRODUCTION

The Diagnostic Trouble Code numbering follows a standardized structure. All Diagnostic Trouble Codes have a letter followed by a 4-digit number (e.g. P1234). The first letter indicates the type of code:

P = Power-train
C = Chassis
B = Body
U = Network Communication

The remaining 4-digit number specifies the problem within that system. The fault codes documented here have been abbreviated and restricted for simplicity to a four cylinder twin-cam with two oxygen sensors.

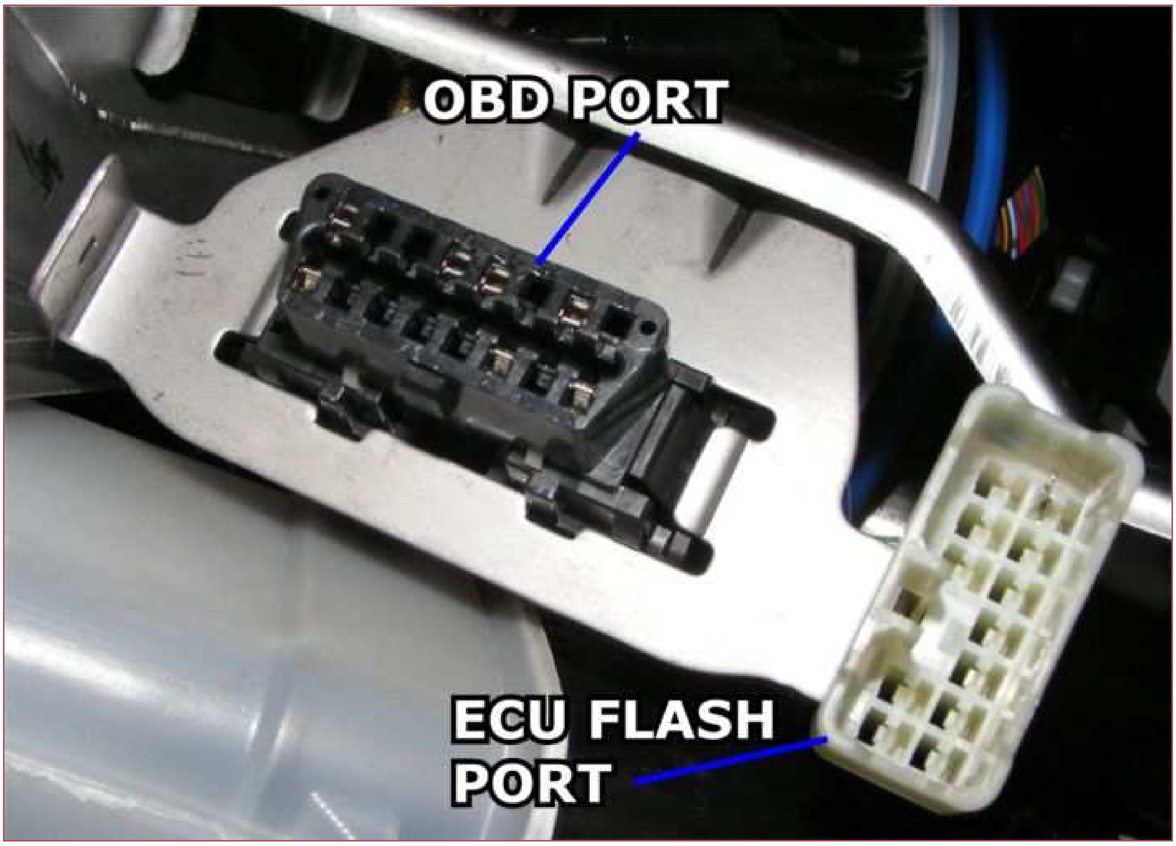
A7.02-MITSUBISHI ECU SELF-DIAGNOSTICS & FAULT CODES

Self-diagnosis of faults can be performed by indications from the CHECK ENGINE LAMP in the dash combination meter, or by displaying data on a laptop PC screen using suitable software with adapter cable. PC software is available on the web and includes the following: EvoScan, MITSULOGGER.

A7.03-OBD-II DIAGNOSTIC CONNECTOR

The connectors are behind the dash facia, drivers side, adjacent to the centre tunnel. On a IX, just feel with your hand and plug the connectors into their receptacles. There is a latch on the white connector, requiring depression on removal. Pix from **Biggles** on MLR.

Figure 58: OBD-II CONNECTOR



The OBD-II specification provides for a standardized hardware interface—the female 16-pin (2x8) J1962 connector. The OBD-II connector is nearly always located on the driver's side of the passenger compartment near the center console. SAE J1962 defines the pin-out of the connector as:

Table 7 OBDII CONNECTOR PIN FUNCTION

DESCRIPTION	PIN #		DESCRIPTION
	8	16	BATTERY VOLTAGE
K line of ISO9141-2 & SAE-J2234	7	15	L line of ISO9141-2 & ISO14230-4
CAN high ISO15765-4 & SAE-J2234	6	14	CAN low ISO15765-4 & SAE-J2234
SIGNAL GROUND	5	13	
CHASSIS GROUND	4	12	
	3	11	
Bus positive line of SAE-J1850	2	10	Bus negative line of SAE-J1850
	1	9	

A7.04-CLEARING A FAULT CODE with EvoScan

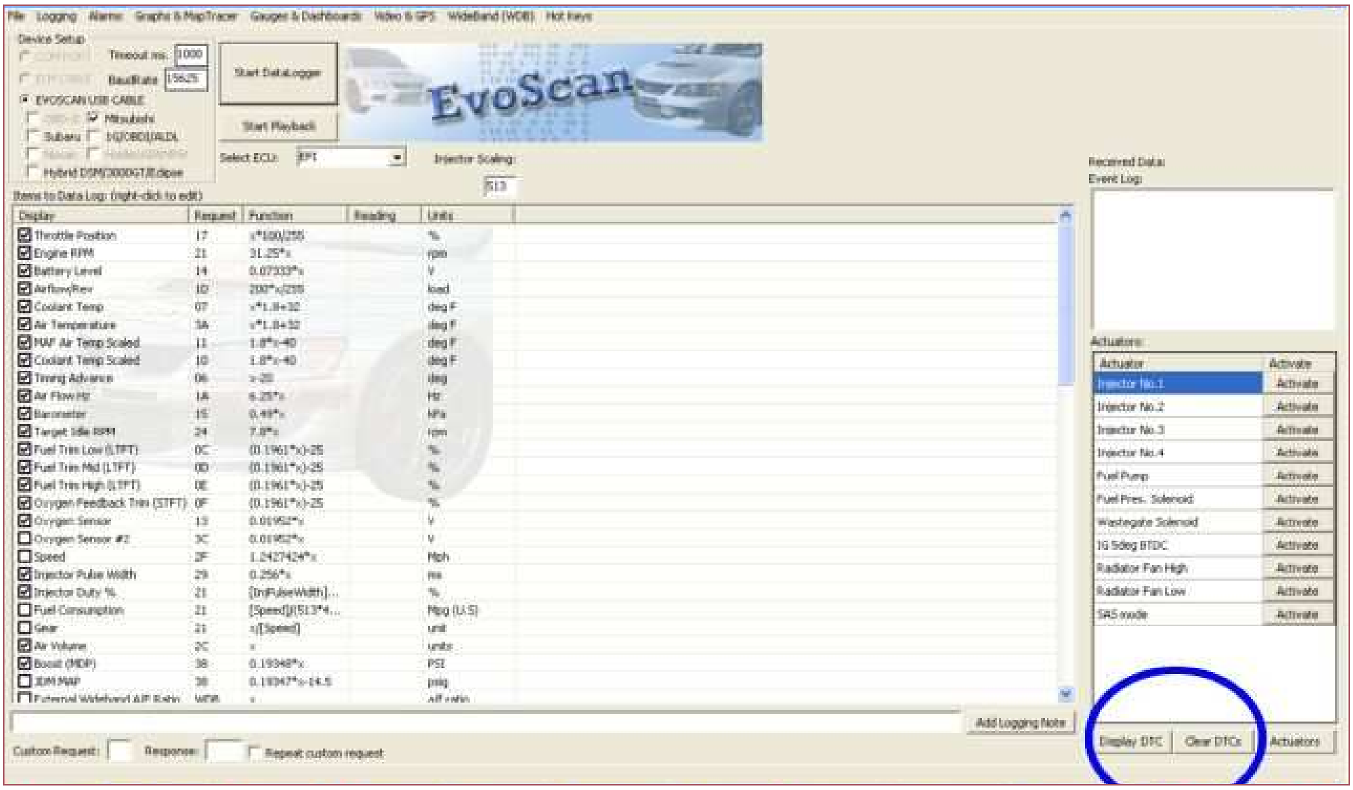
Follow the following procedure to clear a CEL fault code.

Open EvoScan, connect the TACTRIX cable to the OBD-II connector only and switch on the ignition.

Click Display DTC and then Clear DTC. See the bottom right-hand of the display.

Turn of the ignition and disconnect the cable from the OBD-II port, the faults are cleared. Or at least the current flags are cleared. If there is still a fault with the system, it will get flagged the next time the engine is run.

Figure 59: EvoScan CLEARING FAULT CODES



A7.05-CLEARING A FAULT CODE without EvoScan

With the VR4, without recourse to EvoScan, the battery will have to be disconnected from the ECU for approximately 10 seconds. Clunky, but it works.

APPENDIX 8: ROM MAPPING ADDRESS DATA

A8.01-ROM – 20030011 to 20030013

Table 8 VR4 GLOBAL ADDRESS TABLE – 20030011 to 20030013 ROMs

FUNCTION NAME	X – Y or LENGTH	START BYTE	SCALE FACTOR	BYTE or WORD	UNITS or PREFIX
ECU ROM CODE	4-byte	1021A	x	byte	
PERIPHERY 0	1-word	10272		word	16 bits
PERIPHERY 1	1-word	10282		word	16 bits
PERIPHERY 2	1-word	10292		word	16 bits
PERIPHERY 3	1-word	102A2		word	16 bits
INJECTOR SCALING	1-byte	10318	x/29241	word	cc/min
REV LIMIT, STATIONARY #1	1-word	10341	7500000/x	word	RPM
REV LIMIT, STATIONARY #2	1-word	10343	7500000/x	word	RPM
REV LIMIT, MOVING	1-word	1036A	7500000/x	word	RPM
SPEED LIMIT – ACTIVATE	1-word	1036C	x*2	word	KPH
SPEED LIMIT - DEACTIVATE	1-word	1036E	x*2	word	KPH
Possible KNOCK LOAD THRESHOLD	10-byte	1104F	x*5/8	byte	LOAD %
Possible OCTANE UPDATE THRESHOLD	10-byte	11090	x*5/8	byte	LOAD %
FUEL MAP – HI OCTANE #1	X=15, Y=15	110A3	14.7*128/x	byte	
FUEL MAP – HI OCTANE #2	X=15, Y=15	1118B	14.7*128/x	byte	
FUEL MAP – LO OCTANE #1	X=15, Y=15	11273	14.7*128/x	byte	
FUEL MAP – LO OCTANE #2	X=15, Y=15	1135B	14.7*128/x	byte	
FUEL MAP - RPM SCALE	15-word	2CF30		word	RPM
FUEL MAP - LOAD SCALE	15-word	2CF54		word	LOAD %
OPEN LOOP LOAD 1	9-byte	114C6	Load8	byte	
OPEN LOOP LOAD 2	9-byte	114D6	Load8	byte	
OPEL LOOP LOAD RPM SCALE	9-word	2D232	RPM	word	RPM
BOOST CUT LIMIT	9-	1153C	X*5/4	byte	LOAD %
B00ST CUT LIMIT – RPM SCALE	9-word	2CFAA	x*1000/256	word	RPM
LIMP MODE MAP	X=7, Y=5	1157B	x	byte	
LIMP MODE – RPM SCALE	5-word	2D06C	x*1000/256	word	RPM
LIMP MODE – TPS SCALE	7-word	2D07C	x*5/256	word	VOLTS
Unknown sensor	64-byte	115A9		byte	
MAX RETARD ON KNOCK	1-byte	115C2	x/0.35	byte	degrees
INJECTOR LATENCY	7-byte	116AF	x*0.024	byte	mS
INJECTOR LATENCY BATTERY VOLTS	7-word	2CEB0		word	VOLTS
IGNITION MAP – HI OCTANE #1	Y=19, X=17	1176F	x	byte	
IGNITION MAP – HI OCTANE #2	Y=19, X=17	118B9	x	byte	
IGNITION MAP – LO OCTANE #1	Y=19, X=17	11A03	x	byte	
IGNITION MAP – LO OCTANE #2	Y=19, X=17	11B4D	x	byte	
IGNITION MAP – CAT WARMUP RETARD #1	Y=19, X=17	11C97	x-128	byte	
IGNITION MAP – CAT WARMUP RETARD #2	Y=19, X=17	11DE1	x-128	byte	
IGNITION MAP - RPM SCALE	19-word	2CF9A		word	RPM
IGNITION MAP - LOAD SCALE	17-word	2CFD4		word	LOAD %
TIMING TRIM v ENGINE TEMP	8-byte	11F7C	x-128	byte	degrees
TIMING TRIM v TEMP – TEMP SCALE	8-word	2D090	x-40	word	℃
TIMING TRIM v AIR TEMP	7-byte	11F88	x-128	byte	degrees
TIMING TRIM v AIR TEMP – TEMP SCALE	7-word	2D10A	x-40	word	℃
IDLE RPM – NEUTRAL v TEMP	8-byte	12004	x*125/16	byte	℃
IDLE RPM – DRIVE v TEMP	8-byte	12010	x*125/16	byte	℃
IDLE RPM TEMP SCALE	8-word	2D090	x-40	word	RPM
Unknown 3D map	X=9, Y=17	122BD		byte	
Possible EGR or PURGE duty cycle	X=17, Y=15	1235D		byte	
MUT TABLE	X=16, Y=16	2FAD0	x	word	hex