HP Tuning

by Michel Schmets from Final Drive

In collaboration with Automatic Choice and
Bleijlevens Motor & Techniek.

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PREFACE

A Basic Guide into the World of Transmission Tuning Using

HPtuners

This guide is offered to you by a collaboration of ATSG, Final Drive, Automatic Choice and Bleijlevens Motor & Techniek. They have all did a fantastic job to get this guide available for you as a gift for your continuously support and faith in us.

We also want to put out a Special Thank you to Tristan Kustomizing for making some resources available, as well as the members of the Transmission Brotherhood. They inspired and motivated us to get this info out there.

We will cover some basic stuff that can get you started and give you an idea of what you can expect of the program and guide. Please keep in mind that we have no direct contact with HPtuners in any way, or make any money by using their equipment.

Most of the stuff we will present you has been gathered from various sources, years of experience and countless hours of reading and trying.

We do cover a little bit of engine calibration along the line. If you find this helpful and want to learn more, I would like to invite you to visit Calibrated Success at https://calibratedsuccess.com/

DISCLAIMER: User beware. Improper tuning can result in damage. ATSG, Final Drive, Automatic Choice and Bleijlevens Motor & Techniek are not held responsible for such damage.

The information and part numbers contained in this booklet have been carefully compiled from industry sources known for their reliability, but ATSG does not guarantee its accuracy.

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THE WORLD OF TRANSMISSION TUNING

INTRODUCTION

Greg Banish is an OEM level calibration Engineer. He has provided the industry with some amazing timeless books filled with great information, as well as several courses which are available on DVD as well as a streaming option for an amazing price. Both beginner as advanced GM course will give you a major advantage over the competition when it comes to diagnostics as well as the ability to recalibrate the ECU up to a certain level. You can also go directly to https://cartrainingonline.com/ to access the streams of these courses from Calibrated Success.

Hptuners is a Third party company that made a great piece of software and hardware to initially work with the big 3, GM, Ford and Chrysler. The package will enable you to read specific OBD data from the engine and transmission, command actuators, but also read and write the internal memory from the controller to allow you to change the programming of the controller opening up a world of possibilities with a single push of a button.

Recently they introduced their new interface, the MPVI2. This new interface is more focused on the future and supports more cars outside of the scope of the big 3. But also some newer models from the known brands require a more powerful interface in order to have the same options like the original MPVI.

When you buy HPtuners, or you already have one, there are 2 options to choose from. The normal interface and the Pro version. The advantages from the Pro version is that it features additional analog inputs on both MPVI and MPVI2 pro. On the new MPVI2 it also has a CANBUS input to import additional information from a CANBUS stream.

Pro or not? That depends on your budget and what you plan to do with it. Personally I think its better to invest in the future and do it for the long run. So what could the "Pro" version for you.

The analog 0-5V inputs allows you to import external sensor data allowing you to monitor data not implemented in the car. For example, if you put an additional Wideband Lamdba sensor in there, you can use that analog signal to get accurate Air/Fuel Ratio information from that sensor combined with the data your ECM is already allowing you to see. Same goes for pressure sensors. A simple 0-500 PSI pressure transducer on a line pressure port, will give you Realtime line pressure information together with many other transmission data parameters, giving you an unbelievable edge over the competition.

Since HPtuners came out with the 3.x version of their software, they also allow the importing of serial data coming from known wideband controllers. So if you need to import only wideband information, you can do without the need of a Pro version. For editing controller data, HPtuners requires you to license the file using credits. Most cars require two credits which are about 50 dollars per credit.

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If you want to buy a second hand unit, you probably have the choice between the old version and the new. The costs of credits remain the same, but the MPVI2 has a great advantage over the MPVI1. The credits for the MPVI2 are universal where the MPVI uses specific credits for GM, Ford and Chrysler.

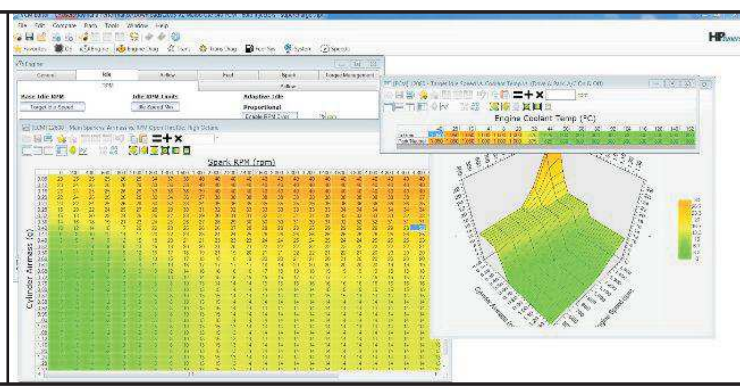
Also there is a big difference in the way they store the licensed vehicles. The MPVI will store the License information on the interface making it a bit vulnerable. The MPVI2 will store this information on the HPtuner server making it easier to recover when losing or damaging the interface. It does have a draw back. In order to license\verify a vehicle, you need to be connected to the Internet. This normally isn't an issue, but is something that needs to be considered when ordering the tool.

THE SOFTWARE

The software package consist out of 2 separate programs.

VCM Scanner for allowing to read the OBD data stream.

And VCM Editor, The software to read, edit and write the programming.



You only need to pay for a license if you are changing data and writing it back to the car. Reading and logging the OBD data stream can be done with any vehicles, licensed or not. Reading the Programming data is free as well. You can license it at any given point if you need it. But only reading it out could help you determine whether the shift speeds are within specs for example.

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THE SOFTWARE

One of the reasons why I like this software so much, is the user friendliness of the package, while still holding a massive punch.

I've worked with many tuning and diagnostic software packages in the last 20 years, and only a few come close to the potential of this package.

The big power hides in the options you have with the data. The program will let you work with own custom formulas to calculate certain data using known OBD data and a formula.

For example, if I would hook up a Wideband Lambda sensor to measure the actual Air Fuel Ratio of my engine, I can calculate any errors in calibration using a simple formula.

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Most of us will look for specific data in the controller in order to make our diagnose. If you have a TCC issue, you want to know your TCC slip. If its not in the data, you can calculate this real easy. The formula is Input Speed – Engine Speed. If those 2 are in the data, TCC slip can be calculated realtime. In the "Engine Tuning" we will demonstrate this option in more details.

Another great powerful feature is histograms.

Some parameter programming of the engine and transmission consists out of data that is written in Tables. These tables have horizontal and vertical axis data. Going to a bunch of logged data and filling in those numbers and averaging that data for that specific "box" is a huge and time-consuming job.

For things like that, Hptuners offers the option to work with Histograms. This enables you to let HPtuner plot the data in a format of your choice, or even simpler, in the format of the maps inside the controller.

Not only will it plot this data in the right "box" and average the data out, but it will let you use filters as well. For example its really simple to let it ignore/discard data logged during conditions know you didn't capture usable data, For example on a cold engine, or decelerating with closed throttle.

By using the histograms, you chop away valuable time by letting the software work for you.

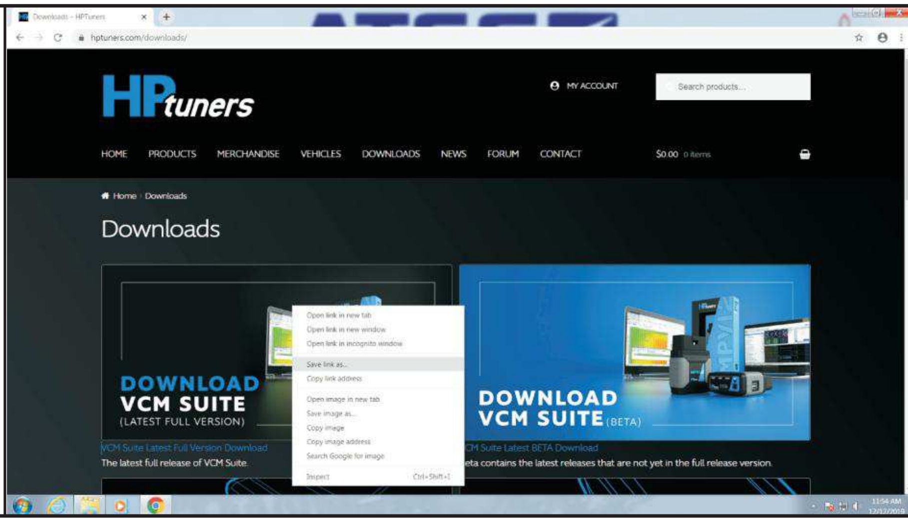
THE WORLD OF TRANSMISSION TUNING
INSTALLATION GUIDE

The software installation is pretty straight forward. Just go to the HPtuners website and go to downloads. You can see that you have 2 options. The latest Full version and the Beta version. In most cases you are best of with the latest Full version.

Only use the Beta version if you are running into issues with the normal version or your car isn't yet supported with the latest full version. The beta version has bug fixes and newer options/calibrations in there, but isn't fully tested as stable, so only use that one if you have problems with the normal version. Please make sure you first install the software before you connect your device!

As for 12-12-2019 4.4.4.0 is the latest version and is located on http://hptuners.com - Click on Download and make a choice between the 2 versions. In this case we will be using the normal latest version.

I right click on it to save it on the desktop.



After the download is completed successfully, I run the setup from my desktop

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INSTALLATION GUIDE

Depending on your operating system and security settings, windows will come with a popup with a warning. Click on “Run” to start the installer.

The installer starts and will automatically give you information on the version you are about to install. In this case, 4.4.4.0. Click on Next to continue. Now the software will show you the license agreement, you need to accept this before you can resume the installation.

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The installer is ready to start, but if your security setting is set at default or higher, windows will ask you to confirm the installation.

After the installer is done, you are ready to go. Both VCM Editor and VCM Scanner are installed and can be found in the program list.

For convenience its easier to create a short cut to the desktop. Simply right-click on the program of choice, select "send to" and pick desktop in the list. Do this for both programs.

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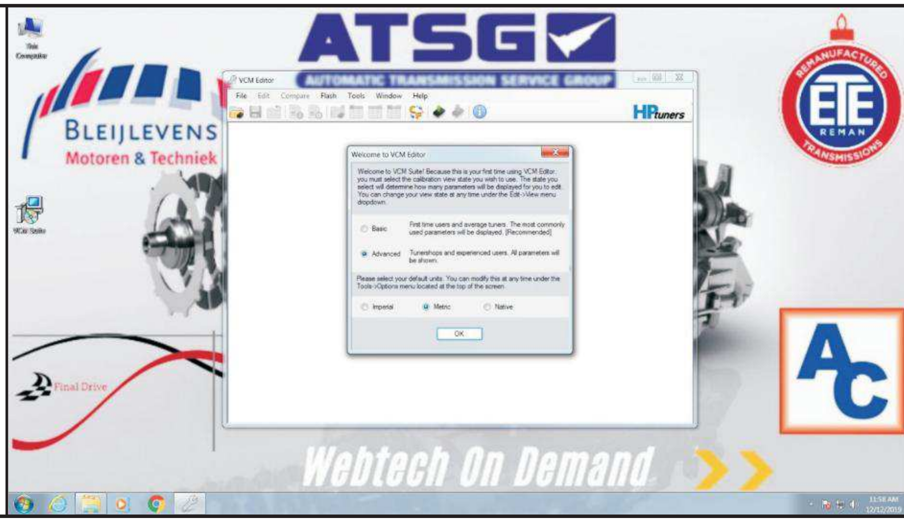
INSTALLATION GUIDE

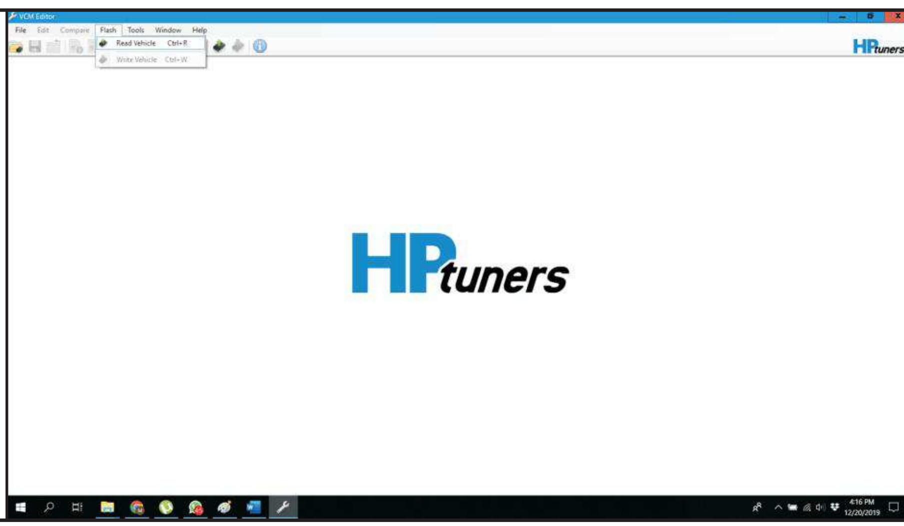
The first time you run Editor it comes with a very important question. It will ask you to choose between beginner view or advanced. If you select beginner, the program will hide certain parameters and give you access to only some basic stuff. For this guide we select Beginner and will be working using the metric system.



That's it. Program is ready to work with. If you don't have HP tuners, you can still install the software and work with some sample files they added to get familiar with the software and see if it has options you will need in your shop.

VCM EDITOR.

If you open the VCM Editor you first need to load or read the cars data.



After it's read, you get the option to license the file in order to make changes.

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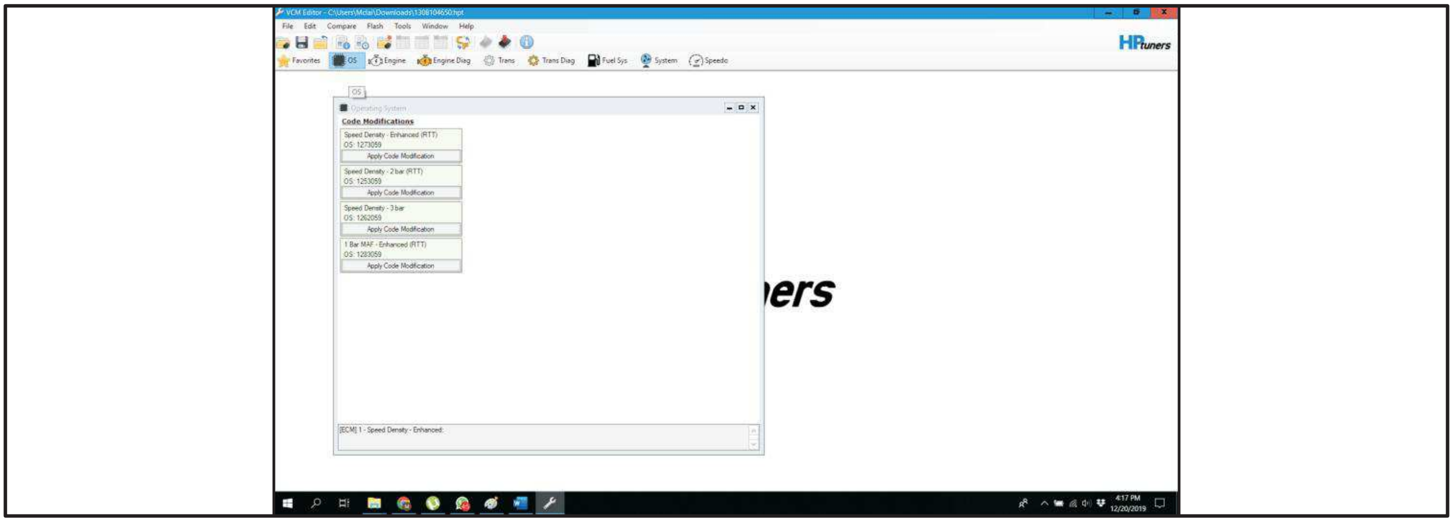
VCM EDITOR

Once the file is loaded you can click on the OS button to get some additional info and possible patches like this:

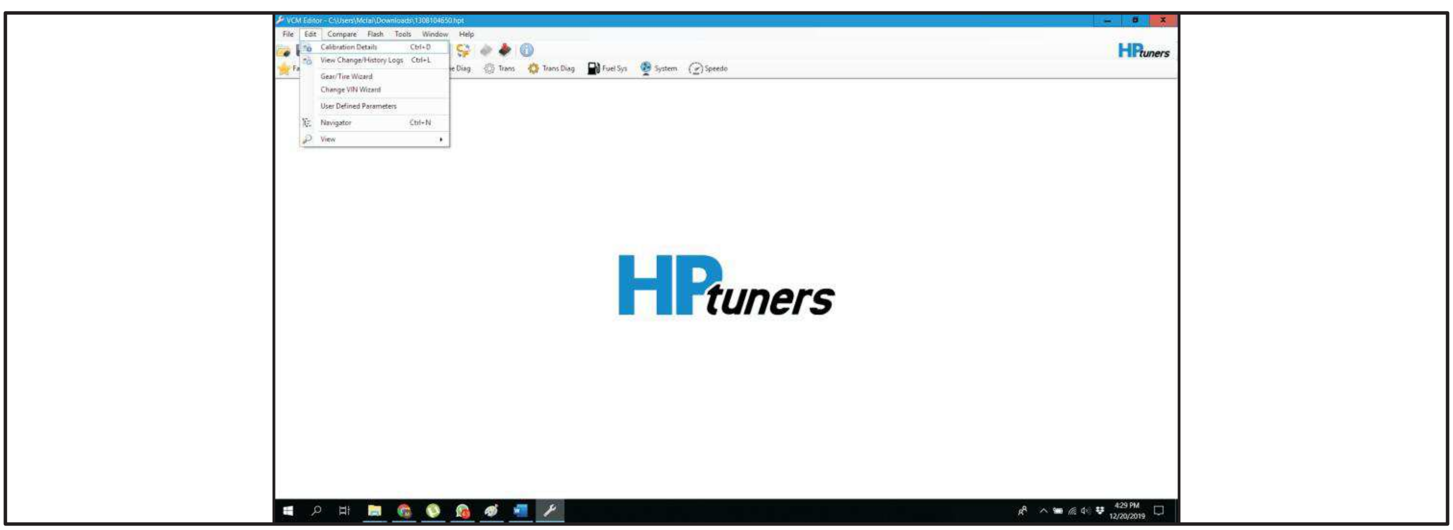


You can see that I can click on a modification in the list. Some custom OS modifications give you the option to change the absolute Map pressure to a 2 or 3 bar system. This is done for engines that will be fitted with a supercharger or turbo. You will also have to exchange the Map sensor to an appropriate model to support this software.

The other options you might find is RTT. This is a modification that will allow you to do Real Time Tuning. This is extremely helpful on a load based dyno. You can get a proper calibration in a very limited time on the Dyno.

The other icons are for changing parameters concerning that particular system. Take your time to get a bit familiar with them as it can give you loads of options to modify. Cooling, tank capacity, AC settings, speed limiters etc.

There is one other usefull button that can give you some additional details about the cars, and that's Calibration details.



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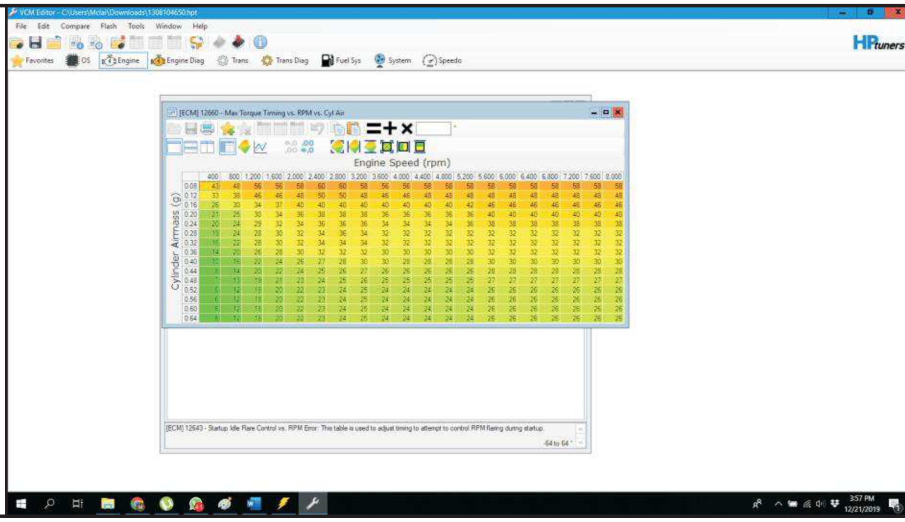
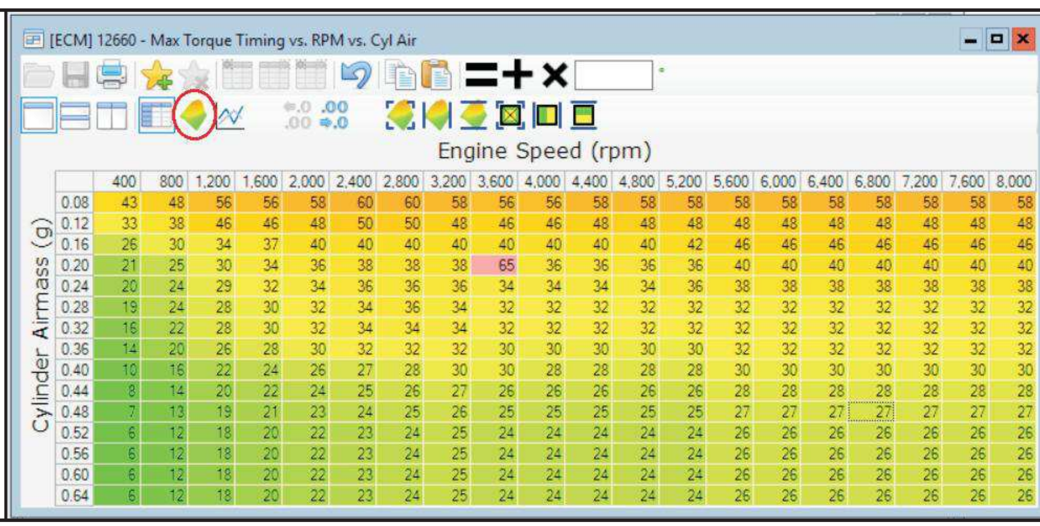
VCM EDITOR

This will give you info on the calibration, Vin number etc. Check it out and see what useful information it holds for you.

When a file is loaded, you can access the programming data in the editor. If we would look at certain tables in the controller, we see them as a table by default (this is a table of spark advance)



As you can see, the table is filled with numbers and they all have a color to give you a instant view of abnormalities. If I would modify one number in that table that's completely different than the rest, it shows instantly. Also note that with every Button and Table, there is a short description in the bottom that's often gives you some useful information plus it will show you the acceptable values you can enter there.



[ECM] 12660 - Max Torque Timing vs. RPM vs. Cyl Air

Engine Speed (rpm) / Cylinder Airmass (g)

	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000	4,400	4,800	5,200	5,600	6,000	6,400	6,800	7,200	7,600	8,000
0.08	43	48	56	56	58	60	60	58	56	56	58	58	58	58	58	58	58	58	58	58
0.12	33	38	46	46	48	50	50	48	46	46	48	48	48	48	48	48	48	48	48	48
0.16	26	30	34	37	40	40	40	40	40	40	40	40	42	46	46	46	46	46	46	46
0.20	21	25	30	34	36	38	38	38	65	36	36	36	36	40	40	40	40	40	40	40
0.24	20	24	29	32	34	36	36	36	34	34	34	34	36	38	38	38	38	38	38	38
0.28	19	24	28	30	32	34	36	34	32	32	32	32	32	32	32	32	32	32	32	32
0.32	16	22	28	30	32	34	34	34	32	32	32	32	32	32	32	32	32	32	32	32
0.36	14	20	26	28	30	32	32	32	30	30	30	30	30	32	32	32	32	32	32	32
0.40	10	16	22	24	26	27	28	30	30	28	28	28	28	30	30	30	30	30	30	30
0.44	8	14	20	22	24	25	26	27	26	26	26	26	26	28	28	28	28	28	28	28
0.48	7	13	19	21	23	24	25	26	25	25	25	25	25	27	27	27	27	27	27	27
0.52	6	12	18	20	22	23	24	25	24	24	24	24	24	26	26	26	26	26	26	26
0.56	6	12	18	20	22	23	24	25	24	24	24	24	24	26	26	26	26	26	26	26
0.60	6	12	18	20	22	23	24	25	24	24	24	24	24	26	26	26	26	26	26	26
0.64	6	12	18	20	22	23	24	25	24	24	24	24	24	26	26	26	26	26	26	26

A different way to view tables like this , is in a 3D mode/ Model. By clicking on the circled icon on top, we can switch to a 3D view.

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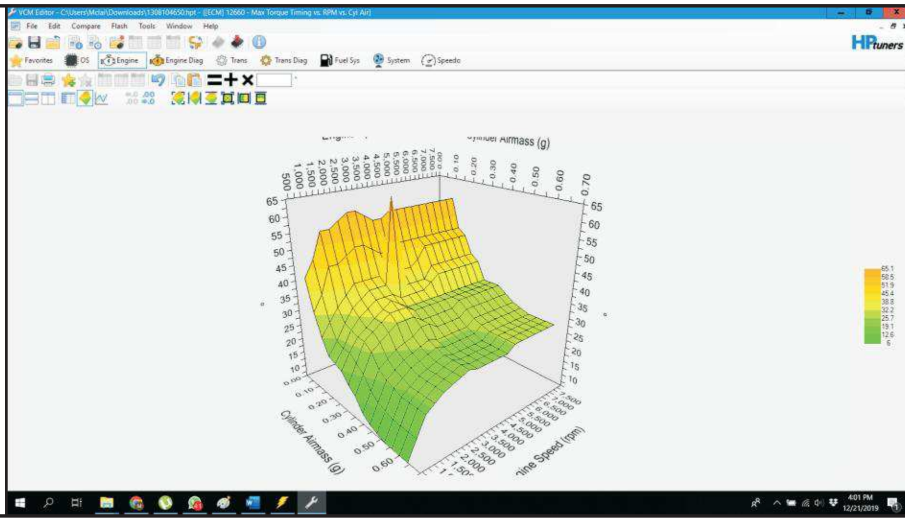
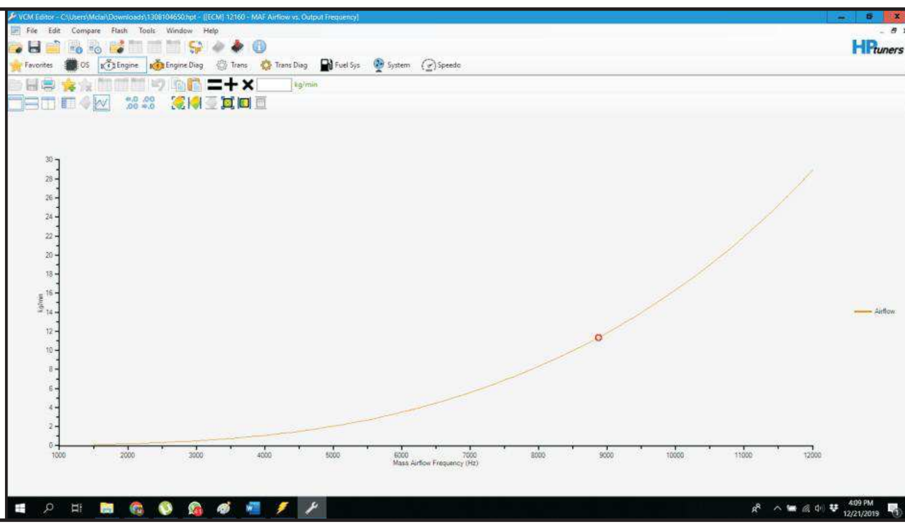
VCM EDITOR



This landscape represents every value in a 3D view. You can easily spot the number that's "off" as well. But one other good exercise is to look at tables like this to see if they are "smooth." With most engine and transmission parameters and tables, everything is smooth and gradual. The environment of operation changes, giving these tables a landscape like look, but in most cased there is no "drastic" change in the operation at lets say 1200 rpm and 1600 rpm. If you changed a table and the results looks like uncharted territory with cliffs and mountains, it might need some work. This will become a but clearer during the guide.

The other view that can help you is the 2D view. This is for tables that only have a single value on 1 axis. This is the 2d representation of the MAF Sensor Frequency plotted against the air flow.



You can see how smooth that line is. If you did some work on this table, and it has spikes in there, its worth looking over the data again to make sure those spikes aren't misinterpreted data.

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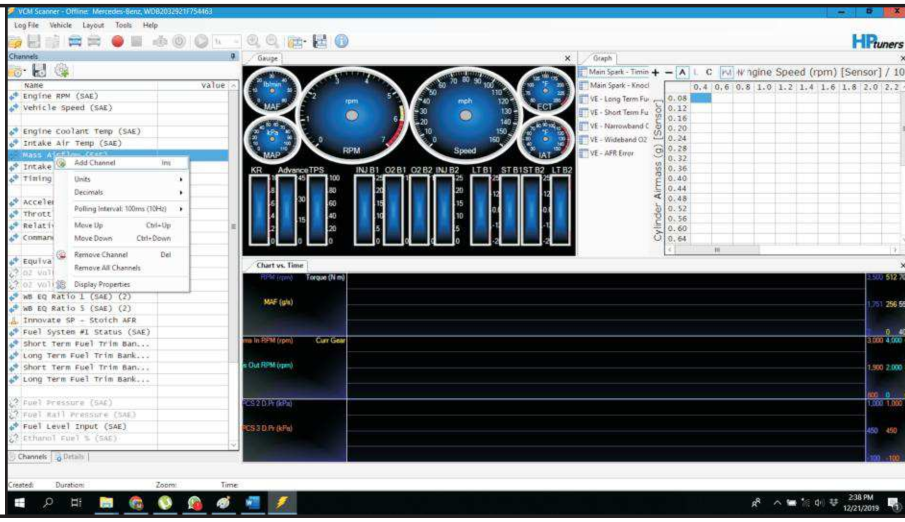
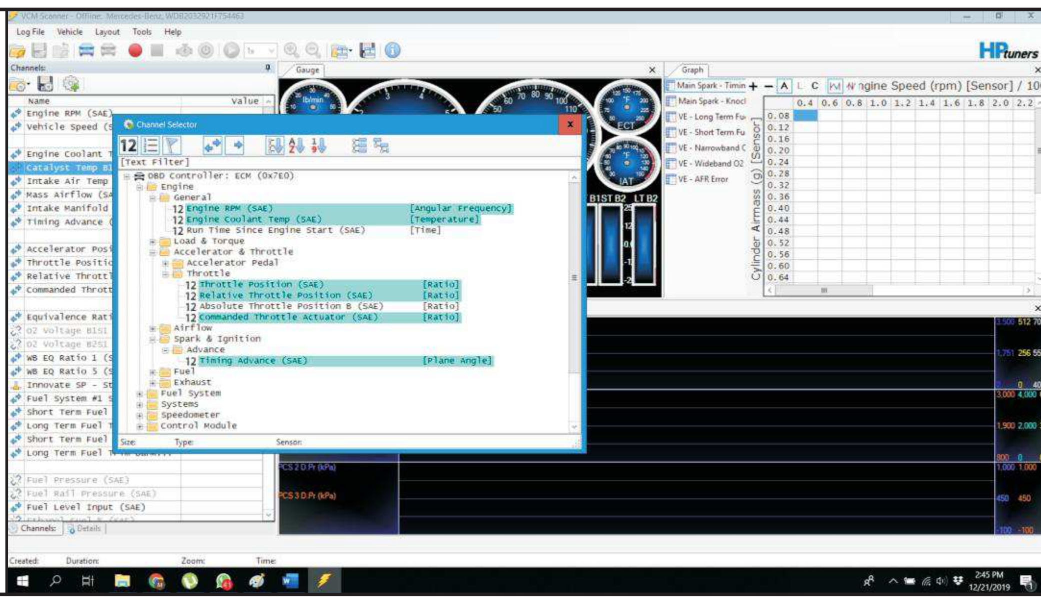
VCM SCANNER

Next is VCM Scanner.
When you start up the scanner, you can instantly connect to the car to let is scan what kind of car it is.

On the left you see some parameters that are selected for scanning. You can add or remove channels, change location and the units, or change the polling interval by right clicking on a "channel.



Adding a channel:
Right click and select Add Channel. You can also speed it up by pressing the "Insert"(INS) button on your keyboard. It will now come up with a list divided in several sub groups. You can go through that list to see if the channel you want to monitor is in there. You can also use the search or filter field up top to narrow it down if you know what data stream you are looking for.



The Parameters highlighted in blue are already in your list.

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VCM SCANNER

Polling Interval
Whenever you are logging data to check the engine/transmission, or gathering information to re-calibrate/tune it, or using it for diagnostic purposes, you want two things.

As much relevant data as possible and the highest possible refresh rate of those parameters. When I would just select all and log that data, I cant miss a single piece of data that might help me do the task I'm trying to do, but there is a big downside. By requesting this much data, I'm overloading the databus and reducing my refresh rate of critical data.

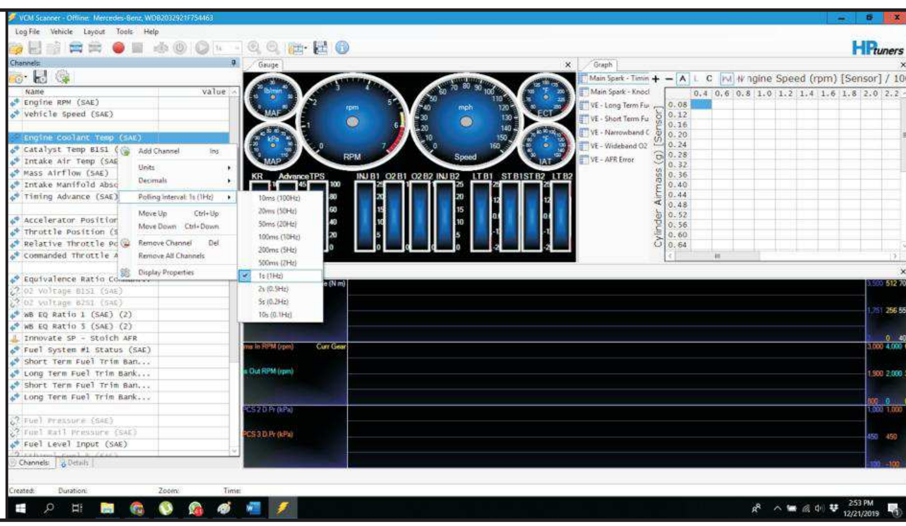
So in order to get data refreshed as fast as possible, you need to trim the list down to the data you actually are going to use or are helpful to complete the task.

Next thing you can do, is to help reduce the refresh rate of very slow signals that are still important, but are unlikely to change very rapid.

For example, I want to capture as much frames of data per second on the Throttle Position Sensor, but refreshing the oil temp sensor once a second is more than enough. That temperature won't jump 10 degrees back and forward in that one second.

So slow, but relevant signals, we could "poll" less often to free up as much speed in the data bus as possible.

Right click on that channel and change the interval on that one to lets say 1 Hz (1x per second).



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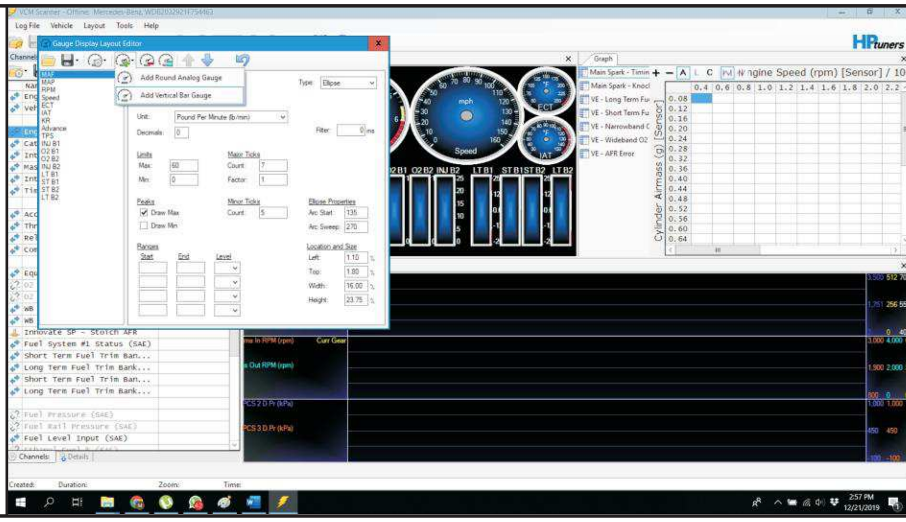
VCM SCANNER

In the middle at the top of the screen, we have our gauges. These give us some of the data we are monitoring, but in a graphical representation which is often easier to read that a line of text during test driving.

The standard layout gives you a pretty good set of data about the engine. You can however change this to will by right clicking on there and clicking "Gauge Layout" to open the layout editor.



On the top you can select Add gauge, and select the type you want to add. You can then select the type of data you want to display by clicking "parameter" and selecting the data you want to show.

After that you can edit the minimum and maximum values, number of decimal points for accuracy, filter and factor options, as well as location. If you are a bit lost on all this, look at some predefined gauges to see what they mean, how they work, and how you can implement that into your custom view.

Underneath the gauges there is our data plotter. Data selected in this layout will be plotted in that chart against time. This can give you a great advantage as you can instantly see a decay or a course of a parameter.

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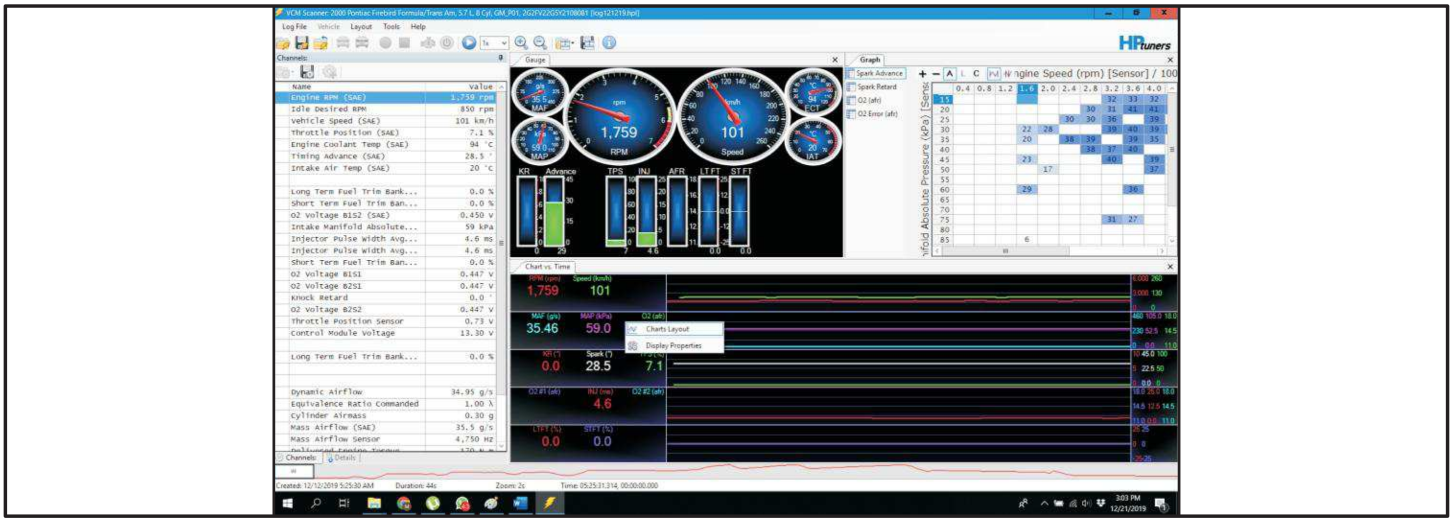
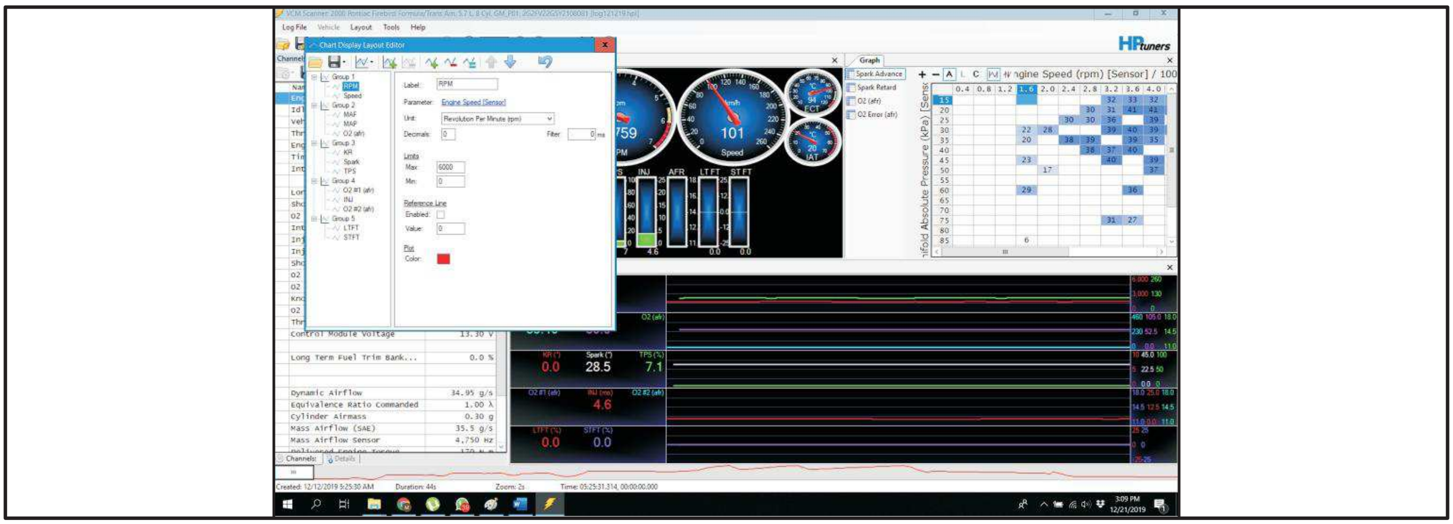
VCM SCANNER

You can of course customize this chart to your wishes by right clicking and selecting “Chart Layout”



This will open up the chart editor which looks like this:



On the top you have a little menu where you can simply add a group or a single parameter (Add Series).

When you add another group, the charts will be squeezed together to let you see all the groups. So its best to keep the maximum amount of groups limited to 4 or 5.

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When adding a “series”, make sure you first select the group where you want this parameter to be displayed in. Grouping specific pieces of data, gives you a great way to see the interaction of certain parameters, and aid you in diagnostics, tuning and overall logging.

After you added a series, you can select the data stream by clicking “parameter” and selecting the right data. You can then define the limits, decimal numbers , color or even a reference line to help you get a better overview. It can take a few tries to get the hang of it, just take your time to set it up right, and you have a new best diagnostic buddy. You can zoom in and out using the “+” and “-“ buttons to give you a better detailed look

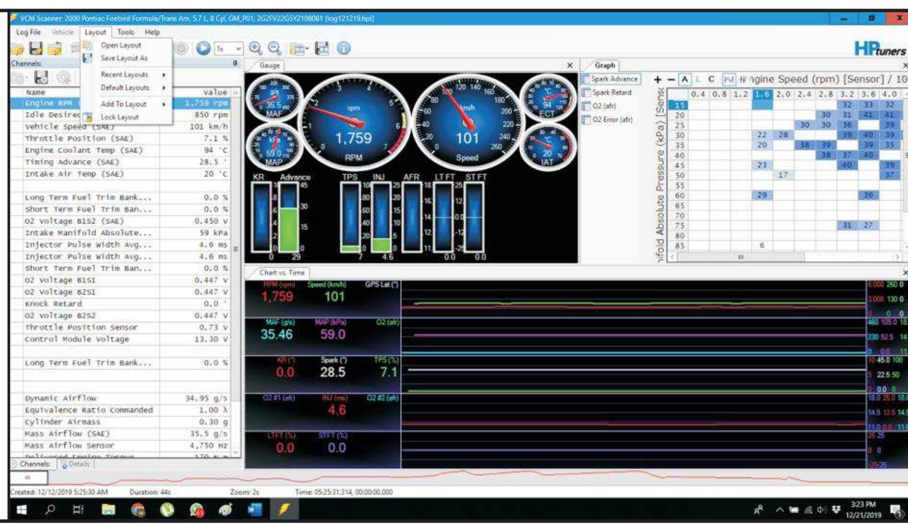
On the top left we have Histograms.

With this we can plot data in a table where we can define our axis breakpoint our self. It will also let you setup filters to give you the option to leave out irrelevant data during logs. For example when the engine is still warming up. You can choose to start logging while it's warming up, or setup a filter that the histogram only uses data where the engine coolant temp is above xx degrees.

In our re-calibration part we will be using Histograms, and its all explained in detail.

A couple of tips.

Once you have setup the layout you are comfortable with, you can save this layout to have direct access to it every time.



The “Layout” button on top will let you save your layout, open a layout or lock the layout as it is now. The VCM scanner will revert to a default layout every time it starts, unless you lock it.

Its best to define certain layouts for certain tasks. For example, the layout for engine diagnostics, differs from transmission diagnostics. If we have a misfire or a loss of engine power, we don't really need to know the current through our 4L60-E EPC. So you can work with multiple layouts designed around specific tasks.

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VCM SCANNER

One last tip, if you are trying to diagnose an intermittent problem, its often hard to find that exact spot back in the logs. You can “mask” these spots in several ways.

You could connect a switch to an analog input on a pro device, and log that input to see when the switch was pressed. This works perfect, but does require a pro version and some wiring.

In most cases you can also monitor some other buttons from the car, for instance the air conditioning or traction control button. By monitoring these buttons, you can use those buttons to “highlight” spots in the logs where you are having the issue, making it easier to spot without using small logs.

Although this guide will hand you some basics on transmission tuning, we cant start with that. The transmission and engine are intertwined and a bad engine calibration, or sensor might not be noticeable while driving the car, but can kill your transmission faster then you can rebuild it, and that's all without any fault codes when reading out the transmission.

So before we can start we need to a sanity check first on the engine, and for that we need to become engine experts.

Next stop.. Some engine basics.

THE WORLD OF TRANSMISSION TUNING
ENGINE BASICS 101

For the transmission to do its job, our engine calibration needs to be valid and healthy. So we will look at some elementary basics of the combustion engine.

The combustion engine is nothing more than a big air pump, no matter if it's a 4 in line, V-8 or even a rotary engine. The engine will move an amount of air, add fuel and ignite it to make power. That's the very crude definition of a very complex piece of machinery.

But before we can start turning knobs and changing numbers we really need to go through some basics and fundamental acronyms.

Physics tells us we need 3 components to make fire. We need O2, or Oxygen. Luckily air has about 21% of O2 in there, so we already have 1 of the 3 items when the engine is turning over and sucking in air.

Then we need something that burns. Fuel in a liquid state doesn't burn, But if we make it into a mist and combine it with oxygen, we got ourselves a pretty potent gas.

Last ingredient we need to make it "ignite" is combustion temperature. This temperature is provided by the spark plug in our petrol engine.

Those are the 3 basic components. But in detail it goes way further than that.

The potent gas Mixture .

Like we said, the combustion engine is an air pump. So when we turn it, it will pump air. In order to make it run, we need to add the right amount of fuel and ignite it at the right time.

The ratio between air and fuel is called air fuel ratio, or in short AFR. This ratio is not in volume, but in weight. For example AFR 14.7 means that we have a ratio of 14.7 units of air to 1 unit of fuel in weight. Doesn't matter if its KG, Pounds or megaton, as long as both units are the same.

The AFR we need or want depends on many factors, for which load and type of fuel are the most critical ones. We will discuss the "load" factor later on, but we can briefly touch on the type of fuel part.

Not every fuel is the same. There are fuels like Ethanol that can be used on cars just as well, but since they have a different energy density and Stoichiometric ratio than gasoline, it's no direct replacement.

Air Fuel Ratio (AFR) or Lambda
We briefly touched the term Air Fuel Ratio, or AFR earlier. One other way of expressing this is done by Lambda or λ. These 2 terms go hand in hand like twins, but are not identical. AFR explains the ratio of both air fuel into terms we can comprehend quite easily, and Lambda tells us something about the combustion.

THE WORLD OF TRANSMISSION TUNING
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When we have an ideal combustion (Stoichiometric), both the Fuel and the Oxygen in that mixture are both consumed 100% without left overs of either. This is what we call Lambda (λ) 1.0 or stoich. Whether we are putting in gasoline, ethanol or nitro, if both the oxygen and the fuel is both consumed fully, we have achieved λ 1.0.

From there on we have 2 other options, either we have a mixture were we have left overs of Fuel (rich) or we have Oxygen leftovers(Lean). Anything lower then λ 1.0 is a rich mixture, for petrol this would be anything lower as AFR14.7. If we are above λ 1.0 we have some oxygen left and we are running lean, this would be anything higher as AFR14.7 on gasoline.

In order to achieve this perfect mixture of λ1.0 with petrol, we need to have an AFR of 14.7(its actually 14.63, but we will round it up to the widely used 14.7). But here is the kicker.. When we are using E85 for example, we are going to need an AFR of 9.9 to get a Stoichiometric balance. Especially with governments demanding the use of a gasoline Ethanol mixture these days and actual Flex fuel systems that can run on 85% ethanol, we need to convince ourselves what is in the tank and what we are dealing with before we make matters worse.

Here are some common fuels with their different Stoichiometric ratios:

FUEL	CHEMICAL FORMULAS	AFR
Methanol	CH_3OH	6.47:1
Ethanol	C_2H_5OH	9:1
Butanol	C_4H_9OH	11.2:1
Diesel	$C_{12}H_{23}$	14.5:1
Gasoline	C_8H_{18}	14.7:1
Propane	C_3H_8	15.67:1
Methane	CH_4	17.19:1
Hydrogen	H_2	34.3:1

So convince yourself what's in that tank. If the car is getting an Ethanol Blend like E10, and we don't tell the controller this, we will re-calibrate the load sensors with wrong fundamental data.

In this guide we will use 100% gasoline and are going to work with an AFR value of 14.7.

If you know that its going to be E10 for instance, you could make an adjustment to let the controller know. Find the right Stoichiometric AFR of the fuel, and input this in the Engine > fuel> general tab and look at the Stoichiometry. As we said earlier, gasoline is 14.63 on which everything was based at the labs from GM.

If you have a Ethonal E10 blend with Stiochiometric AFR of something like 14.1. Problem is that you never really know for sure. E10 from the pump could easily be E7. So whenever you are doing this, either make sure its not an Ethanol blend, or get a sample tested.

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Ethanol Percentage in Gasoline	Stoichiometric A/F Ratio (Lambda = 1)	Air/Fuel Ratio for Maximum Power at WOT
0	14.7	12.6
10	14.1	12.2
20	13.0	11.2
30	13.0	11.2
40	12.4	10.7
50	11.9	10.2
60	11.3	9.7
70	10.7	9.2
80	10.1	8.7
E-85	9.9	8.5
90	9.6	8.2
100	9.0	7.7

When you are 100% certain it's a E10 blend, change the Stoichiometric AFR in the controller accordingly.

If you are not familiar with AFR or lambda and you are still in the learning curve, my advice would be to work with Lambda instead of AFR. This will pay out in the long run as you are not converting any ratios and are purely looking at the combustion side using lambda as your guide, Remember that λ 1.0 is stoichiometric for gasoline, nitro E-85 or anything in between.

The other benefit with using lambda over AFR is that when you are commanding stoich (lambda 1), and you are measuring something else, that number instantly represents the factor you are off your target. Lets say we are cruising and commanding a stoich mixture, but we are measuring lambda 0.95 instead of 1. That means that our commanded fuel is off by factor .95 or 5%. We will discuss this in a bit more detail further on.

Since HPtuners actually works with AFR in this guide, we will be using AFR and convert it to Lambda to aid us later. To make sure there is no confusion on AFR and Lambda, all our Air Fuel Ratios will be based on Petrol and we will use 14.7 as that number, unless addressed otherwise.

Lambda or O2 Sensors

The engine is a equipped with lambda sensors that monitor the exhaust gasses to determine if the commanded Air Fuel ratio is actually within specs. We basically subdivide lambda sensors into 2 categories; Wideband and Narrowband. Other terms are Air Fuel Ratio Sensor (wideband) and Oxygen sensor (narrowband).

Both sensors are located in the exhaust and can tell us something about the combustion that has taken place, but both differ very much when it comes to the use ability of that data.

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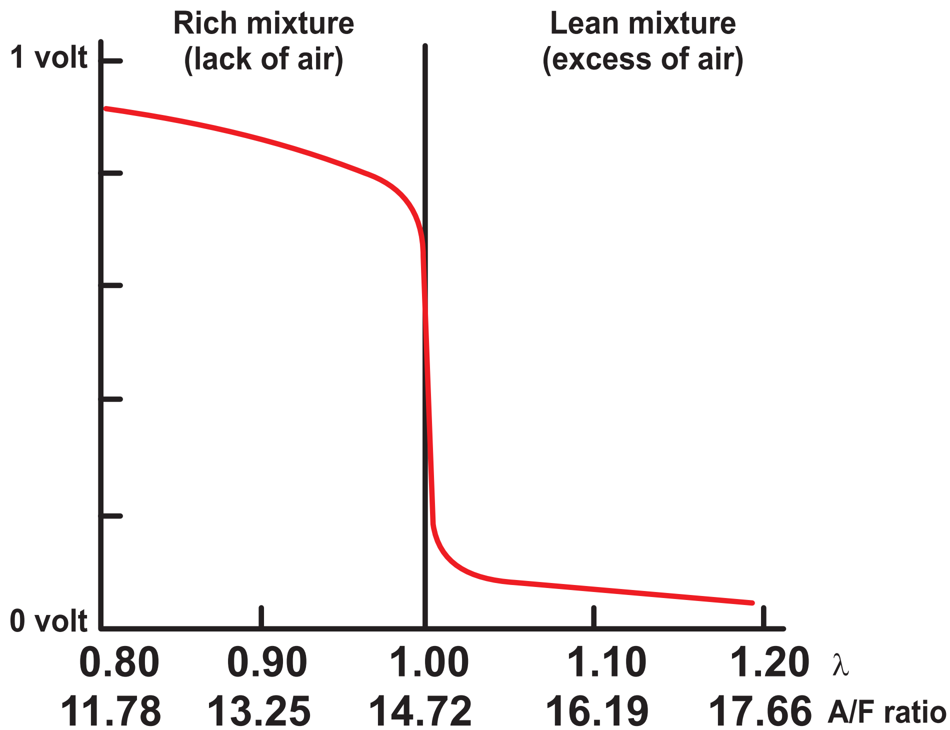
First let's start with the Narrowband Sensor. This sensor has been in cars for decades and the reason is simple. It's cheap and pretty reliable and has a long life. The downside of this sensor is that its not really outputting the most usable data.

This is a graph of the sensor output a typical Narrowband / Oxygen Sensor.



As you can see in the picture, this output isn't linear and is basically only accurate in a very narrow band. Richer or leaner than a Stoichiometric AFR of 14.7. Knowing that our engine lives most of its life combusting Stoichiometric mixtures, this sensor is perfect. When we are too lean, we know it, and when we are too rich, we know that as well and can react accordingly.

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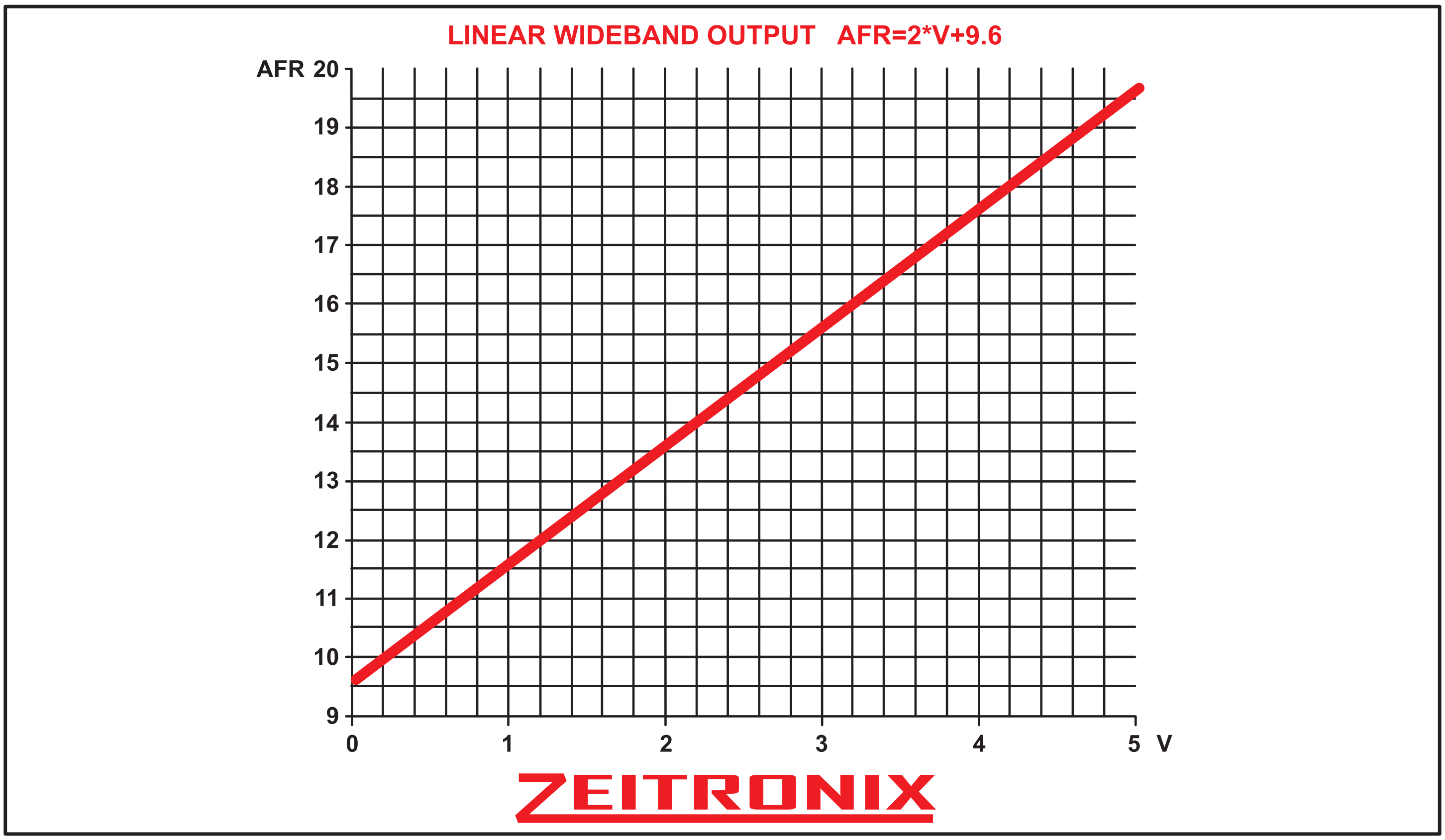
The wideband sensor, or Air Fuel Ratio Sensor
Sensors like this are becoming more and more the “Default” sensor in OEM applications. One of the reasons is that they are becoming less expensive. When I bought my first wideband sensor over 20 years ago, it cost me as much as a monthly salary. Back in those days they are not available as they are now, and yes, it still works ;)

The other downside on these units was the limited lifetime. They usually failed within a couple hundred of hours of “cruising.” Both price and lifetime are much better now and we see them becoming standard on many engines.

The wideband sensor also required an additional controller as its output wasn't as simple as a voltage like the narrowband.

This controller will interpret the current consumed by the wideband sensor in order to determine the AFR and outputting a voltage accordingly. An output of such controller would look something like this.



You can instantly see that this sensor gives you the exact ratio your engine is running on. This makes it a lot easier for the controller and the operator (you!) to see if we our engine is running as it should “Fuel” wise.

So let's go to how the controller measures the amount of air entering the engine to determine how much fuel to inject.

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Load Sensors: MAF & MAP
This guide is basically sculptured around GM based vehicles, but the fundamentals can be applied to other brands as well. So how does the engine know how much air is entering the plenum.

One sensor in particular is designed to measure this flow, and that's the "Mass Air Flow" sensor.

The name basically says it all, it measures mass of air. It's conveniently tucked in the intake pipe before the butterfly valve, and very important, before the crankcase breather pipe. This sensor can't handle oil saturated air like the stuff that is coming out of the breather pipe, or open filters that are treated with an oil substance. Always keep the MAF sensor away from stuff like that. It will either give you trouble in the long run, or destroy your MAF sensor beyond repair and possibly your transmission/engine in the process.

MAF sensors have either a hot-wire or a strip located within the air stream. The element is exposed to only a small part of the total flow. By knowing the diameter of the body relative to the size of the element, you can convert the measured flow to the total flow. This also poses a potential problem. If the air isn't flowing nice and straight, the total air flow doesn't follow this multiplication. That's why we normally see an additional screen in front of the sensor to "straighten" the flow as much as possible.

Removing this screen is done by some folks in order to open up the flow. In normal circumstances this sensor opposes no restriction whatsoever. De-screening it will give you loads of trouble without any potential gains. Inside the sensor is little controller that will keep the wire or strip at a constant temperature of about 100 degrees Celsius.

When air flows through the sensor, the wire/strip will tend to cool down and the sensor controller will flow more current through this element to keep it at the set temperature. By measuring the amount of current, you directly measure the amount of air flow. The sensor controller will output either a voltage or a frequency for which the engine controller can work with and determine the amount of air passing the sensor simply by looking it up in a chart. GM works with frequency and the following chart/table is from an LS1 in a Camaro.

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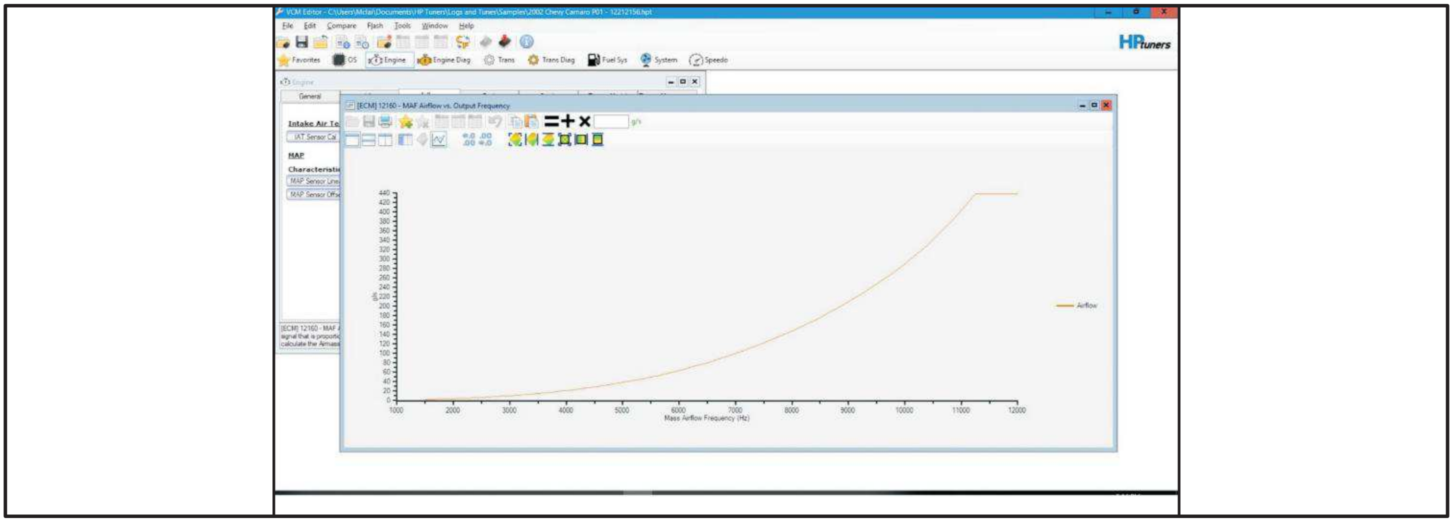

This is a very important “Calibration” that you cannot, I repeat CAN NOT transfer from car to car. For those who have joined us at the scope seminar in Frankfurt have seen how much the airflow frequency changes when anything is changed to the intake. GM invested a lot of money to get this calibration perfect in order to get the engine running as good as possible. Even small changes like switching the panel filter to an aftermarket kind can and will skew, distort or shift this calibration feeding the engine and transmission controller “false” information. We will discuss how to do a sanity check on these values later to see if they are within the allowable range of the calibration.

The other way to determine the amount of air entering the engine is to measure the pressure in the Intake Manifold, also known as Speed Density. It's not as simple as dividing the engine displacement by the pressure, but with the right formula, it's a great air model to calculate air with.

Let's say we have a 6.0 liter engine. This means that theoretical we displace a volume of 6 liter with every 2 rotations (1 full event for each cyl). The air model however doesn't work with volume, but with mass. So we have a formula to convert it to grams/stroke per cyl using basic gas laws.

Without going to deep into this stuff there are a few key components that we can look for.

When we lower the pressure in our intake, the total amount of mass entering a single cyl will decrease. That's basic physics. One other main component in there is Volume Efficiency.

This is another “Table” in the controller that will tell us how efficient the engine is at sucking in air mass at any given point. I'm using the term Table or Chart for a specific reason. In most tuning software this will be called a map or in this case a 3D map . But since we are discussing the MAP sensor, it can get more confusing than needed, so I will use the term table or chart to discuss the airflow calibration and other tables in the programming.

This 3D table is called Volume Efficiency and has an X-axis and a Y-axis.

By putting Engine RPM in one and Manifold Absolute Pressure in the other, I can start filling out the table. The number in that table will represent the efficiency the engine is “filling” the cyl. So if it says our engine is operating at 2000 RPM with a intake manifold pressure of 40 Kpa, in the factory the engineers already calibrated this table for you, and you can look it up by going to airflow, general and opening the main VE table.

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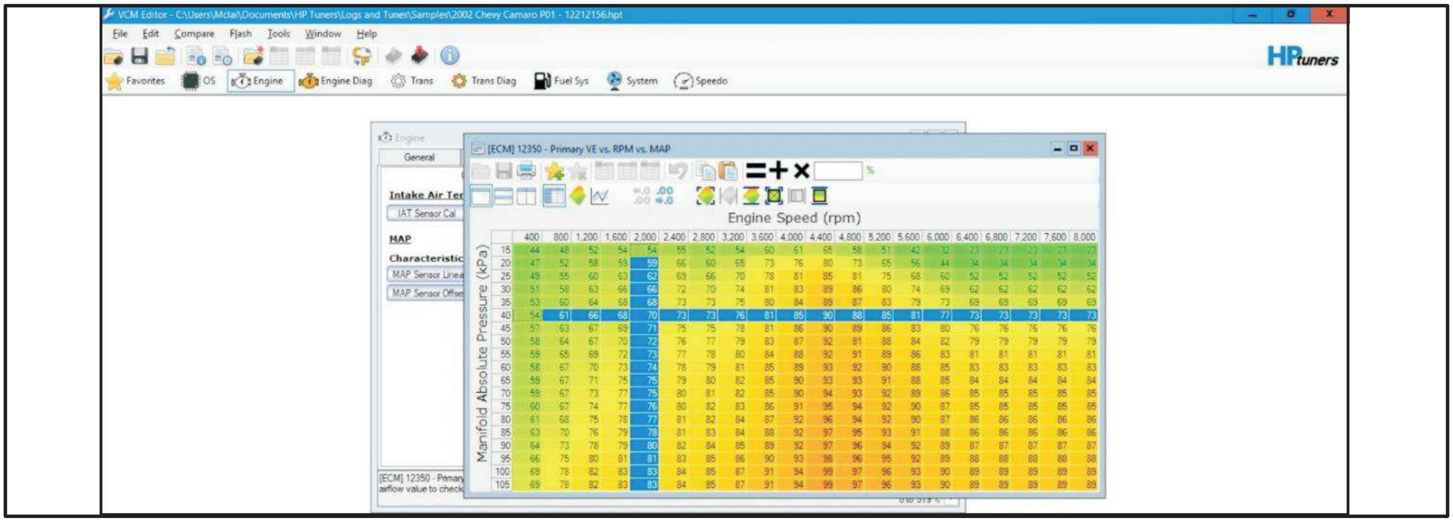

In this case 70, it means my engine is filling the cyl only 70%. However that's not the whole story, it's not as simple as taking the 100% mass and reducing it by this VE number. This number tells us how "full" our cylinder is. It's not telling us with what it's filled.

We know how lower pressure and higher temperature means less air amount as the air density is decreased. The controller will not only take in account the volume efficiency, but also the density of the entering air to calculate the mass entering the cyl.

Again, not doing the math here, if you want to learn more about this, calibrated success will explain this in a detail nobody else does while still talking "English."

If we would crunch the numbers, we would probably see that we are only displacing 40% of the mass that we could displace when we would have 100kpa pressure and 100% volume efficiency.

Since they calibration engineers did a great job in the factory, the displacement of the engine is still the same and the air outside hasn't changed since they wrote the calibration. I only have to worry about the Main VE Table. Changes to either intake, exhaust, cam or even supercharger will affect how efficient the engine is pumping this air. So when I am going to re-calibrate a car, I will restrict my efforts in making this table as spot on as I possibly can.

So we now have two ways to determine/calculate the amount of air entering the engine. On most GM cars both ways will be used and blended into one outcome. If you look at the table above and focus on the 100kPa pressure, you will see that it doesn't really have a lot in the high rpm. For reasons like this, MAP calculations will not be used above a certain RPM, as the MAF sensor give much more details regarding the flow in that area, and it is very good in measuring high amounts of flow. So that's a big plus for the MAF sensor.

In low loads there isn't much airflow and if you look at the chart of the MAF sensor, you will see that low flow isn't its strong suit. Also rapid changes is not being picked up by the MAF sensor as there is some delay due to mass inertia, which will be visible to the Map sensor as the pressure is measured directly in the intake and changes are measured instantly. So chances are that the controller will use the MAP over MAF information while doing the calculations in low load. Both these sensors are known as LOAD sensors as the mass of air entering the cyl determines the engine load.

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The transmission uses this signal as well. If the signal is "off" chances are that the engine controller can adapt to this situation using the O2 sensor as a feedback, while the transmission lacks this option.

What else do we need to know?

Controller Strategies
When controlling an actuator output based on signal inputs or "demands," the controller can use different strategies; Open Loop and Closed loop.

Easy way to explain this is using examples we are familiar with, in this case transmissions. If you are doing a transmission oil change you can also use open or closed loop. In open loop you would drain the transmission, look up how much oil it needs, fill it up and send it. You are basically working from a "Base" value to achieve an actuation; a transmission with the right oil level. However, luckily we always check our work. So after we fill it up with the oil quantity we looked up (base value), we check the oil level again. If its still a little low, we put in a bit more, adding "output" to our base value." After that we check it again until it's good and go on to the next car. It might be a crude comparison, but it does explain the difference between open loop and closed loop very well. In a closed loop environment, I'm using feedback to determine if the actuation I want is actually right or that it needs to be adapted.

How does the Fuel system fit in this?

Fuel Trims
We have discussed the way how we determine the amount of air entering the engine. Let's say we are running pure on the MAF sensor and this sensor is dirty measuring only 80% of the air it actually flows. We cleared all the adaptations and are running the engine at a constant load and rpm and the engine is flowing 120 gram/seconds. Since our MAF is dirty, it will only read 80% of that, meaning the MAF sensor is telling the controller its flowing 100 grams/sec.

So we have 20% more air entering the engine than we are calculating fuel for. This is result in a lean mixture and our narrowband is a low voltage (lean mixture).

If our fuel system is running in closed loop, it will use the feedback from the sensor to accommodate as much as it can. In order to do that, it will add fuel on top of the calculated amount. It will do this by setting the Short Term Fuel Trim (STFT) to a positive number, lets say 5%. So its now injecting the original amount +5%.

Since we are flowing 20% more air, the mixture will remain lean. So another 5% will be added very quick and it will keep adjusting this until its in a balance. So in just seconds it can be already adding 20% using the STFT. Since we know that the sensor can't actually measure a real AFR number, you will see that the controller will richen the mixture till the O2 sensor will measure a Rich mixture.

After that it will start to decrease the fuel step by step till it's lean again. That's one of the reasons why you see this sensor always dancing around the 0 number. The other reason is our Catalytic Converter. In order for this to work properly, it needs a to have a mixture that has a surplus of fuel at one point, and an surplus of air the next. So that's another reason why this is dancing around.

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Now these adaptations have limits, and in case of the STFT, its very fast, almost instant. Most of the time the controller is limited to add or subtract 25 or 30% of its mixture before setting a Too rich or Too lean code. In this example we are running at +20% and with a limit of 25 or 30%, we have very limited headroom on the short trim. Plus since this sensor is fast, it can go down to 10 % for the next “cell” in the chart and will be all over the place before the fueling is right. So that's where the Long Term Fuel Trim comes in. We are still running the engine at a constant load and rpm and the STFT is still at 20%... If the STFT will be there for seconds on end, we can easily assume that the calculation for that Cell is off by 20 %. So instead of letting the controller go to that 20% every time using the STFT, the LTFT starts to add fuel. Since the LTFT is a much slower form of adaptation, it won't jump up and down like the STFT. So now we are having our base fuel, + 20% of STFT and our LTFT rises to let's say 3%. So now we are having more fuel than we need and our mixture is and stays rich.. The STFT will instantly react and starts taking fuel out dropping to 17%... Time passes and the LTFT react to another prolonged term of positive fuel adaptation from the STFT.. So it ads another 3%.. This will continue till the total amount of adaptation will be done by the LTFT and the STFT will jump up and down near 0%.

This has two clear advantages. The head room for the STFT is back to the maximum, and the LFTF values are used and “saved” as adaptation data. Every time the controller comes to that specific cell, the MAF sensor will read 100 grams, and the LTFT will be taken into account when calculating the amount of needed fuel.

And this process will happen for any cell it comes across, giving you a good running engine with a bad sensor.

So everything is well right… not quite. Like I mentioned, this sensor is a load sensor, which is also used by the transmission. In our example, our sensor is 20% off. Lets say this 100gram/sec of air flow equals an power output from 100 BHP. But we are actually flowing 120gram/s. The additional 20 grams are not in the measurements. The fuel system adapts to this and is now giving a proper fueling for 120gram, bringing the engine power output to 120 bhp, instead of the 100 bhp we are expecting judging from the information from our load sensor… This means that our Transmission controller is controlling the transmission with a pressure suitable for 100 bhp, but the transmission is in fact enduring 120 bhp, ergo, we are not having the right pressure in our transmission. On the long term this can kill the transmission even though its been rebuild to specs. So that's why every transmission tuning starts with a sanity check of the engine.

Take it for a drive and watch the STFT and the LTFT using the VCM scanner. Anything on the LTFT that's out of + or – 7% can cause an issue and its advices to recalibrate the Maf sensor and Main VE to get the calibration of the engine as close to 0 as possible.

Proportional Integral Derivative or Differential (PID) and Parameter Identification Data (Pid).

If you start the VCM scanner, you might see it say, scanning for Pid's. This means its actually interrogating the controller to ask with Parameter ID's are available for display. Not every data the ECU/TCM will work with is available as realtime data and sometimes you need to collect your own data by hooking up external sensors or calculating the exact information using other bits and pieces.

Please note that we are talking about Pid's here. PID is also used a lot in controllers and has to do with a way a control system operates. PID stands for Proportional Integral Derivative or Differential. It's a pretty complex system we don't have to go into it in this guide as we have no need for it at this point. It is widely used in the automotive (for example idle control) and if you are interested in learning more about it, I would suggest going to HP Academy and sign up with them to view their course about PID. Their approach on PID control is very good and much easier to understand than most video's I've seen.

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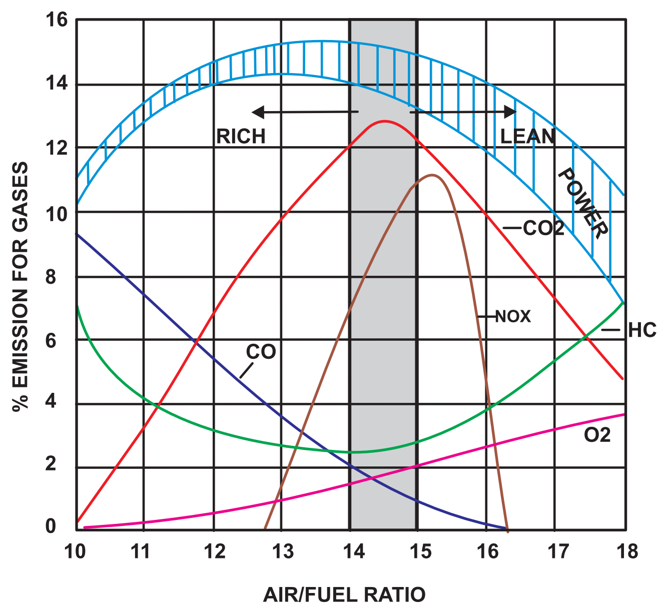
Emissions, Power and AFR
One last thing I want to discuss about AFR as we never covered why we would like to have a specific AFR to begin with.

We talked about λ 1.0 as being the ideal combustion. This type of combustion will give you almost the lowest of emissions of dangerous CO combined good fuel economy, a smooth engine while still providing good power.



So it's not that weird that 14.7 is right in the middle of all. All the fuel burns, making the combustion very hot creating quite some NOX while being as low as possible on HC levels.

The dangerous gas CO is very low and can be further reduced by the help of catalytic converters.

And as you can see, it did not leave much power on the table.

So for most of its life, the engine will work in that area.

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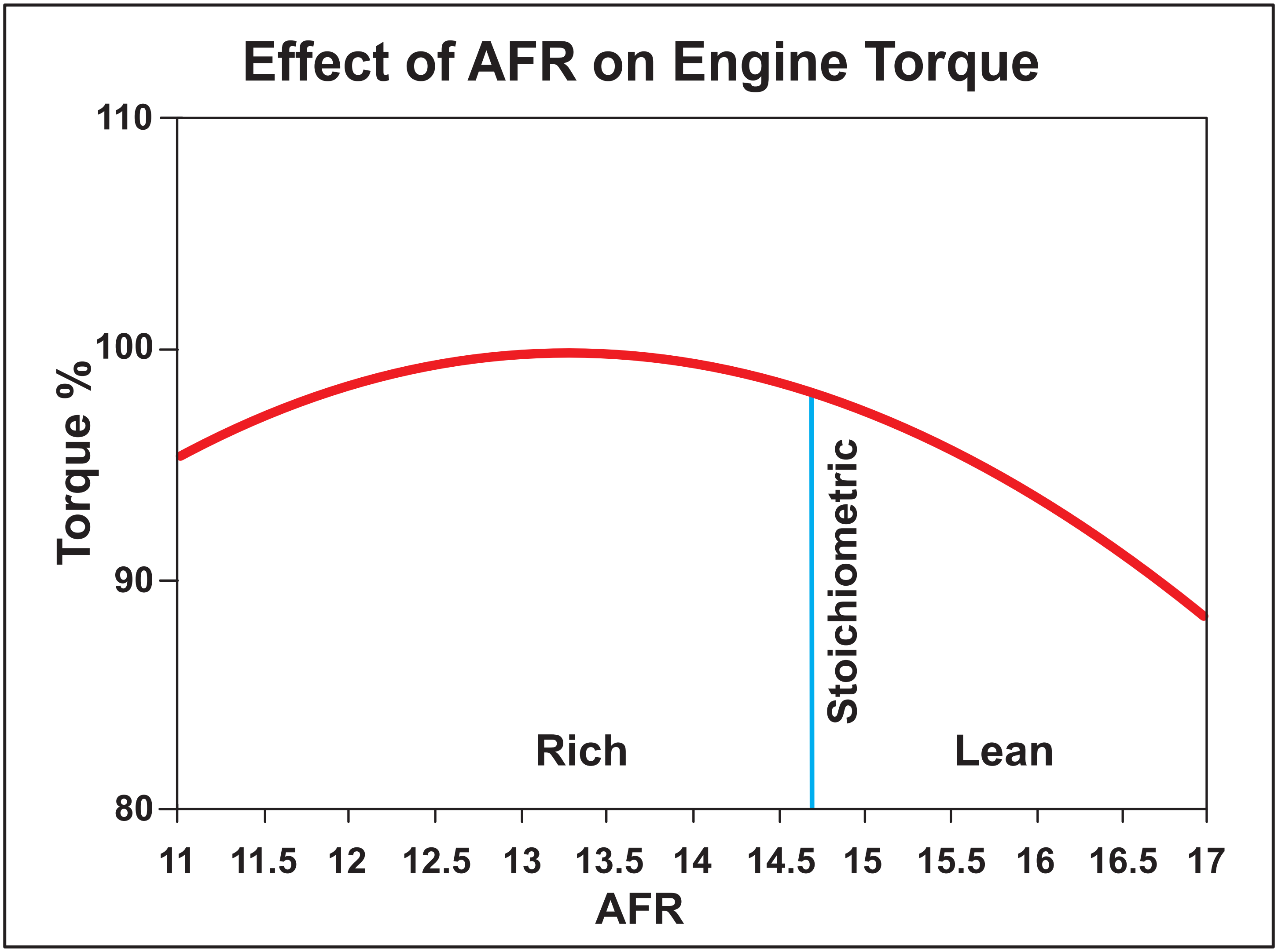
What about the other parts of its life?

That's where the engine has to deliver the maximum amount of power and torque and is not looking for economy or the best of emissions.

If we would plot AFR vs power, it would look something like this.



You can see we are that we have the best power somewhere between 12.7 and 13.6. We can generate the maximum available torque there fuel wise. Of course there are much more aspects to it then this, but in general, this is a good chart to get an idea, but if you are going to approach tuning using this chart, you might kill your engine.

The reason why is because the exhaust gas temperature and load runs very high at this level, high enough to cause Knock during Wide Open Throttle (WOT). This can destroy your engine within seconds. Therefore we normally go a bit more to the rich side of the chart to help cool the combustion temps down and have a bit of a safe guard while still having big torque numbers.

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Pre-ignition and knock(detonation)
These terms are widely used together, and although they have similarities, they differ very much.

First we need to look at a combustion first. People often believe that when the spark hits, that mixture goes BOOM like dynamite. That's not the case, it might go fast for us, but its actually going relative slow and at a predictable rate. This rate is known as the Laminar Flame Speed and can be something between 0.2M/s and 0.5M/s depending on the AFR and pressure for instance. So in the cylinder chamber everything is pretty predictable and gasses expand at a certain rate.

Now if I would draw in air that is already 70 degrees. This means that it needs less energy to ignite and that compressing it generates enough heat that it will ignite on its own without the sparkplug even firing. That is what we call Pre ignition. Our peak pressure will be there at a wrong time and the laminar flame speed might rise out of control. That's not always the case, but its most likely to happen.

Then there is knock. Knock happens when the spark plug ignites the mixture as it should, but the flame is unstable. Flame speed can hit sonic speeds , and instead of one molecule "triggering" the next one to ignite, its chaos in there. Everything is bumping into each over and there is literally a shockwave traveling through the chamber bouncing of the cylinder wall making allot of noise.

This is very dangerous and there is a good reason why you don't want to experience it. Combustion temperatures can go as high as 900 degrees in certain conditions. This temperature is contained in a aluminum chamber and aluminum piston with a melting point of around 660 degrees.

When there is a normal combustion, the outer layer of the combustion gasses serve as a barrier from the heat of the actual flame front. This keeps the components alive.

When there is knock occurring, the combustion is so violent that it strips away this layer resulting in full contact with the high temps. Within seconds you can kill the piston and lose the game against knock.

Fuel model
In order to mix both fuel and air in a certain ratio, the Air mass is measured. In order to inject the right amount of fuel, the controller needs some information to do so.

This is what we refer to as the fuel model. It contains information about the flow rate of the injector, how long it takes for them to open at a given voltage, pressure etc, etc. With this information the controller can calculate the exact amount of time it need to open the injector to inject that specific amount of fuel. So knowing the exact information of the injector is a must.

Changing out injector will require you to not only change the flow rate, but every aspect that comes with it. This is also referred as injector characterization. This is however not discussed in this guide as most of us won't have the tools needed to do any of these tests. So during this guide we will assume that the injectors in the car are either stock, or that the injector information in the controller is 100% correct so that when the controller opens the injector to inject 2.7 grams worth of fuel, that this amount is what is injected no matter the environmental parameters.

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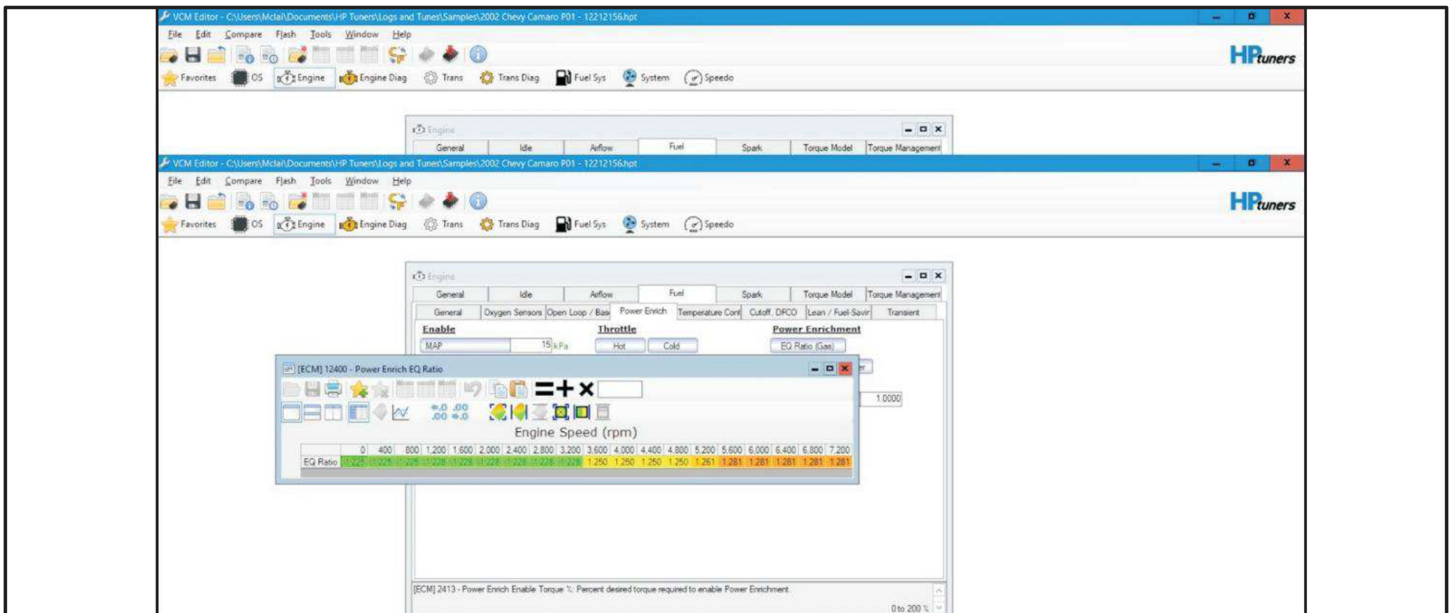
Not-Stoich

In the GM software everything is basically sculptured around lambda 1. This is good for allot of things, but not for power and especially not to help us fight temperatures and knock.

So if we would drive the car at wide open throttle, we want a richer mixture then lambda 1. The controller will calculate the needed fuel for lambda 1 and use a multiplier function to get a richer mixture. This way the air model can be used over the entire scope of demanded AFR and a simple 2D map can make the difference. We are not going to work on the fuel side in this guide, but it's good to know that it exists and where to find it 1 specific map about it.

This function is known as Power Enrichment, or PE. This function works with EQ Ratio. In short, the commanded AFR will be your Stoich AFR divided by this number. Lets say its 1.2, then the resulted commanded AFR will be 14.7/1.2



DFCO: De-acceleration Fuel Cut Off

This function will make sure that when the conditions allow it, fuel is fully cut off during de-acceleration. This will make sure the engine isn't trying to achieve lambda 1 during de-acceleration. During our Re calibration we tend to disable this function to get as much undistorted data as possible.

COT: Catalyst Over Temperature

This function will richen the mixture in order to reduce the temperature of the catalyst. This can shift our measurement without knowing, so during re-calibration or tuning some will disable this function. I like to leave it alone for now.

Transients or Transition State

Most of the examples we have or are discussing is in a steady state. So our engine rpm is steady, butterfly valve is the same position all the time, pressure in our intake is the same, temperatures are set at a fixed temp, everything is basically stable. If we would suddenly stump on the gas, or shift gear, we are no longer in a steady state. Our load changes, air flow rises (after a short delay), intake pressure goes up etc. During stages like this, our sensors are often not adequate to react fast enough, are in a position to react in order to maintain our demanded Air Fuel Ratio. For this there are calculation models in the Controller to cope with situations like this. Even rpm change is a transition state.

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Volume Efficiency
We will go into more details about this in the re-calibration section. But basically this is a table that tells you how efficient your engine is in sucking in air at a given RPM and pressure. We know that a Cyl has a certain amount of volume, but this volume isn't always filled 100%. This table will tell us, and the controller just how much it is filled at a given point. Please note that this is just how much its filled, NOT how much mass air is in there. It doesn't account for air density, temperature etc.

A different variant of this is the Virtual Volume Efficiency table. When GM came out with their Gen4 they threw away the "solid" table and did the VE calculation based on factors and coefficients. The Volume Efficiency is now calculated on the fly using a whole lot of coefficients based on physics. This made it almost impossible for the human mind to work with it. Hptuners and others have come up with a way to give us a Virtual VE table by calculating this table based on the coefficient, making it possible for us to actually modify it and work with it. In this guide we will restrict our self to the Gen 3 with a solid VE table for simplicity. However, if you want to have more training on these Virtual Volume Efficiency tables, check out the GM Advanced Guide from Calibrated Success.

Heat Soak
When you are driving your car down the road, temperatures are normally pretty steady. Although your exhaust gassed may have heated up your exhaust manifold to 250 degrees under the hood, that intake manifold that's under there as well, is letting air come in at 30 degrees.

Once you stop the car, that's where things tend to happen. The water pump stopped, so no more cooling. The block might be hotter than the coolant, so it will continue to heat that up. Same goes for the manifold and the head. Those are packing some energy as well which they are now dissipating to the surrounding materials. So temperatures can rise pretty fast under the hood and “soak” everything with heat.

3 minutes later you hop in the car and start it up again. Suddenly the car is breathing in 70 degrees of air while our ambient temp is only 25. The coolant temp has risen to 105 and everything is hot as hell. The controller reacts to it as good as it can, trims are flying up while you drive along. After 5 minutes of driving the temps are all stabilized again and are within their normal range.

During those first few minutes the controller relies heavily on adaptation and trims. That's not something they can fix real easy at the factory without putting in a bunch of additional sensor etc. So the trick is to only log data after you have driven it for a bit and watched the temps to come back to normal ranges.
Base, Adders and multipliers.

As you will see in the rest of the guide, controllers often work with multiple tables for the same type of control. In that case they work with a Base table to start with. This table contains fixed values which are at the base of the equation. But if there is a condition that will not work with the base values, the controller must know that and take that in account, For example high intake air temp. This is less dense, is already pre-heated and can cause issues when applying the same base value as we would use on a cold afternoon.

So they came up with adders and multiplier tables. In an adder table I can design a function to either add or subtract a specific amount of the base value to compensate my base table for certain conditions. Same goes for the multipliers. Here is can put in a value that the base value will be multiplied with to increase of decrease the outcome.

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Spark table hi and low octane
Changing spark advance is something we normally do when tuning a car. We optimize these numbers to achieve the maximum torque available. The maximum allowed spark is not a fixed number as there are many factors that affect it. Most of these factors are ironed out at the factory, but they can't look into your tank. So they cannot anticipate on the quality of fuel in your tank. So instead of setting for low numbers that can work with everything, they made 2 different spark advance tables, a Hi Octane and e Low Octane one.

If the engine controller is picking up allot of Knock events, it can switch to the low octane table to get rid of knock. Now, the reason why we need to know about this, is because in case of an error or failure with a load sensor like the MAF, the controller automatically defaults to the low octane table as its base table. It will not blend the hi octane and the low octane or will use solely the hi octane table as a base spark advance.

So when we need to re-calibrate the engine calibration, we get into situations where we disable 1 of the 2 air mass calculations and revert to only MAF based air mass calculations, or only Speed density. At those points we will be getting our spark advance from the Low octane table. In order to get the most accurate condition as in the normal driving situations, we will temporarily mess with the spark table.

Sanity Check
Before we can log the data and trust that the controller is reverted to MAF of Speed density only, we need to have the error set in at least two trips. So start the car up a few times and check the DTC. As long as the code is Pending, you might not be able to trust the data. If the code is set active, go ahead and test drive the car and log the data.

Does every car need a re-calibration? Depends on the model you are looking at in your shop. Most corvettes I've seen will have some work done that might screw up the original calibration. Whether this is a different exhaust system, open air filter, air box modification or even a different intake, in my experience they are bound to have modification more often than your average daily truck.

Please keep in mind that we will only cover re-calibration of the engine, not tuning. When we are tuning an engine, we modify the programming to optimize power output and engine operation. With re-calibration, we merely modify the sensor or Volume Efficiency calibration to provide the controller with the most accurate data we can provide it. There might still be more power on the table that could be achieved with tuning, but that's not what we will cover in this guide, this will only cover re-calibration of engine data along with Transmission Tuning.

For more information about engine performance optimizing I would suggest to get some course material of Calibrated Success or HP Academy.

How do we know we need to do some re-calibration?
In the engine diagnostic information there are some value's that can help you determine if a re-calibration is in order. On of the values that can help you with that are the Fuel trims, and specifically the Long term kind.

We already discussed the function of this adaptation. I personally will do a re-calibration of that value is anything beyond + or – 7 %. But seeing that number wont instantly means we are having a calibration number. Remember that those calculations are using sensors, one of which is the MAF sensor. This one is very sensitive to dirt and oil. So a bad sensor can also give you high fuel trims. It could also be a bad sensor that is giving the wrong value even after its been cleaned. Since the air model in the GM car is based on a blend of two, we can's 100% say that's it's a bad sensor or a bad calibration without either switching the sensor for a good known one, or tinkering a bit with it.

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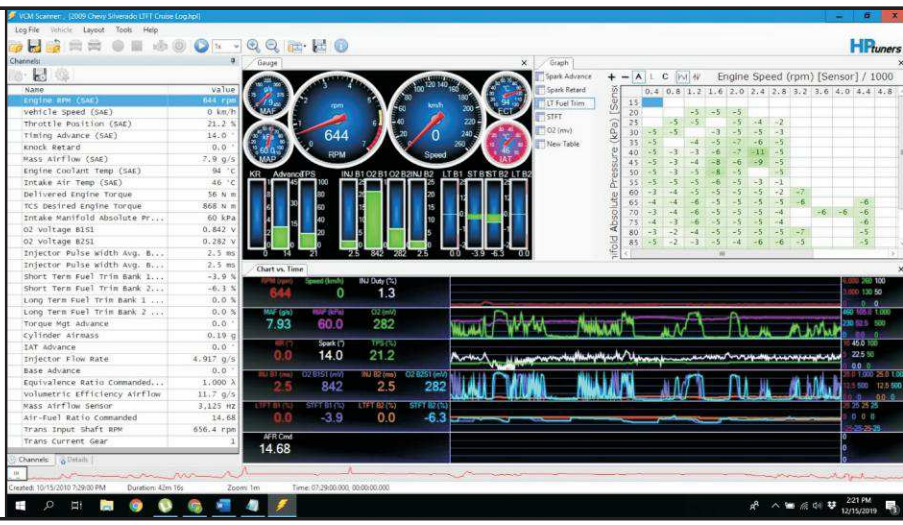
One way of checking a dirty sensor this would require a log of the trims, clean the MAF with certified cleaning spray, measure again and determine check for differences. If you have just rebuilt the transmission, put in the extra 5 minutes and clean the MAF no matter what. You need to do it anyway if you want to make sure its not dirty, so this saves you one drive and log time.

But how do we distinguish the blend model calculations. We cant really without going way to deep into algebra and trying to replicate all the formulas the engineers are using. There are two tricks we can use. Either change the programming to a MAF or speed density only requires you to license the file and "lose" money if the calibration checks out (assuming you are not already committing to tuning the transmission) or we will try to fool the controller in switching to one mode.

Normally we would just unplug the sensor and drive it. Unfortunately the MAF sensor also contains the Intake Air Temperature sensor. Disconnecting it would automatically result in Guessing this temp, giving you a bad result anyway.

So what can we do. We know it's a 5V based sensor, outputting 5 or 0 volts. We could take apart the connector and disconnect the 5V power supply. This would stop the MAF sensor from having a valid output signal and reverts the ECU to a Speed Density system. You will get a malfunction error with an Active MIL and perhaps even a reduced power mode. This is ok. We don't need, or even want full power to check out our calibration.

You can also take a wire with two back probes and connect the Signal out to the ground if you are more comfortable doing that.



Warm the car up, reset the fuel trims and drive is as steady as possible. You want to stay a few seconds in each load of the car for the trims to really show. Monitor this using VCM scanner by either looking the trims in the "Dashboard" or looking them up in the histogram they conveniently already defined for you.

Once you have done that, you an idea of your trims for the Speed density system. We are not looking to fill the whole graph, we just want some useful data. Normally a 5 minute drive with an engine at temp is enough (watch out for heat soaks). Stop the car, plug the MAF back in and disconnect the MAP sensor. Same rules apply. You will get some errors and now your system HAS to work with the MAF instead of the MAP.

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Reset your fuel trims and go for another ride. If the trims correspond with the trims earlier, and they are within a percent or 5, they are reasonably good and you don't need a calibration by default, although it can benefit from it.

If there is a big difference between MAF and Speed Density, check the setup. Any modification on the air-box or filter type results in throwing the MAF calibration off, without screwing up the Speed density calibration as much. Is there some work done than you may need to calibrate to these changes. Is it 100% stock and your speed density values are really good but the trims are very active on MAF-only, your MAF sensor is probably the cause of it. You can re-calibrate it, but putting in a good sensor later would mean you have to re-calibrate is again after replacing it. So its best only to re-calibrate with known good sensors. Same goes for aftermarket sensors. Cheap sensors normally are not as accurate or follow the exact same calibration as the OEM ones. So also check if its an OEM sensor when you are at it.

Also worth mentioning is that these V engines have 2 banks. We are just working with combined data, but actually both sides are monitored. The difference between bank 1 and 2 should be minimum at best. If you have 1 bank -12% and the other +18, there is something wrong that needs to be addressed first and which is not an load sensor calibration error.

So take your time to ensure that you are working with a good sensor and determine if you need a re-calibration. If you do, the next chapter is for you. If you don't need it, you can skip it, but it does contains a bunch of information that can help in the future.

Engine Re-calibration
We have seen that there are two parts of the equation we discussed, fuel and air. Both of these portions can be tuned or re-calibrated. In this guide I am going to assume that the fuel side is fully operational, the injector information in the ECU matches the injectors fitted to the car, the fuel pressure is spot on, the injectors are in good working condition, the fuel filter is working and clean, and that the tank is filled with 100% gasoline and not an Ethanol blend. If there is anything not calibrated right in the fuel delivery system, we have a wrong base to work from and can really get lost in re-calibrating the air calculation.

One other thing, re-calibrating the air model of the car will not fix a problem with the car. If you have a misfire, diagnose that misfire. If every cylinder is working perfect, you don't have a calibration issue. If it runs like a dog and every aspect of the fuel system turns out to be good, that could very well be a problem with calibration. So use this guide with care and use common sense. This guide is a tool, not a magic wand.

If you have driven the car and came to the conclusion that the car needs to be re-calibrated, you want to do this yourself. Best option is to replace the standard O2 sensors with a Dual Wideband system that you can hook up to your HP Tuners. If you don't have that, you could try to work with the Long term Fuel Trims to get the car in the calibration in the ball park.

Lets say your fuel trims are about 15% out. Since the GM car uses a blend of two load sensors, you need to disable one in order to get the data from just one sensor.

If I want to re-calibrate my MAF sensor, I have to find a way to disable my MAP sensor. You could disconnect it, but chances are you will be in a reduced performance state.

Read out the car with VCM Editor by going to flash, and click Read out flash, or simply pressing “CRTL +R”

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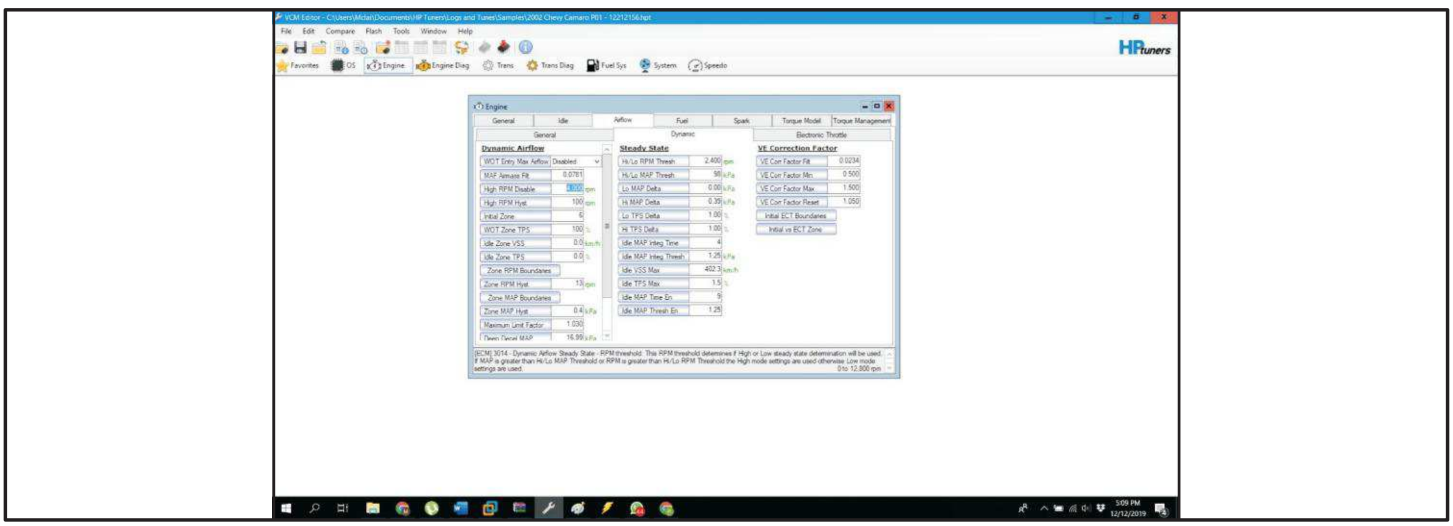
Make sure the car is hooked up to a battery maintainer and wait for it to finish. In order to write it back, you have to license the file. This will be a popup and make sure you want to as there is no refunds after you press license.

In my case I'm using the 2002 Camaro P01 sample file which is a Gen3. We know we want to “mess” with the Airflow, so go to engine, and select airflow. You already will see MAF calibration, as well as Main VE (volume Efficiency). But we need to tell the ECU to ignore the MAP sensor, so we go to “Dynamic.”



You can see that I highlighted the High RPM value. This basically tells the ECU to ignore the MAP sensor if the RPM is higher than this value. So by putting in 400 rpm for instance, we will never use the map as our idle is higher then this value.

If you are going to rely on Fuel Trims to calibrate your MAF sensor, skip the next step as you need to remain in closed loop. You can either choose to work with the Long Term Fuel Trim of the short term. Using the long term takes much longer, but is more accurate over time as you are doing allot of logging.

In this case, we go for the short term to help us out.

Go to Fuel System and select Oxygen Sensor. Select LTFT and put this on Disable

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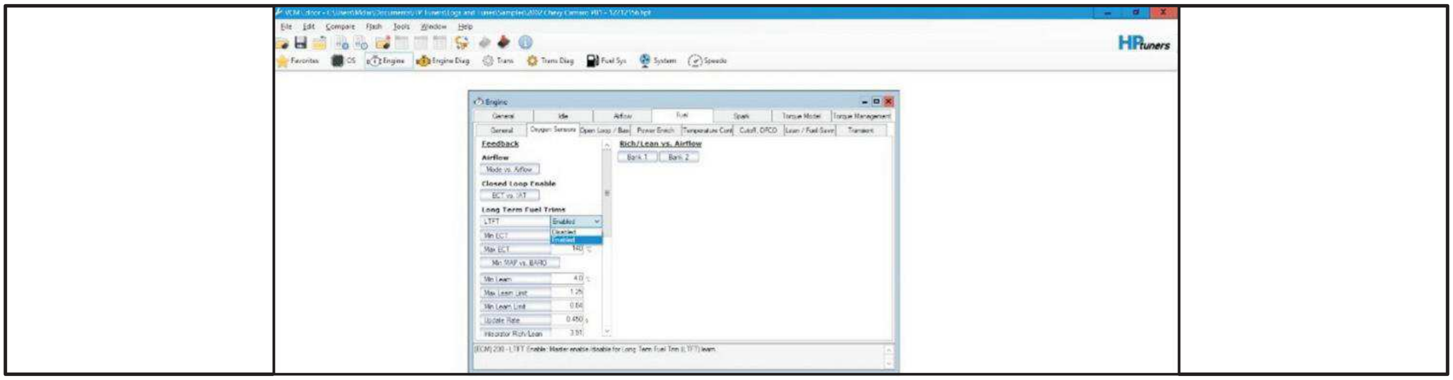
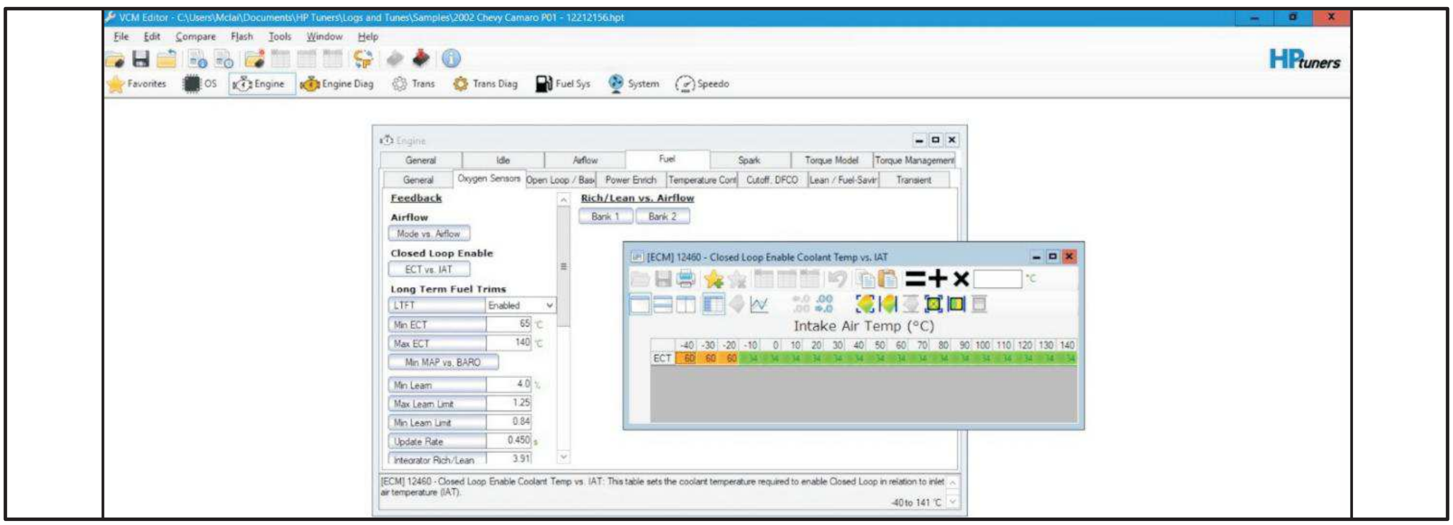


If you are using external Wideband Sensors, you want the ECU to remain in open loop to dismiss any multipliers, adders or adaptations the ECU is commanding or using in order to figure out the right air flow itself. So how can we do that.

One of the easiest ways, at least for me, is to look for an parameter that will enable Closed loop. Some controllers demand a minimum cooling temp, exhaust temp, throttle position or a combination of any parameters. This ECU uses both Intake Air Temp and Engine Cooling temp as a condition to enable Closed loop



This data-map has the function that Engine Temperature has to be xx degrees in relation to the Intake Air Temp to become active. If my Intake air temp is -20 degrees, my Engine Coolant Temp needs to be at least 60 degrees. With 20 degrees IAT my Engine Coolant temp will need to be 34 degrees to enable Closed Loop.

If we set this to 140 degrees across the line, it will never become active. We will be having major different issues long before it goes into closed loop. So I basically forced it to stay in open loop all the way. This is only when you are using external wideband sensors, if you are relying on the factory narrowband sensor data, you need to keep this table original and you can skip the next setting

Off course in open loop the Controller will use some other tables to determine its commanded air fuel ratio.

In this Gen3 controller it's the EQ Ratio Table for Open loop.

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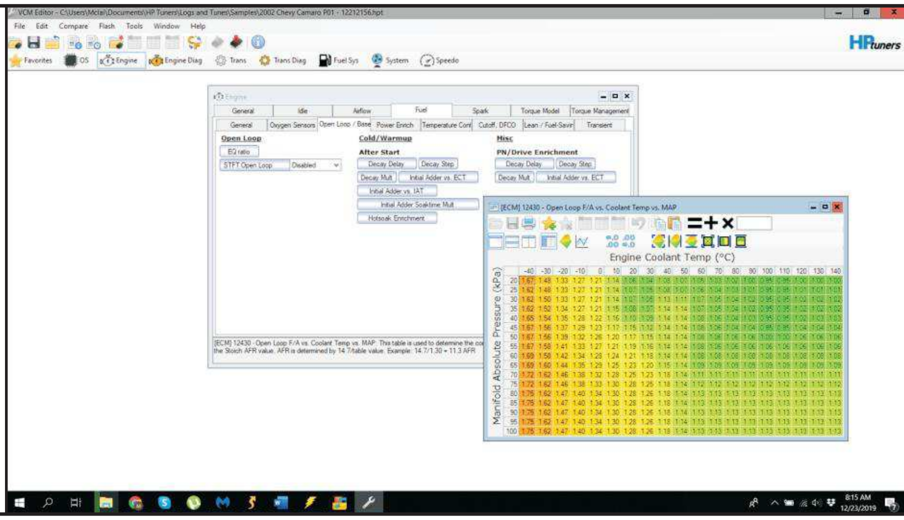
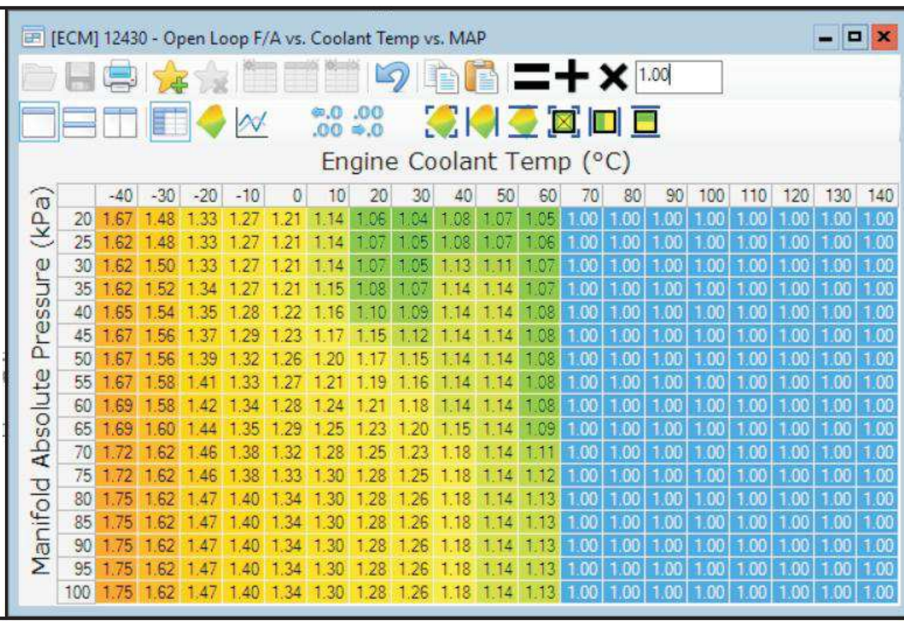


Since we prefer to run as close to an environment and engine state as we will be doing in normal conditions, we will change this table to aim for Stoichiometric.

But you can see its using a lot more fuel in low temps and higher loads. So what we will do is only change a portion of this table to make sure we don't run into some driveability problems when we are getting the engine up to temp.

Select the columns 70 to 140 and equal them to 1.00. This will make sure that once we have warmed up, we will be commanding stoich.



	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140
20	1.67	1.48	1.33	1.27	1.21	1.14	1.06	1.04	1.08	1.07	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	1.62	1.48	1.33	1.27	1.21	1.14	1.07	1.05	1.08	1.07	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	1.62	1.50	1.33	1.27	1.21	1.14	1.07	1.05	1.13	1.11	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	1.62	1.52	1.34	1.27	1.21	1.15	1.08	1.07	1.14	1.14	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	1.65	1.54	1.35	1.28	1.22	1.16	1.10	1.09	1.14	1.14	1.08	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45	1.67	1.56	1.37	1.29	1.23	1.17	1.15	1.12	1.14	1.14	1.08	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50	1.67	1.56	1.39	1.32	1.26	1.20	1.17	1.15	1.14	1.14	1.08	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
55	1.67	1.58	1.41	1.33	1.27	1.21	1.19	1.16	1.14	1.14	1.08	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
60	1.69	1.58	1.42	1.34	1.28	1.24	1.21	1.18	1.14	1.14	1.08	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
65	1.69	1.60	1.44	1.35	1.29	1.25	1.23	1.20	1.15	1.14	1.09	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
70	1.72	1.62	1.46	1.38	1.32	1.28	1.25	1.23	1.18	1.14	1.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
75	1.72	1.62	1.46	1.38	1.33	1.30	1.28	1.25	1.18	1.14	1.12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	1.75	1.62	1.47	1.40	1.34	1.30	1.28	1.26	1.18	1.14	1.13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
85	1.75	1.62	1.47	1.40	1.34	1.30	1.28	1.26	1.18	1.14	1.13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90	1.75	1.62	1.47	1.40	1.34	1.30	1.28	1.26	1.18	1.14	1.13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95	1.75	1.62	1.47	1.40	1.34	1.30	1.28	1.26	1.18	1.14	1.13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	1.75	1.62	1.47	1.40	1.34	1.30	1.28	1.26	1.18	1.14	1.13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

With wideband we have the option to measure the real Lambda value and comparing it to whatever the ECU is commanding, so we aren't limited to just lambda 1 like in the narrow band. But we will try to get as many adders out of the way as possible to get a fixed lambda as much as we can. If we would leave certain strategies , we will be trying to hit a target that's moving.

With narrowband we are filtering on commanded AFR of stoich. Anything else will be discarded. So running the engine hard will result in power enrichment and has no use for us. With wideband users we actually can work just fine with that as well. But since we want our commanded fuel ratio to be as still as possible, we can also modify the power enrichment table to give us one value over a complete range.

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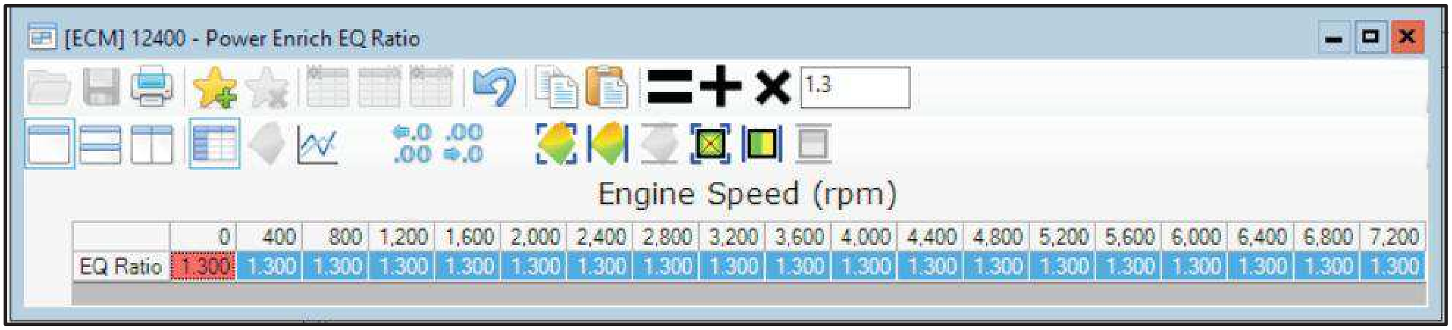
In your tune go to Fuel, Power enrichment and select EQ Ratio.

You will see a row with numbers higher as 1. This does NOT represent our target lambda, but is 1/λ. Our highest number in the list is 1.281. Select the whole table and equal everything to 1.3 for easy viewing and calculation.

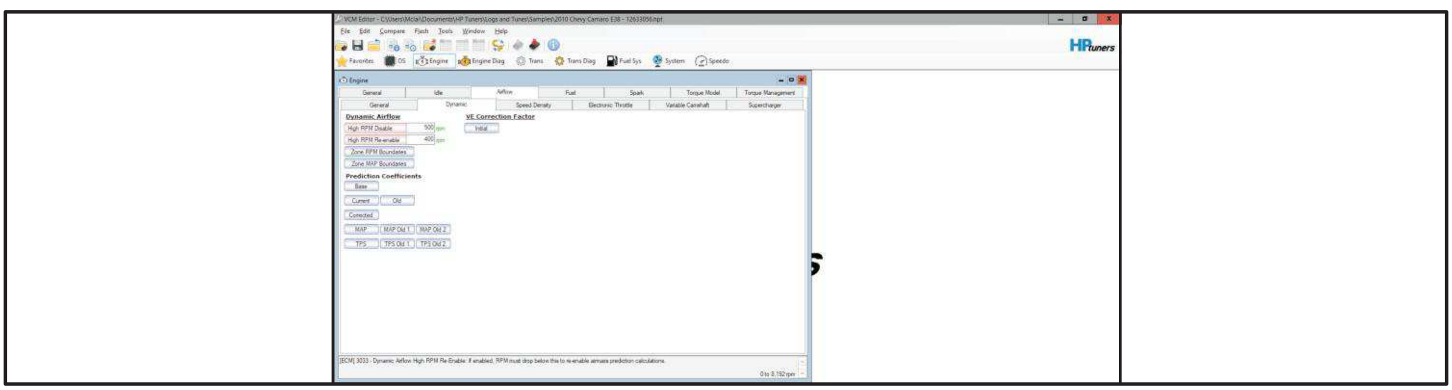


That's one if the reasons why doing these calibrations on a dyno is preferred. You have much more control over the environment, and you can actually take the car through each cell using the load function of the dyno. On the road we can never drive at precise the same load. So whenever you are limited to road re-calibration, drive as smooth as possible.

Next thing I want to do is make sure my ECU will only use the MAF sensor as a load option.

It normally blends 2 different measurements to calculate the load, but im going to focus on the MAF sensor, as this one is very sensitive to small changes like a sport filter (yes, even a panel filter can throw you the calibration). So I need to make an adjustment to the "Tune" to make it MAF only.

This can be done by changing the Dynamic Airflow Rpm "Enable/Disable" values. By changing the disable value below the idle rpm and the enable even lower, the ECU will never use both the MAF sensor and the Volume Efficiency calculation to determine the load and thus the fueling.



I also want my de-acceleration Fuel Cut Off to be disabled. I want my controller to achieve its commanded AFR in any possible way.

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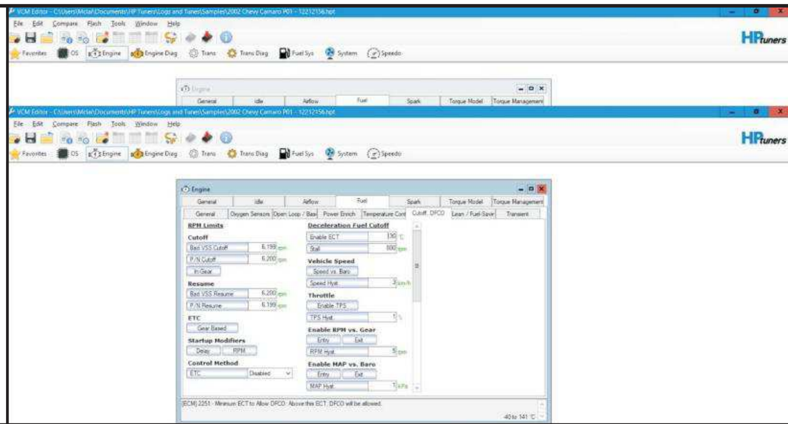
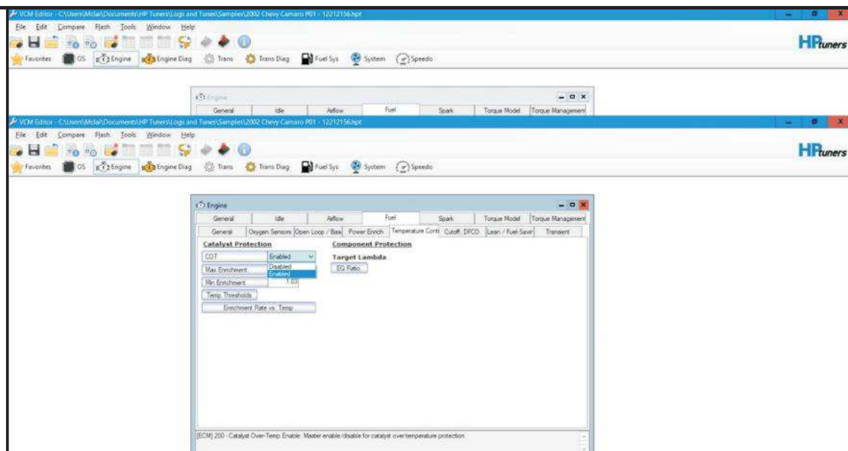


This menu has a neat box letting me choose an Engine Coolant temp where this cut off is allowed and enabled. Change this value to something unreachable like 140 degrees.

Since most cars have catalytic converters, there is also a strategy in the programming to protect them against over temperature. This is perfect to protect the Cat, but during dialing in the MAF sensor we won't be pushing the engine over the cliff that it needs protection. It can however affect our measurement as it might be adding fuel to lower the exhaust gasses. But since we filter our data to only collect STFT when commanding Lambda 1, we are good. But if you ever run into a situation were this is needed, this is where its found.



So now we have set it to MAF only, Open or closed loop depending on your tools, and DFCO disabled. Only one thing is missing, the spark table.

Remember that we will be in the low octane Spark table by default? Now it's time to modify that table temporary.

Open the Spark tab in the Engine, it will automatically show you're the Spark Advance tab which we need to have.

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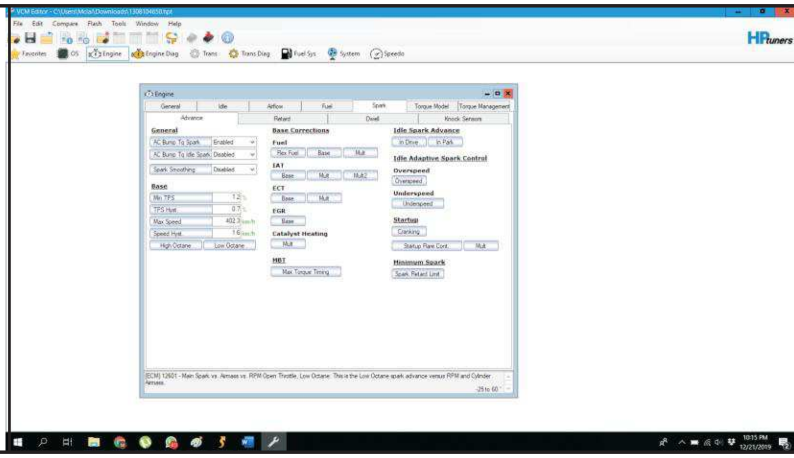
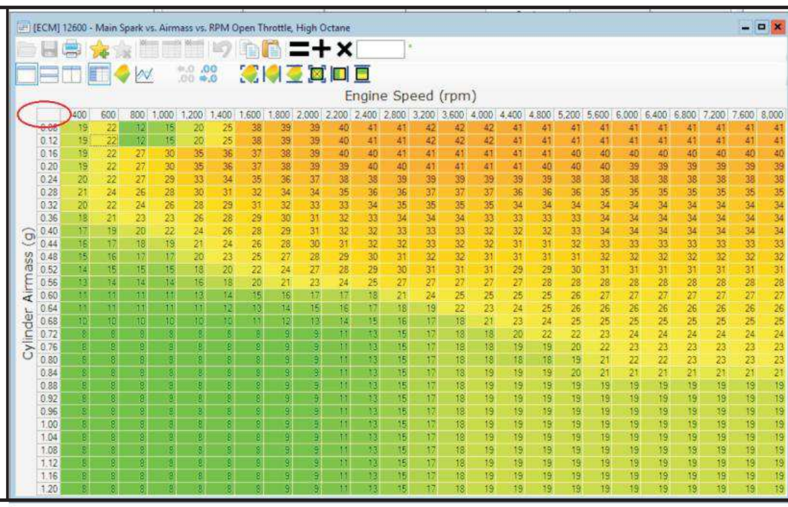


On the bottom you see the high and the low octane table.

Open the High octane table and click on the upper left blank cell to select the whole table.



After selecting it, Copy it and open the Low Octane table.

Select this complete table as well, and paste it in there.

After we are done re-calibrating the car, remember to revert this back to the original table. This can be done using the Compare option which we will discuss later.

Save the file to something like “MAF-Tune 001” and write the calibration to your controller by pressing CTRL+ W. Again, make sure you have a battery maintainer on there to keep the voltage on a good level. We only need to write the calibration in this case. Unless you are doing a custom OS patch or a different modification like segment swap, there is no need to write the entire controller. When you select something that needs a full write, Hptuners will give you a heads up.

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Narrowband re-calibration

For those using the original narrowband sensors, we need to start the car and drive it till its up to operating temperature. Again, we are sure that our fuel system is 100% and that we are actually using 100% Petrol without Ethanol. If you are using an ethanol blend, your AFR target of 14.7 will not correspond with lambda 1.0 and your fuel system is not setup correctly.

Once the car is up to temp, open up the VCM scanner and press spacebar to let it connect with the car. I don't have a car at my disposal, so I will be using logs to demonstrate the procedures.

First I want to setup the scanner in a way that it will give me a fuel trim error based on the “transfer function” of the MAF Sensor. Basically I want them to talk the same language to make it easier to spot any mis-calibrations.

So I first need to create my own data string to use. I want my scanner to spit out an error rate instead of a percentage of fuel it's adding or subtracting. But first lets do the math on that data string. Normally we use an AFR error rate that's nothing more than the actual AFR divided by my commanded AFR.

In theory it would look like this. Lets say my actual AFR is 14 and my commanded AFR is 14.7. The outcome would be 14/14.7 = 0.95

What does this number tell me. It tells me the “factor” the air model is of. For instance, lets say our air model spits out 100g/sec. The fuel model will calculate the amount of fuel needed to get the 14.7 AFR.

However my actual AFR is 14, not 14.7. If our fuel model is untouched, and everything is ok, that means our air model is of. But by how much. Easy, that's the number 0.95.

If I want to correct my air model, I need to look in the data what frequency my MAF sensor is putting out, and multiply this by our correction factor.

Remember when I talked about preferring Lambda over AFR… Lets look at the formula once again using Lambda. Actual Lambda / Commanded lambda.

Since we are commanding 14.7 AFR and are working with 100% petrol, commanded lambda will be 1. Actual lambda will be 0.95. So 0.95/1 is our correction factor. Since we know we are using only data that will fall into the commanded Lambda of 1, measuring in lambda will automatically tells us our correction factor.

Since I'm using the narrow band, I have no information on the actual lambda of AFR. I can however use the adaptation value of my STFT to come up with a similar correction factor.

Lets look at is once more. If our STFT value is positive, its running lean and is adding fuel. So more air is entering the engine that the controller is calculating for. That means that the air mass coming out of the Air Model is too low and needs to be corrected with a factor higher as 1. Multiplying it with higher as 1, will increase the determined air mass in that cell and will rectify the equation.

The opposite is also true. A negative STFT number means we are subtracting fuel (too rich) and the calculated air mass is to high. Less air is entering the engine that we are calculating. So we need to multiply that cell with a number lower as 1.

Lets put that in a Formula.

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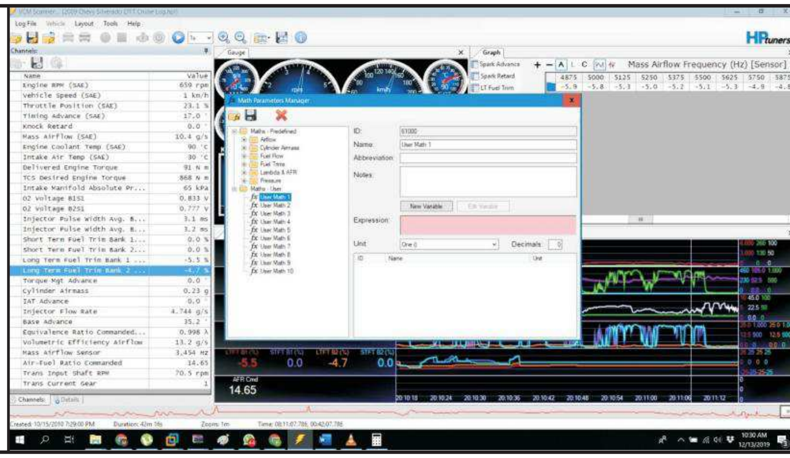
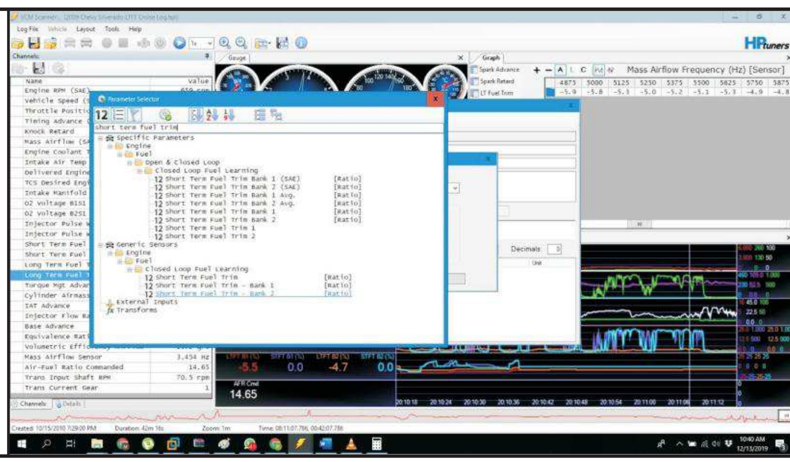


Since its going to be a user defined channel, click on the User Math 1.

First we will give it a name we can work with, STFT error factor.

Click on new variable and it will come up with a whole bunch of parameters to choose from. This list can be overwhelming and takes quite a bit of time to go through, but we can also try finding the information you need by typing it in on the top. Our Math is based around Short Term Fuel Trim, so let's type that in the search bar to see what comes up.



These are the results. As you can see, there are two lists to choose from. “Specific Parameters” and “Generic Sensor.” We will choose the Generic in this case, I will show you why in a minute.

But if you are going through the list, some PID's are in there twice and 1 will have SAE (aka generic sensor) behind it. The SAE version is a parameter which is available in the standard OBD2 datastream. The non SAE version is a manufacture specific value. This is often a higher resolution data stream with a much faster rate. So if we are looking for “glitches” in sensors like TPS, choose the manufacture specific over the SAE. But for now we can work with either, but there is an advantage on using SAE we will discuss later.

After you selected the Short term fuel trim in the Generic sensor list, click on “units” to let it output as a percentage. Leave the special function alone for now. Click ok to add it to the “Variable.”

The variable is added (this is an ID number) and we can complete our Formula. We just gone over this, so lets add this as well. It will end up looking like this.

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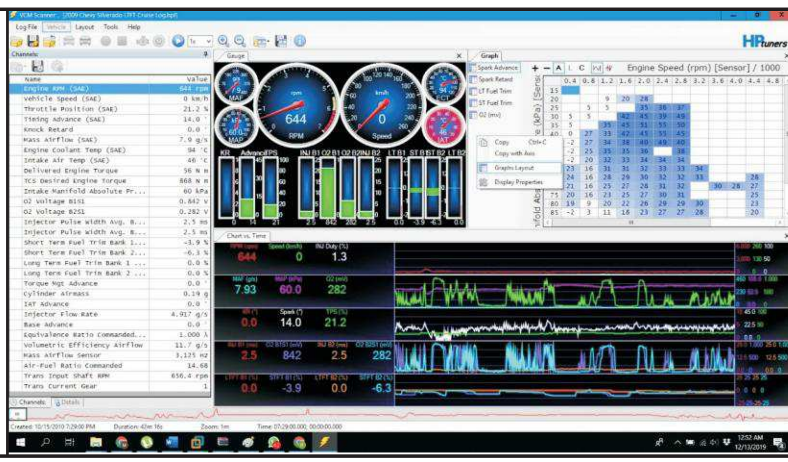
Notice that we are displaying the unit as One and we are displaying it with 2 decimals. Don't forget that last part as it will then only display anything in front of the decimal point.

Also look at the top and write down the ID number of the math channel we just created.

If we want to use this information we either add this channel to our view list, or use this ID number to verify it. In this case our calculated information can be extracted using [61000] as a variable.

Close the windows and let's setup VCM scanner histogram.

Right click underneath in the list of all the graphs and select “Graph Layout”



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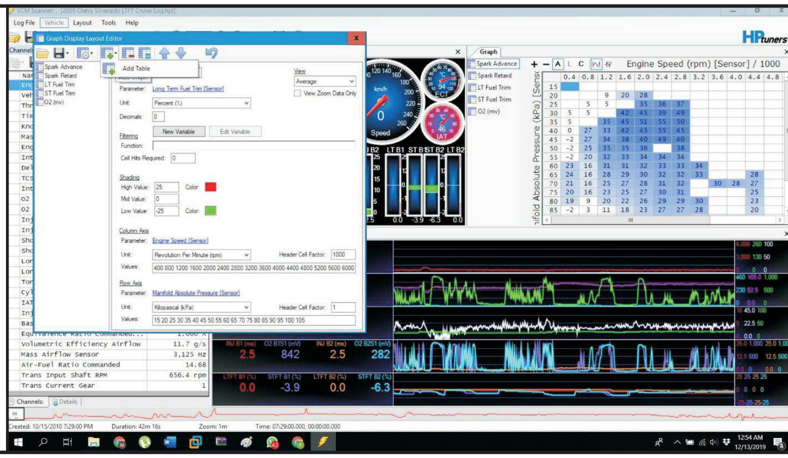
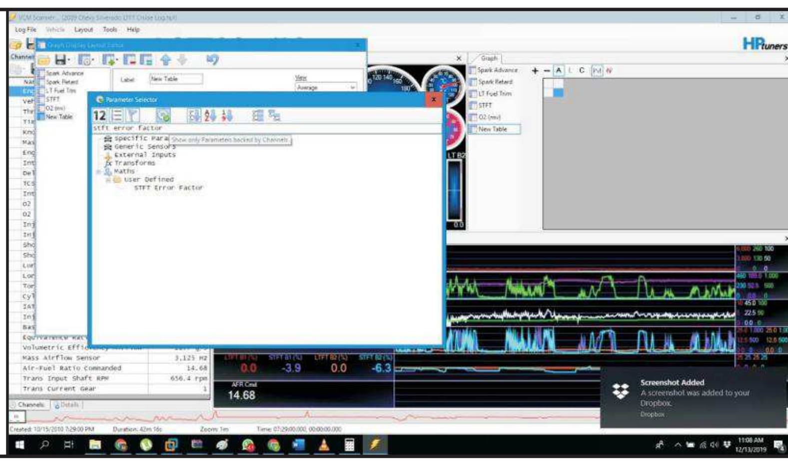
Now select Add table to start telling the program what to look for, how to write it down, and what to discard.



As you can see, it's beautifully setup to be sculptured to our wishes. The program will name this Graph according to our Parameter we wish to display as data. Remember that math channel we created just now, let's put that in a parameter.

Click parameter and search for the data set we just created, STFT Error Factor. If you search for it, but it doesn't show up in the list, click the little "wheel" with the green dot. That will toggle the list to parameters that are actually backed up by a real channel. Your data will be in the "User Defined" section.



We also have the option to do some filtering, which we really want. Remember that the sensor can only detect richer or leaner than Lambda 1.0.. So any time the ECU is controlling anything other than Lambda 1, I want to ignore the data captured by VCM.

So click on new Variable and lets begin defining our filter.

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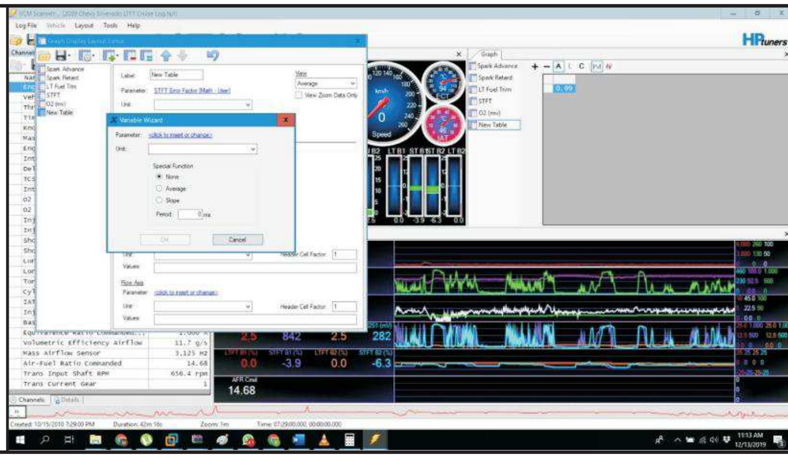
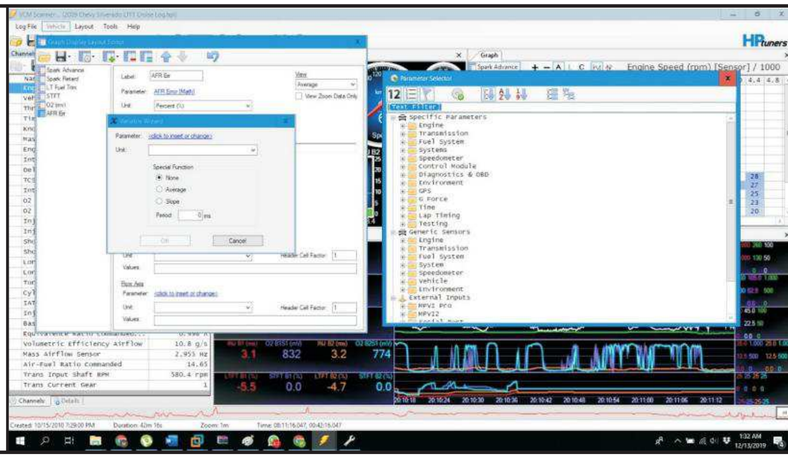
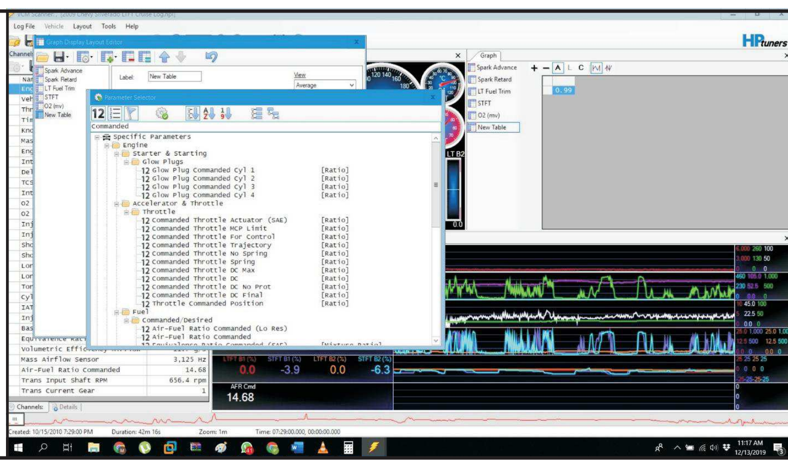


Click on parameter to setup the data we want to use as our base for filtering.



The list is still pretty big, but we are looking for the commanded AFR. Type in “Commanded” and see what remains.



The list is still pretty big even after filtering out a lot of things. The commanded air fuel ratio is again found in multiple places. I said before that choosing the generic sensor is preferable for a simple reason, but I will select manufacturer for this to let you see the difference and what HPtuners will do.

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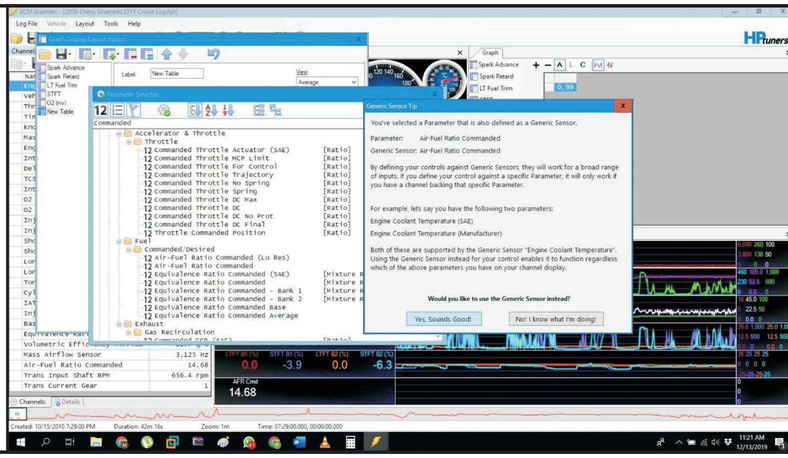
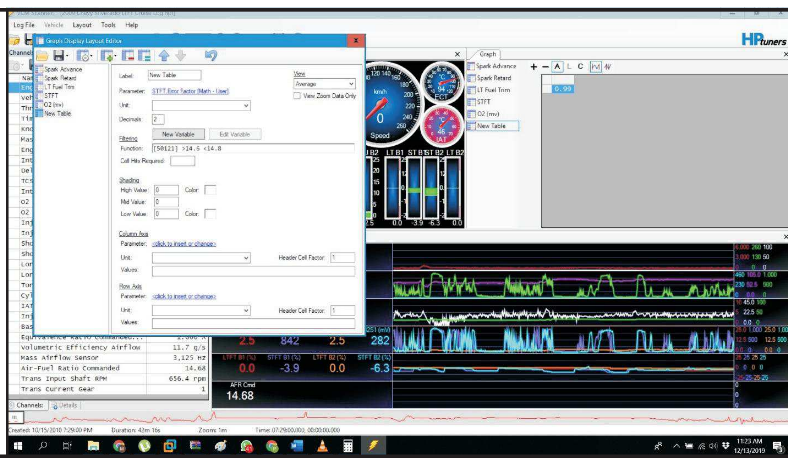


Basically it's telling us that the information we want is also available as Generic. The upside from generic sensor data is that you don't have to log it in your channel list to use it. The downside is that its not always in the same resolution and speed available as a Manufacturer specific PID. But even if our commanded AFR is only updated 5 times per seconds instead of 25 or so, it wont change the outcome for us in this situations. But there are enough cases where you definitely want and NEED that speed and resolution.

So for now we will listen to the tip from them and select yes to switch over to the Generic Sensor.

Now click ok to let the VCM scanner input the ID of the data stream we want to have.

So now this stream is available to use as a filter.



Since we are only interested in data that's recorded when the commanded AFR is 14.7(rounded up) we can simply use math by saying: [50121]>14.6<14.8.

This defines that the commanded AFR needs to be within these boundaries to count. If we know the exact Stoichimetry of the controllers calibration, we could define the boundaries even further. But with these limits, if the commanded AFR is outside these defined boundaries, the values will be filtered out. You could take it a step further and filter out even more. You could put in to filter data where the IAT is way to high after a heat soak for example, but also throttle position, but also filter out data when there is a torque reduction request from the transmission.

Another great option is cell hit required. We want as much data as possible to make it as accurate as possible. For this we want to only see data that has been measured an xx amount of time. Data that only past 3 times is pretty much unusable.

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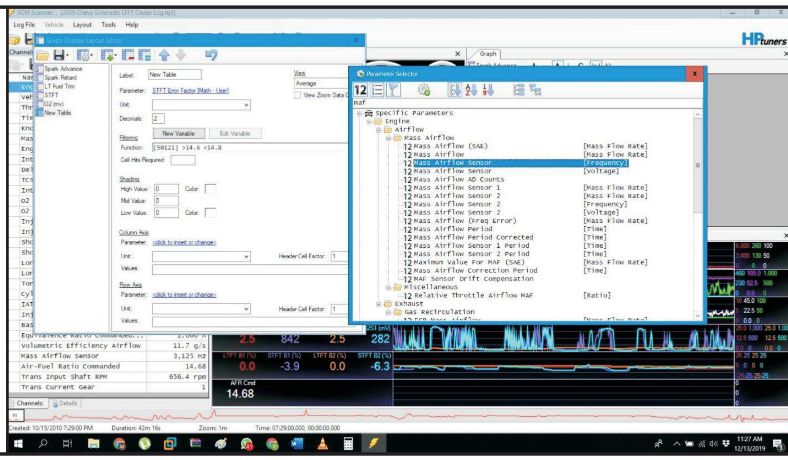
So by putting in 100 for example will filter out data that hasn't been recorded in that cell at least 100 times. Remember that we haven't touched the "View"of the data. Standard it will display us the average number. By putting in a high number like 1000 will cancel out bad data pretty good. If you now have four readings that are bad because of an transient condition, it won't weigh up against the other 996 pieces of data, giving you some real good reliable data.

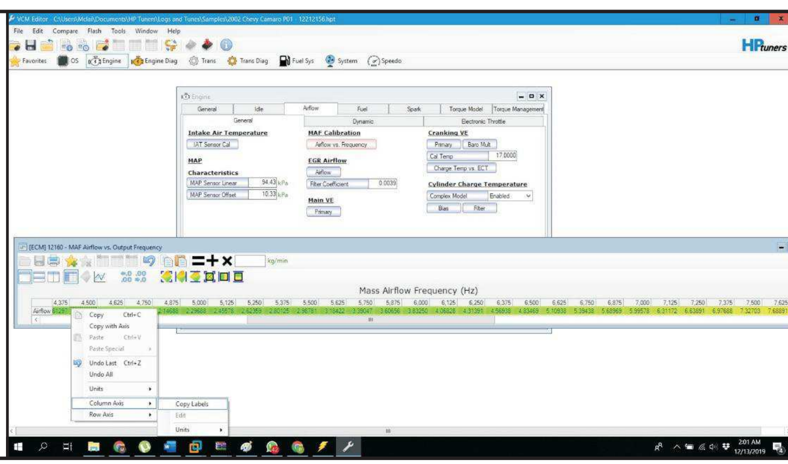
Axis Data

This is the fun stuff I love about Hptuners.

We want to write the error Ratio in the exact same format as our MAF Frequency table is. So first we will select the Column Axis Parameter and look for MAF sensor with frequency in the list. Select it when you find it.



So now we just need to input the right columns. You could go to the editor, write every column definition down and start typing, but Hptuners has got you covert. Open the tune file corresponding with your car. Go to Engine, Air Flow and click on the MAF Airflow vs frequency. Right click on any part of the data, select column and click on copy labels.



Go back to your VCM scanner and click on the values and paste your copied label data.

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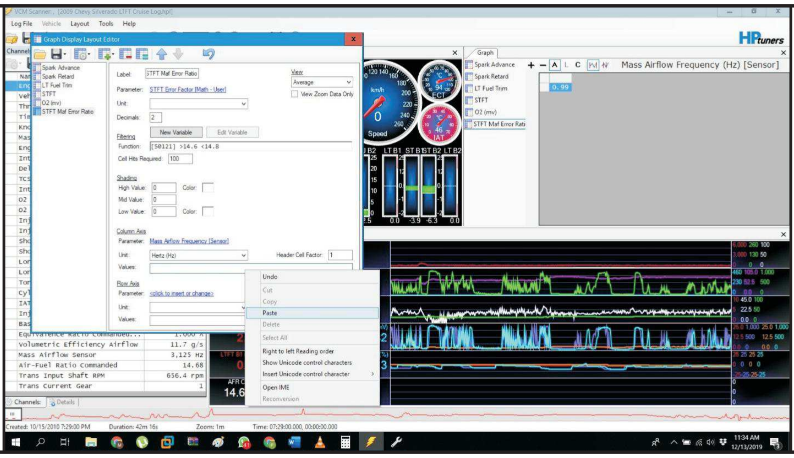
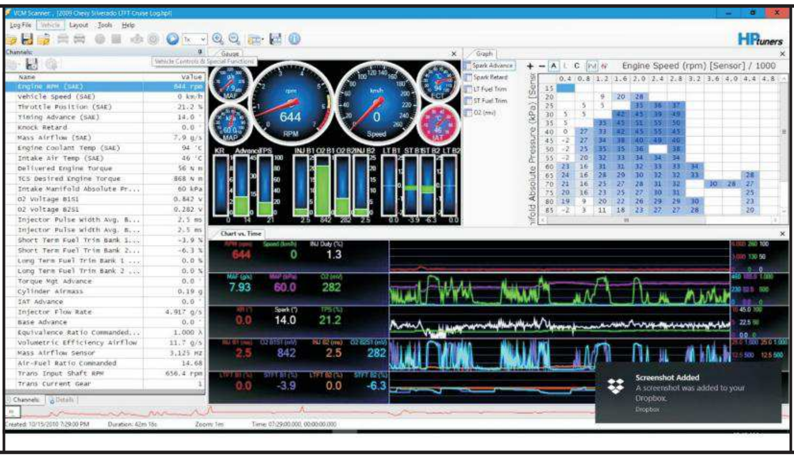


It will now write the data in the right cells making it easy to adjust our calibration later.

You are almost done. VCM scanner is now setup to use your STFT correction to plot an correction factor using the layout of your MAF sensor using your narrow band. Press spacebar to connect to the car and reset the fuel trims before we start logging. This is just a precaution to make sure we are off to a good start.



Click on the Button next to the Engine icon to open Vehicle controls. Go to Fuel and spark and select “Reset fuel trims”.

You are ready to drive the car. Avoid sudden changes in load and drive as gradually as possible. This will give you the best data available. Since we are only focusing on stoich, this means our load is also limited. Use manual gears to get rpms up to 4000-4500 rpm to get higher MAF frequency data. My advise would be to drive the car for a few minutes, then reset the fuel trims while driving, or just after stopping, hit spacebar to start logging and drive a good 5 minutes or so. Stop logging and save the log so you can save it to review later if you want.

What you are looking for is the error rate of the MAF table. Normally you will see a discrepancy of a few perfect, but its almost always in a trend. For example, if Cell “5750 Hz” has factor 0.95, chances are the cells left and right of it will have a similar amount. Look for the trends and go to your editor to change the MAF sensor output.

In my case cell 4000 Hz to 5875 Hz all have factors of 0.94-0.95. So basically the calibration is actually pretty good and doesn't need altering as its within the + or – 7%. But for this guide I will modify the MAF output accordingly. Please keep in mind that you will never see all 1.00 in the error rate. If you are re-calibrating and you are within 2-3%, you are basically spot on, especially with narrowband sensors. You can try to bring it down even further, but time vs reward quickly starts to fade with numbers like that.

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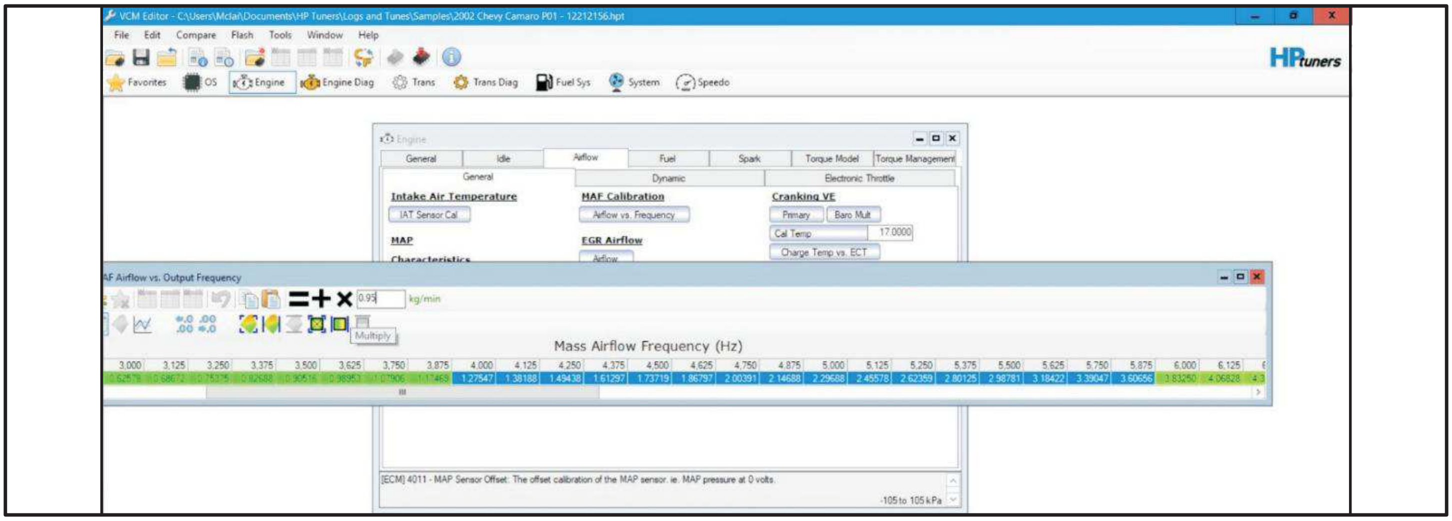
Open up the Editor and Highlight the columns 4000 to 5875Hz. Above the chart there is a little calculator box. It will let you set a number. Put in 0.95and click the multiply button. This will alter the data in those cell by that number.



Repeat this for clusters of data. Combine those strings of data that are similar, like 0.94 and 0.95 like we did. This will speed up the process. There are always spots you cant touch as they are in such a high load that you cant reach them while the controller is automatically using power enrichment to get the fueling up to get that demanded torque. So you need to look at the data really well. Lets say we got to 7500 Hz and the range from 6125 to 7500 showed us we were at 1.04 correction, aka 4 % more air then we are measuring. Chances are this trend follows the next untouched numbers. In a case like that, I would definitely select everything from 6125 to 12000 and multiply is by 1.04. If it where .98 I wouldn't touch it until I would have verified it. If I would touch it, I would lean it out without knowing if that will be ok. So in that case I would rather play it safe and only modify the know data.

If there data cell that you didn't have a lot of data captured and it's between two other cells that you have got good known data for, change every piece between the two cells as well. The only cells that aren't altered after this are the ones that recorded 0.99 , 1.00 and 1.01.

You could also use the option special paste. With this technique you select the whole measured row, and past it as multiply by %. For this you do need to have the histogram setup as a percentage error instead of a factor. This is easily done by choosing the Short term fuel trim as parameter data instead of the STFT error.

Using this will speed up the process even further, but there is a huge downside. This will remove the common sense of the user. If there is a number in there that's not realistic at all, the program will copy it. So lets say 5500 to 6000 Hz give you a factor of .93, 6125 Hz give you a factor 1.05 and 6250 to 7000 is again on 0.93. If you would look at that and you see one data point not matching the rest, you wouldn't copy that into your calibration without checking and rechecking.

Using Past Special Eliminates This Entirely

The other downside is the absence of common sense thinking. Uncharted numbers stay uncharted numbers. But when we see a trend in data, we will extrapolate that throughout the complete line. With special paste, this uncharted data remains untouched and could leave important cells incorrect.

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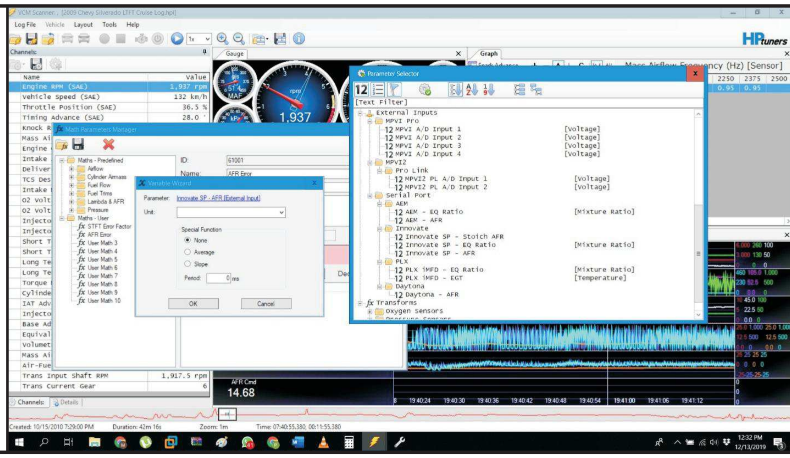
Wideband Calibration

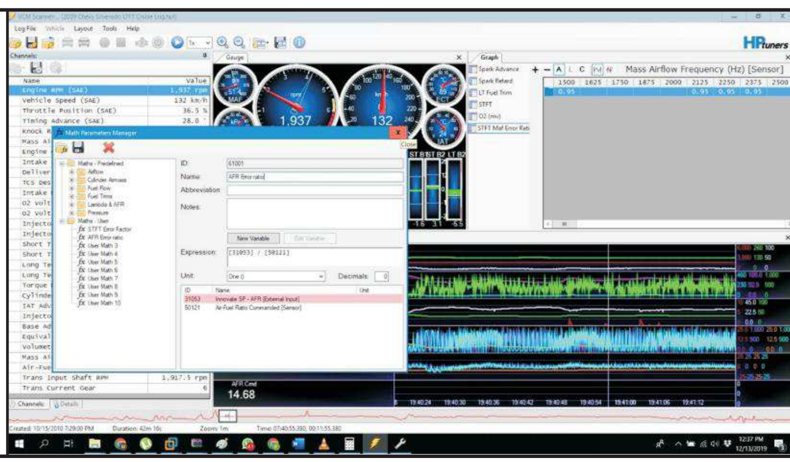
When you are using the wideband, things aren't that different. The only difference is our sensor input, math equation and filtering.

Since we are using a wideband sensor we can import that information in two ways, hard-wire it to your interface if you have a Pro version, or import it as serial data (if your brand is supported).



I will select the Serial Port input, innovate AFR.

You can see that it's in AFR instead of the preferred Lambda. So instead of converting everything to lambda, we will just work with AFR numbers. Remember, we like the lambda number as it directly the error we have when we are commanding 1. But since we have our Wideband sensor in AFR, and our Commanded Air Fuel Ratio in the same AFR unit, we can skip the step of converting it to lambda. If you want to use Lambda instead of AFR, just make a math channel that polls the Innovate in AFR and divide it by the Stichiometric number of the fuel, 14.63 for example. Now you have a Lambda output instead of AFR.



The output will be a ratio that explains the difference between calculated air mass, and actual airmass and can be plotted in the MAF chart just like we did with the narrowband. The only difference is that we are not limited to stoich. So we could delete that filtering to get more data out of the logs even when we are not staying in the 14.7 commanded AFR.

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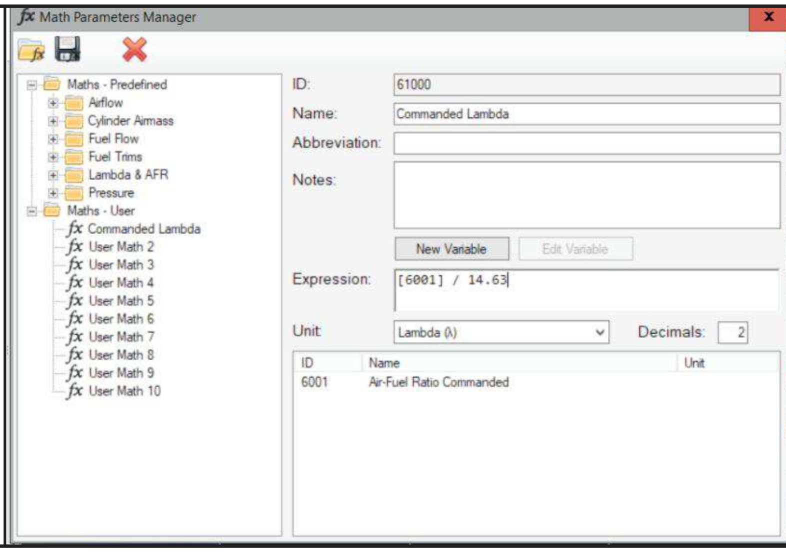
Since I'm working from a log file here, I have some limitations when it comes to adding channels. So I'll be using math channels where you are able to use real channels. Like we said, we love to use lambda for this as it gives us some aid in seeing the error instantly.

So I open my Math Parameter Manager by pressing CTRL+M (you can also go to tools and open it from there).

I select a free user Math and input a new variable parameter for me to use. I want to do everything in Lambda, so I'm going to use a math channel to get from commanded AFR to Commanded Lambda. Click on New Variable and select the Air Fuel Commanded in the list. In this case that's ID [6001]. To convert this to lambda, I only need to divide it by the Stoichiometric value of my fuel, 14.63 in this case. So I add "/ 14.63" to the variable.

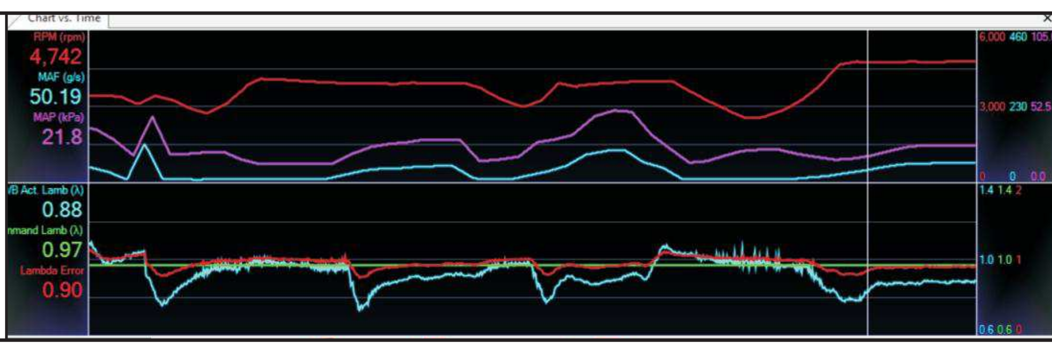
Now the result will be Commanded Lambda. I can define the units as Lambda and set it to 2 decimal points.



Next to this I also want to plot the Lambda Error which is actual lambda – commanded lambda.

Use the same tool to add a math channel where your actual Lambda is divided by the commanded lambda. If commanded lambda isn't available for you, you probably didn't add it to the channel list. You either add it to the channel list, or use the equation to get lambda (commanded AFR / Stoichiometric).

I've added a bunch of parameters in my chart and you can now see the lambda commanded, actual lambda and the error clearly in my chart.



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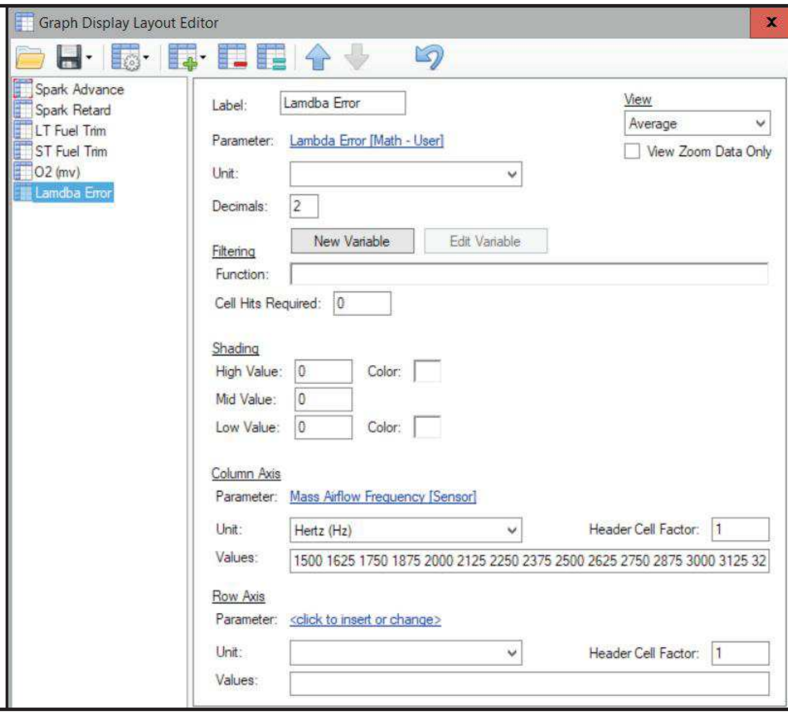
You clearly see the difference between the commanded Lambda and the actual lambda. The program calculates the difference in the two with a ratio and outputs it. So in this case we are richer than we are commanding, meaning we are flowing less air than we are measuring. Since the commanded lambda isn't 1.00 at this point, the actual lambda isn't our error. But would we commanded lambda 1.00, the error and the actual lambda are identical.

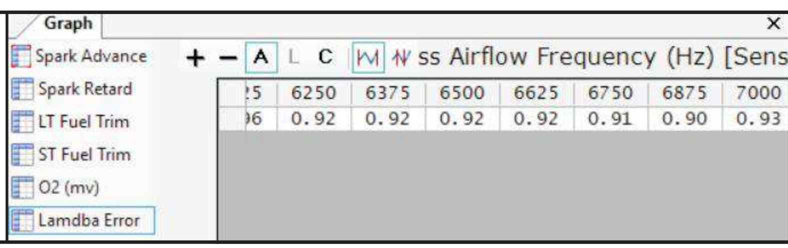
So now for the histograms. Open the layout and add a table like we have seen before.

Select our user lambda error as a parameter and don't forget to set the decimal points to 2!

As Column axis set the MAF frequency like we did earlier and copy the labels from your tunes to give us the exact same breakpoints.



Close it and either start driving and logging, or like me check out the numbers that came from the data log.



As you can see, the MAF calibration is off quite a bit. Check the cell count and start on changing the MAF calibration in your tune accordingly.

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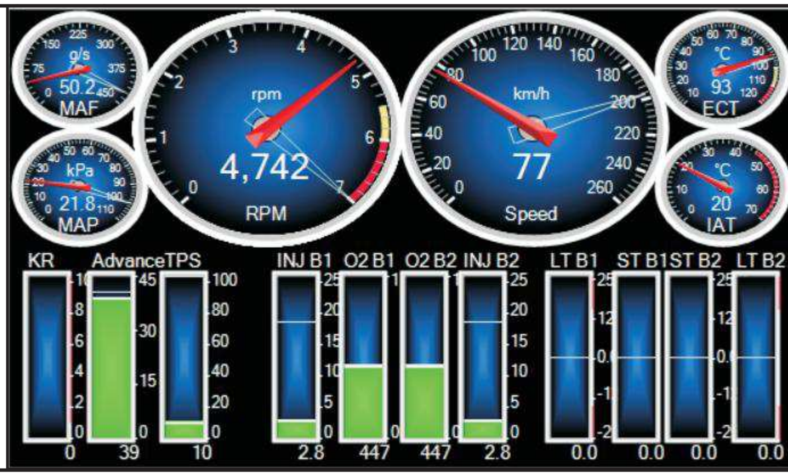
Also note that we are indeed working in open loop and that our Fuel trims are absolute 0. If they are not, discard the log, find the problem and start over.



Notice here that the Fuel trims are disabled and don't change the injector opening to adapt for error.

You probably wont get the MAF re-calibrated in 1 go. Its better to do 4 test drives of 5 minutes, changing the MAF curve every time, then to drive 20 minutes in 1 go. While you are driving, look at the “tracer” in the cell. Using that, you can put change the load while driving to hit each cell for a period of time. Remember, more hits equals a better and more precise average.

After you are satisfied with the result, we will use the latest Tune file to switch to VE tuning instead of MAF Tuning.

VE Tuning, or Speed Density

For this actually the same rules apply. Only thing that's different is the histogram where we plot in our data. But in order to tune nothing but the VE, we need to switch on the MAP reading again and disable the MAF at this point. So go to Engine, Airflow, Dynamic and change the disable RPM to something unreachable like 8000 rpm. This will sure that the MAP based air flow model will be used in the whole region. Now for disabling the MAF sensor, close the Engine tab and open up the tab on the right, Engine Diagnostics.

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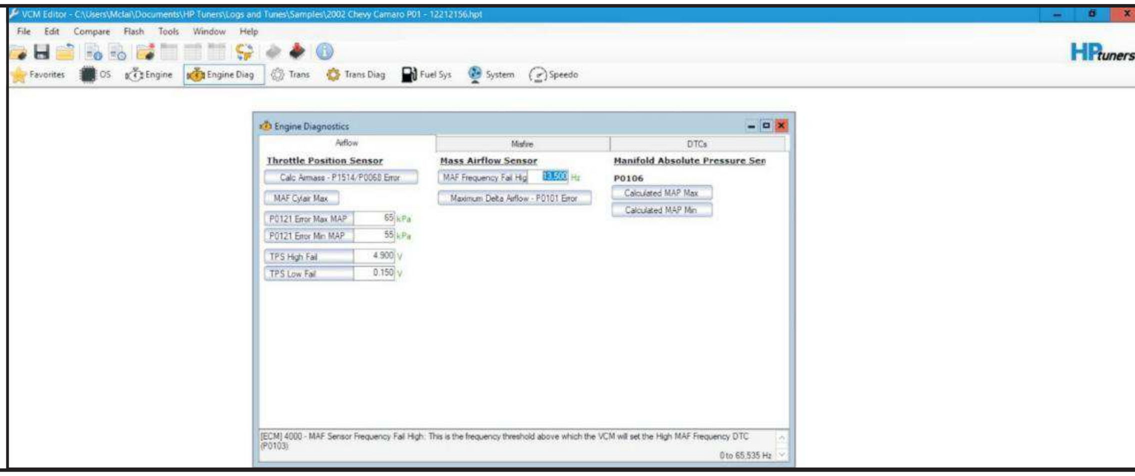
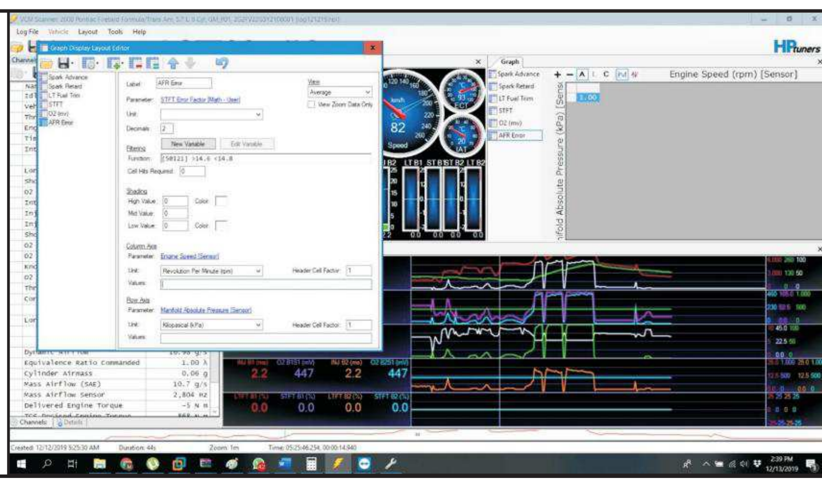


Here are some boundaries on sensor data. If the Controller sees a value higher or lower (depending on the definition of that parameter) than the number in that box, it will automatically see that sensor as faulty and will stop using it. For our MAF sensor we have a neat trick, By putting in a absolute possible and low number in that “MAF Frequency Fail High” box, we effectively disable the MAF sensor. So go ahead and put in 1 (Hz).

Now save the tune as VE tune 001 and write it to the controller. After that is done, open up the VCM scanner to get the right histogram to work with.

As we saw earlier, our VE table has Engine Rpm as X-axis (columns) and Manifold Pressure as Y-axis (rows). Put in those in the Graph layout for the histogram (instead of the MAF Frequency we used earlier).

To make sure the ECU goes to MAP sensor instantly, we want to setup the controller that it will “set” a faulty sensor DTC instantly and revert to speed density. This is done by changing the way the DTC for the Mass air flow sensor is setup. Go to engine diagnostic and open the DTC tab. Change the P0101 to set at the first error. This will make sure the fault sets immediately and enables Speed density only.



If there are any labels in the rows or columns, delete them and get the Axis data from your VCM editor by right clicking, selecting row, or columns and select copy labels. Paste the right data in both and close the layout editor.

You have now successfully altered your Histogram settings to plot the same AFR or STFT error in the layout of the Main VE Table.

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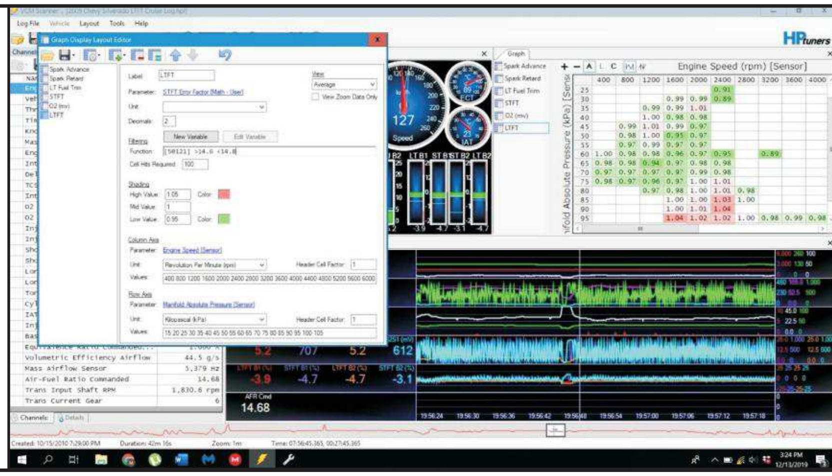
If you have set it up it should look something like this. You can add visual aid by selecting colors for shading. In this instance I'm using a light red for 1.05 (lean is mean, so I want to have that pop out) and 0.95 (rich mixture as green). My lambda 1.0 is white by design. This will give me a direct overview of my current fueling, and thus my Air flow calibration.



Lets also set this up for wideband users.

Basically, it's the same as before, only again we stay in Open loop instead of letting the ECU do some closed loop adaptations. This gives us the full error between Commanded AFR and Actual AFR. Next to that we don't have to worry about staying in the lambda 1 region. If we would go into a transient state and the controller is commanding a richer mixture, we can still monitor the actual AFR perfectly and calculate the error, if any at all.

If you have set up the file right, flash the calibration in your car and take it for a drive. Make sure you drive as smoothly as possible to get the best possible data.

Repeat the process a few times until you are stuck with an error of 1 or 2 %. I wouldn't invest more time to get closer. Even when using a dyno, you will still have minor error rates and its not worth you time to chase everything down to the last percentage.

After you have both calibrated the Maf and the VE table, it's time to set it back to a dynamic blend by putting in the original MAF fail frequency, reenabling DFCO, Low octane spark table, LTFT if needed and anything else you might have touched. You can open the last tune with the new calibrations for both MAF and VE, and open the original file as a compare file. That will help you get the original needed data for the low octane spark table, and it can show you the differences between the original file and your tune. After you are done, the only difference at this point should be calibration of the MAF table and the VE table. Save the file as something that makes sense and flash it back into the car. Your trims should now be spot on and you are ready to start with transmission tuning.

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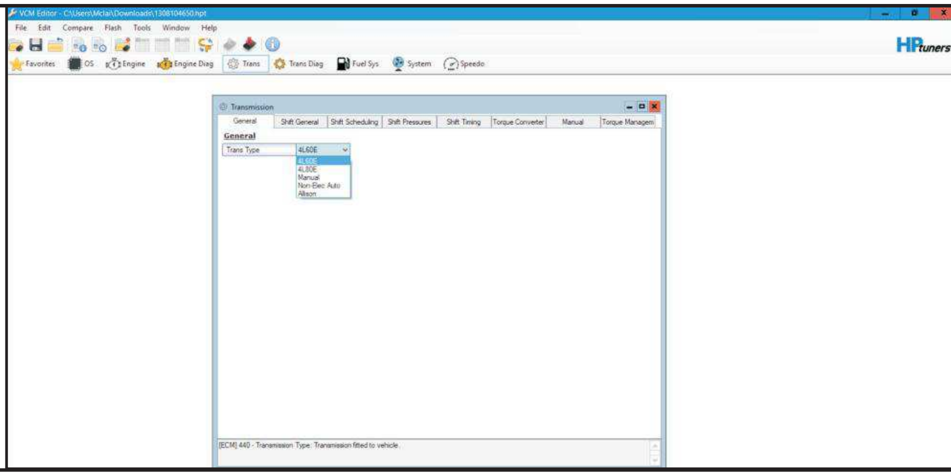
TRANSMISSION TUNING

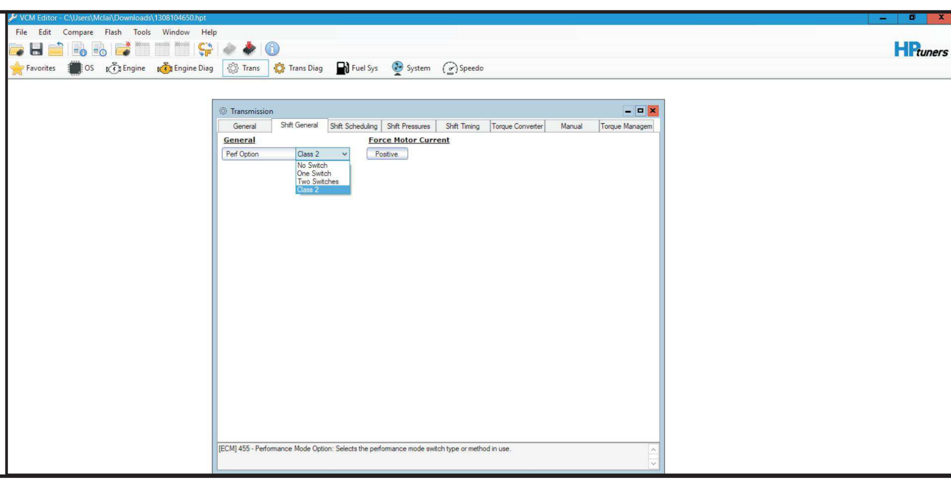
Now for tuning the transmission. Like you have seen, the software gives you a lot of options. Since most of us are very familiar with how transmissions work, we will cover "the basics" within the guide when needed.

Tuning a transmission can have benefits. You can extend its life, tune it to hold more power, change the way it behaves to make the car more alive, or even fix certain issues that are mechanical by nature.

So lets look at a typical 4L60-E application that really can use a tune to live longer, the Hummer H2. Please note that some cars have more or less options. This all depends on the software version and car platform. But basically every option we explore in this file, will be available in other cars as well.



Ive opened the drop down menu to let you see the options the software has. Changing this option to 4L80-E will not automatically mean you can hook up an 4L80-E and be done with it. For changes like that, there is an option called Segment swap. This means swapping a segment of software from, in this case a 4L80-E vehicle, in our tune. We are not going to cover that here, but it might be good for some of you to know that there is this option available instead. Saves a pretty dime on a standalone controller, and it gives you more options on tuning than most stand alone systems available today.



This will let you select the "input" for the transmission to switch to Performance mode. Class 2 indicates a "communication request" from the BCM. There are options to add another wire to the Controller and use an actual additional switch. This is very dependant on the type of controller the car is running. Exploring this specific option for your car would require some research. The HPtuners forum would be the best place to start.

We are actually more interested in the Force Motor Current.

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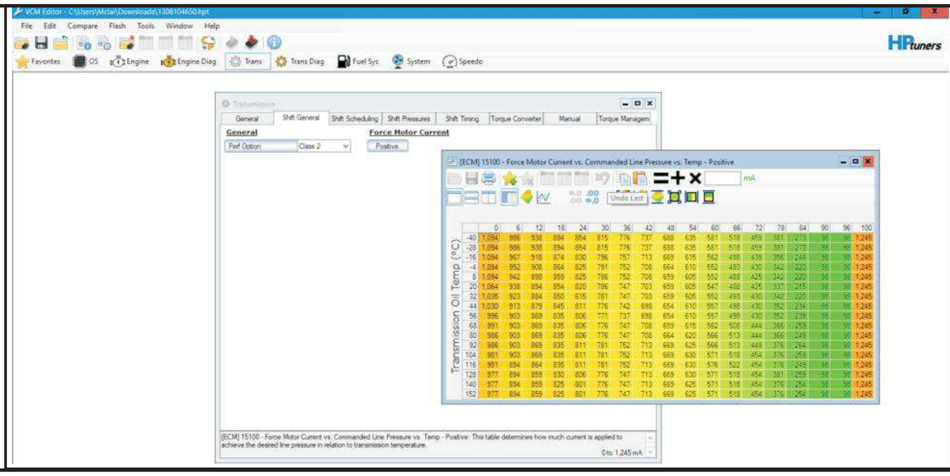

This table actually defines the current through the EPC to achieve the desired line pressure.

Now, line pressure we all know, it affects everything in a transmission. You have to know that with systems like this, as well as engine control systems, it works like a spiderweb. Poking on this very far end in the web, will result in a little "tremor" through out the web.

You will see that we have no real control about our line pressure. This is mostly done by the controller using the load sensors from the engine controller, hence the need to for good calibration. This pressure is also dependant on factors like rpm. One thing you need to know, and probably do, is that this is en Open loop system. The controller will calculate a pressure and actuate the EPC to achieve that pressure. There is no feedback on the 4L60-E to actually check if we are getting this value in any way. Lets look at this table in a bit more detail

On the Y axis we have temperature. Different temperature will affect the viscosity of the oil as well as the clearances in the transmission. Gm used quite some expensive tools to populate this table with actual good value's, so this is a good base if we ever want to change something.

On the X axis we have desired line pressure. We will see in the rest of the guide that Hptuners uses a "pressure" for this axis. We can see that the breakpoints go from 0 to 100. They will say that's 0 psi to 100 psi. I think that's a mistake they never corrected. We have a mechanical minimum pressure depending on the setup and eventual modifications. Normally we will see a minimum pressure of 35 to 85 psi (max current through the EPC) depending on type of transmission, setups and modifications. So 0 psi is not a valid value. Then there is the maximum pressure. According to this Table that's a max pressure of 100 psi, while we know this is more likely to get in the region of 200+ psi . So the notification of pressure throughout the HPtuners is most likely % instead of actual pressure. So we will use this axis as Percentage instead of pressure.

One other thing that is weird, is the last column of 100% pressure. The current there is above anything else and would result in the lowest achievable pressure. Ignore this column as the programming will never use that column. We will see why in a minute.

What can we do with this table? We know that this is the "translation" from commanded line pressure (in percentage) to current. So we could use this table to affect our line pressure. By lowering or raising the current in every cell by the same percentage, its like we are turning the screw of the EPC. So if you did this and the engagement is a bit to harsh due to a line pressure that is too high, you could try raising the current with 5% or so in the cell of " 0% line pressure." Best option is too hook up a gauge or pressure transducer to check if its working.

Next Tab. Shift scheduling

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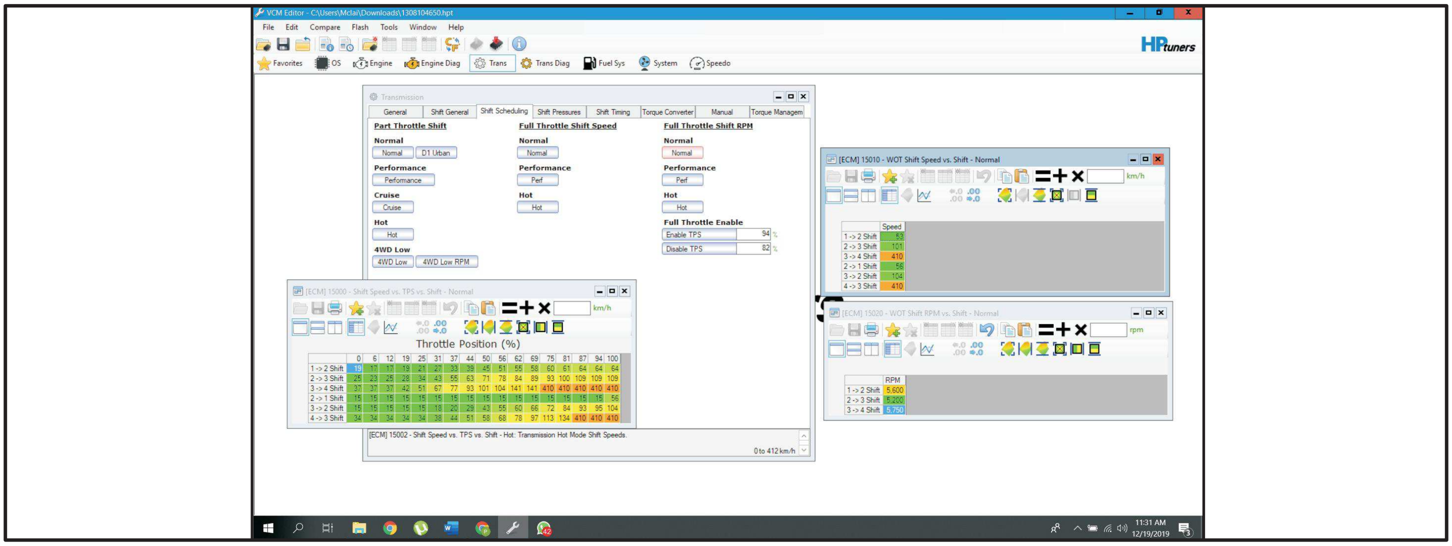

In this tab you have to option to determine the speed the transmission will up or downshift depending on the mode its operating in (multiple tables).

You can tailor the shift speeds to your, or the customers wish. Changing the speed (normally up by a few percent) makes the driving experience completely different. On a sports car like a corvette, the car feels a bit more alive as the engine isn't choked to death while driving with 1200 rpm.

The table tells you what shift the row represents, and the column defines the Throttle position. The reason why this is TPS instead of a load sensor, is because TPS is a “DEMAND” or a “Wish” input from the driver. Load signals can be altered by traction control or any other controller interrupt, while the driver wish will always be a raw value from the driver itself.

Next to the part throttle tables, there are also two WOT (Wide Open Throttle) tables.

One is RPM based, the other one is Speed based. If we look at the RPM one, its strange to shift at rpm's that are quite lower then the max rpm of the engine (6000 for this on). If we would put in 5950 in all of them, we would shift 50 rpm before the limiter would become active. We would however hit the limiter every shift. The reason for this is lead time. Everything takes time. Some shifts take up more time then the other, and the ecu will initiate the shift at that point. So if it initiated the shift at 5950 rpm form 1-2nd gear, the shift would have to be instant not to hit the limiter. That's pretty much impossible, so you need to take in account that these rpm's are not the actual rpms it will actually shift. If the engine is tuned, you might have to lower them as it ramps through the speeds faster then GM anticipated.

Same goes for speed. This is based on the weight of the vehicle, aerodynamics, power etc. If its shifting to early, raise them till they are to you liking. This can take you several attempts to get fully dialed in.

The last thing that you might wish to alter is the percentage Throttle is considered Wide open throttle. If for any reason you want the controller to consider a lower TPS as wide open throttle, you can modify this here. For normal to mildly modified cars, the stock values are a good base number.

The tab next to it will let us allow to change shift pressures.

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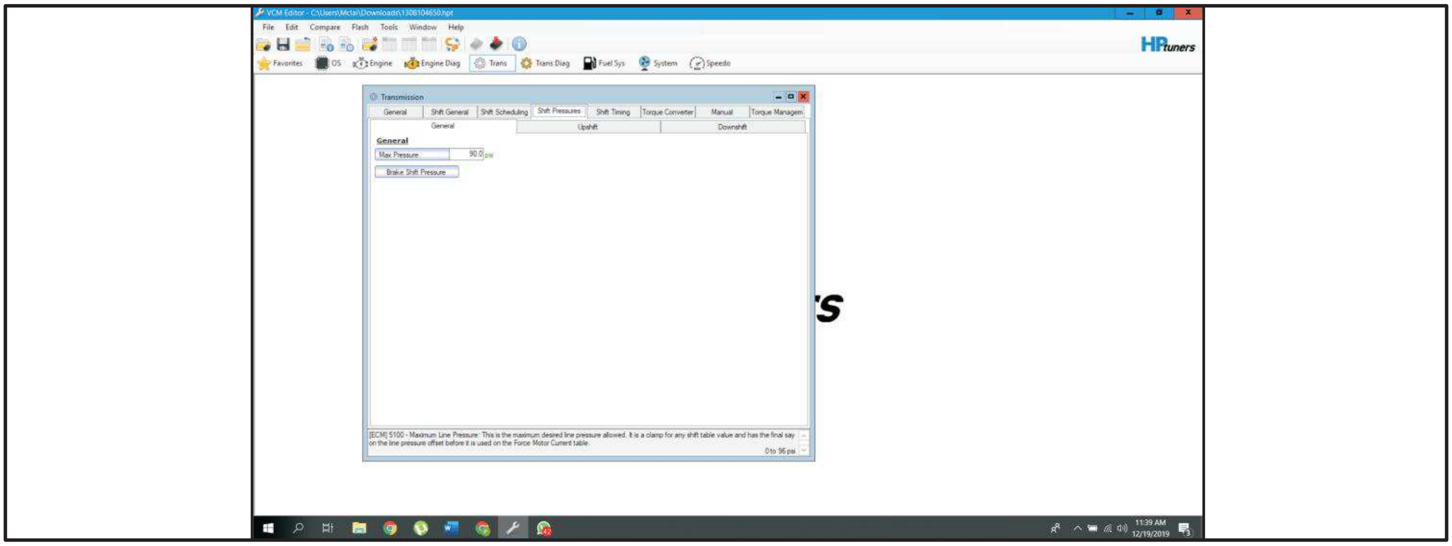


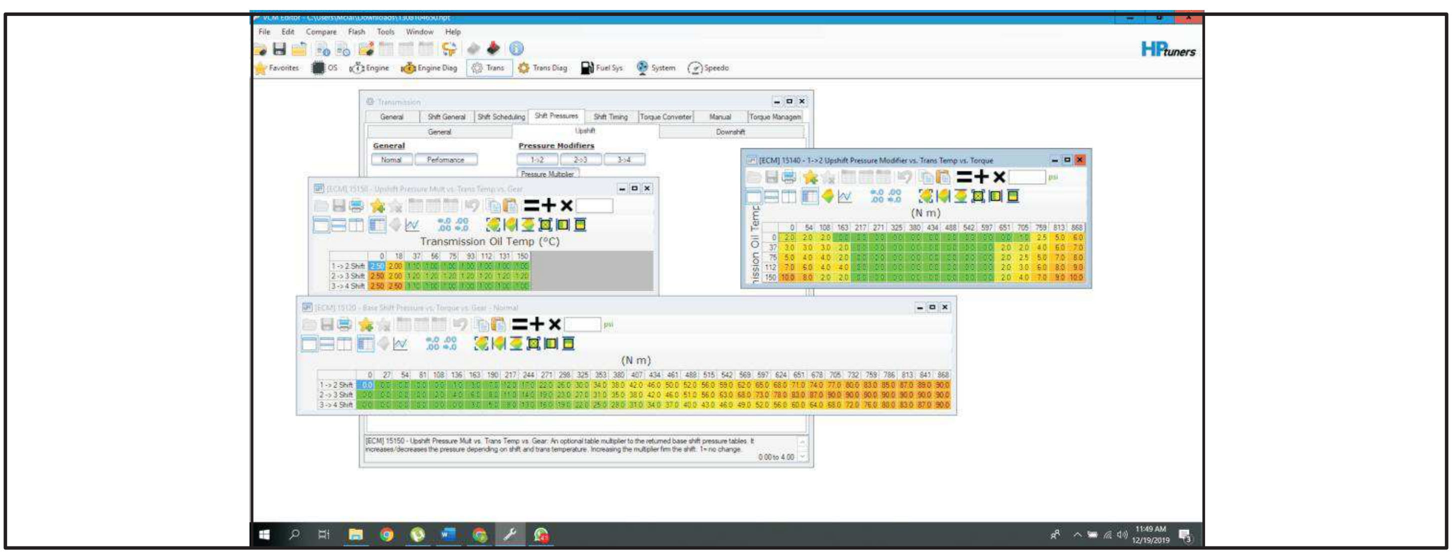
The first general tab has an important value in there, the max pressure, buts its obviously isn't PSI, but more likely the percentage of line pressure.

Remember the force motor table. This field will let you define the max column you will be in. you can raise this value to a max value of 96. This will let you operate in the “96%” column. But if you look at the Force Motor currents from 90 en 96, you will see that they are the same. Raising this to 96 will have no result if the column in 96 isn't changed.

If you want to see if it will help, put on a gauge and use VCM scanner to control your transmission. Read out the value with 98mA and then control a lower current to check the pressure. If the pressure rises, there is room left and you can use that to occupy the 96% column. Change the max pressure from 90 to 96 to let you select this column in different tables.

Brake downshift pressure. In case you are downshifting manually, you can use this table to get the desired brake pressure. The table is now filled with 0. That way the controller ignores it and reverts to its base pressure table.

Up-shifts and Downshifts



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As you can see the up-shift tab has multiple tables in there. This is a good example of the "spiderweb" analogy. I have my BASE pressure in the "Normal" and "Performance" tables.

If we are driving in 1st gear, and our engine is putting out 217Nm, our base pressure is "12"%". This can be "translated" into a current. But next the controller will check if it needs to add or multiply this value based on temperature. The up-shift pressure modifier has all "0" in the 217 column , so it will not modify this in any way regarding the temperature.

The pressure multiplier however doesn't look at torque, but checks the temp, lets say 37 degrees C, and determines if the pressure needs to be multiplied. In this case we are going to command a 1-2 up-shift, and with 37 degrees, the pressure will be multiplied with 1.1

So you see that I have a BASE pressure , but adders and multipliers play a role in the final pressure.1

In my experience the modifiers don't need any tuning in most cases. Modifying the base pressure is often the only pressure you need to modify to get the wanted results.

Remember that when you multiply all the cells with 1.1 to raise the shift pressure by 10%, the cells occupied by 0, will remain unchanged. 0 x 10 is still 0.

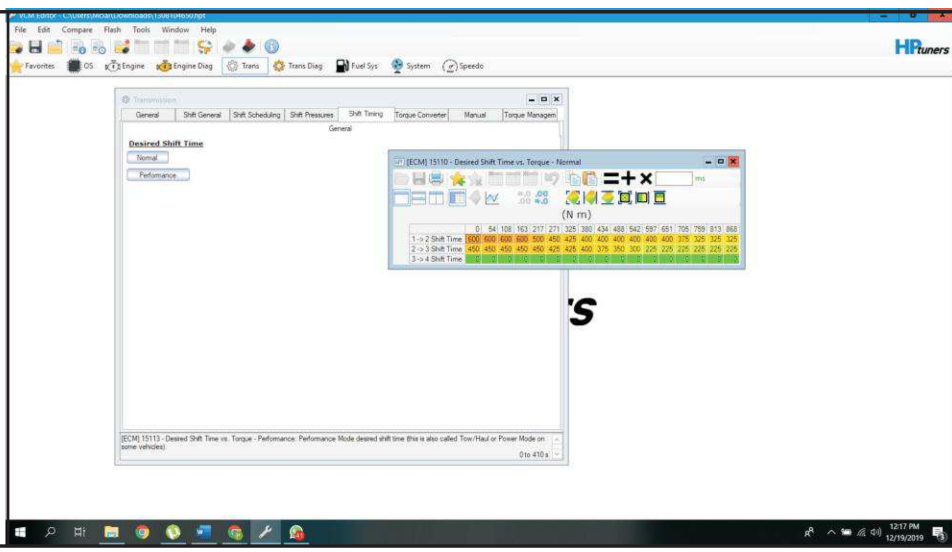
If you want firmer shifts by raising pressure in the low loads, use the "ADD" function instead of the multiplication. You can also fill in numbers by hand. I normally will start off by adding 3 to 7% in the low region.

Downshifts

The options for downshifts are limited to base pressure modifier tables. In these tables you can desire increased or decreased pressure based on Temp and torque.

Having a hard downshift from 3-2, you could try to reduce the base pressure in this table by setting it to -10 for example in the temp and torque range you are experiencing the issue. You need to use VCM scanner to log and monitor these parameters to make an educated guess where to start.

Up to the next one. Desired Shift timing



I think this table is one of the most important one to change to get a very noticeable change in transmission behavior and live.

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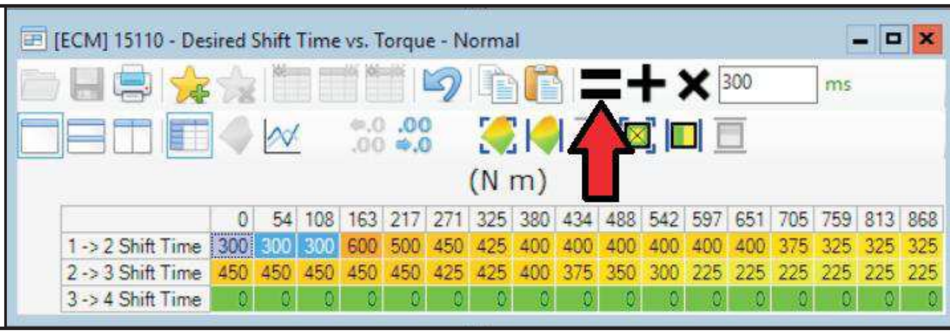
We know that we are bound to mechanical time to shift. These are never instant, but we can try to achieve a specified time for a shift. Little tip, by left clicking on the green indicator next to the box you use to modify the values, you can change the notification of the parameter. If your Hptuners is giving your values in Seconds instead of milliseconds, you can change it here.

So let's look at this table. We can see that we are demanding some high shift timings on this transmission. Up to 600ms for a 1-2 shift. That's a long time to let the transmission "Slip." Even though the H2 is a heavy hector, we can reduce this significant without putting the transmission and the comfort at risk.

I'm comfortable by reducing the shift timing to 300 ms in the lowest load, and 200ms in the high load. You can then try to "shape" the transition from the highest point to the lowest, but there are some tricks in HP tuners that can help you.

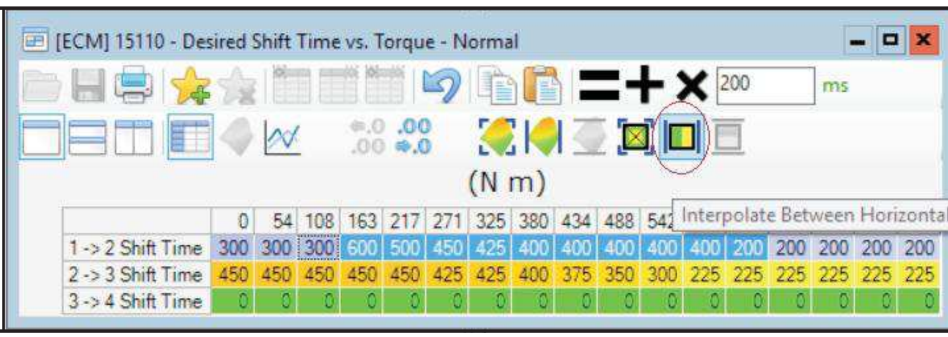
Here I select the first 3 cells of the 1-2 shift. I put in 300ms in my "calculation" box, and press = (replace)



	0	54	108	163	217	271	325	380	434	488	542	597	651	705	759	813	868
1 -> 2 Shift Time	300	300	300	600	500	450	425	400	400	400	400	400	400	375	325	325	325
2 -> 3 Shift Time	450	450	450	450	450	425	425	400	375	350	300	225	225	225	225	225	225
3 -> 4 Shift Time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The selected cells are now instantly 300ms.

I will do the same for the last 4 cells and change them to 200ms in this case. It now looks something like this.



	0	54	108	163	217	271	325	380	434	488	542						
1 -> 2 Shift Time	300	300	300	600	500	450	425	400	400	400	400	400	200	200	200	200	200
2 -> 3 Shift Time	450	450	450	450	450	425	425	400	375	350	300	225	225	225	225	225	225
3 -> 4 Shift Time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Now I want to let HPtuners to make the remaining values gradually transition from the highest value to the lowest. For this I selected the last "300ms" cell and the first "200ms" cell. The values within these 2 boundaries I want to modify.

You can also see the icon I outlined. This is interpolation horizontally between two selected values. Clicking on that, the program will calculate the remaining values in a smooth order to interpolate between these two.

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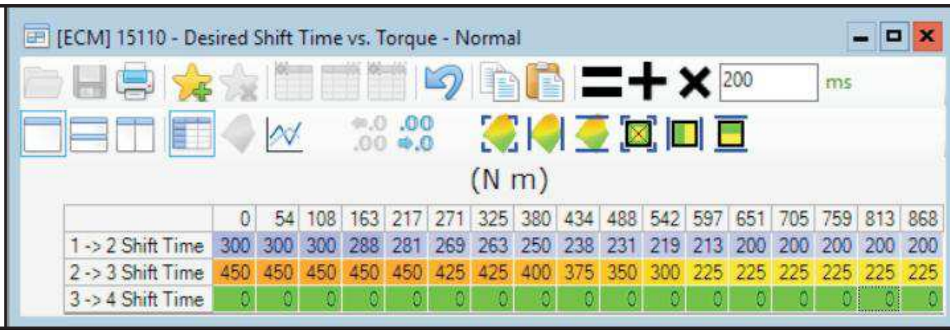


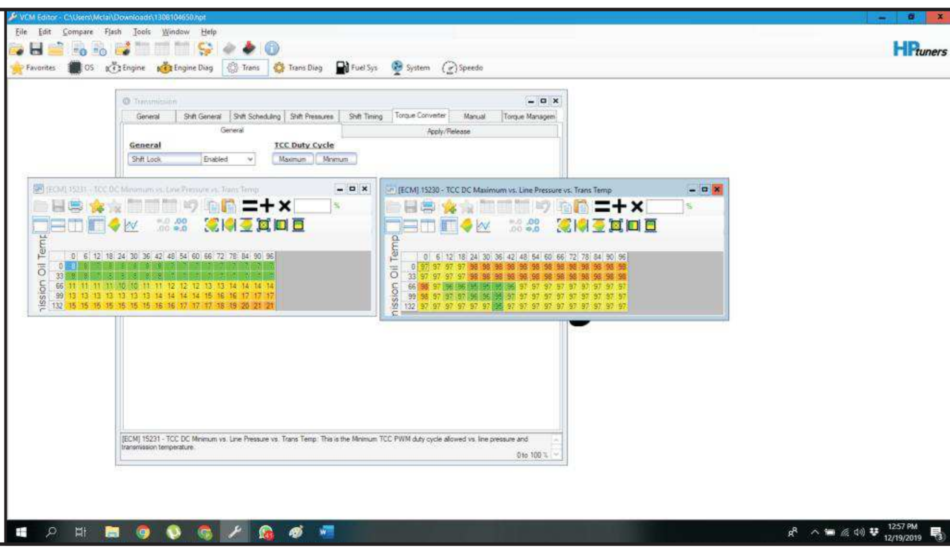
	0	54	108	163	217	271	325	380	434	488	542	597	651	705	759	813	868
1 -> 2 Shift Time	300	300	300	288	281	269	263	250	238	231	219	213	200	200	200	200	200
2 -> 3 Shift Time	450	450	450	450	450	425	425	400	375	350	300	225	225	225	225	225	225
3 -> 4 Shift Time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

You can do the same for the second gear. On an H2 I cut the low number down by 50% resulting in a 225ms desired timing in the low region and will settle for something like 175-185 ms in the high torque region. But again, these are not obsolete numbers. It depends on your wishes, setup and build. Flashing these cars only takes 30 seconds, so its easy to test out some values to see what suits your needs and wishes.

For 3-4 the desired timing is 0. So the controller will shift as fast as possible. If you ever looked at OBD data from this trans and think back to your "shift time error," 3-4 was always high. This is why. It tries to achieve a 0ms shift time, but that's not possible. Shift time error is desired time minus the actually time.

The transmission will adapt pressure and solenoid application time in order to try to get the desired timing from this table.

Moving on to the Converter tab



First thing you see it shift lock. This lets you control the TCC strategy during shifts. With this enabled, the TCC will NOT unlock during a shift. It can result in a smoother ride as the tcc doesn't unlock, shifts and locks again. Especially with higher stalls this can be very annoying. But it will need to be tuned correctly with shift pressures to get it operating smooth. For most cases I leave this option disabled.

Other options in this tab is the minimum and maximum TCC Duty cycle. During operation, the TCC will try to maintain a certain amount of slip. Its limited to the values in these boxes. If you want to change the operation of the converter lockup from a slipping one to an pure ON/OFF clutch, raise the minimum Duty cycle. Select all cells and "equal" them to lets say 95%. Go to the maximum DC table and change all cells to 96%.

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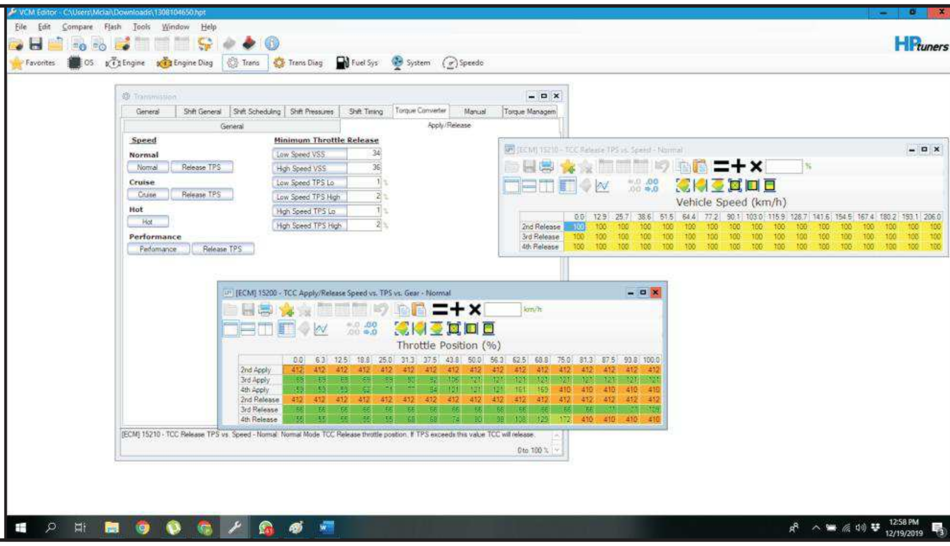
You are now on an ON/OFF strategy.

If you don't want to have this strategy, but are trying to help a customer with a bad TCC valve get some additional miles out of his transmission, you can also add a certain % to the minimum table. This results in a higher apply pressure most likely eliminating TCC hunts and excessive slip.

Apply and Release

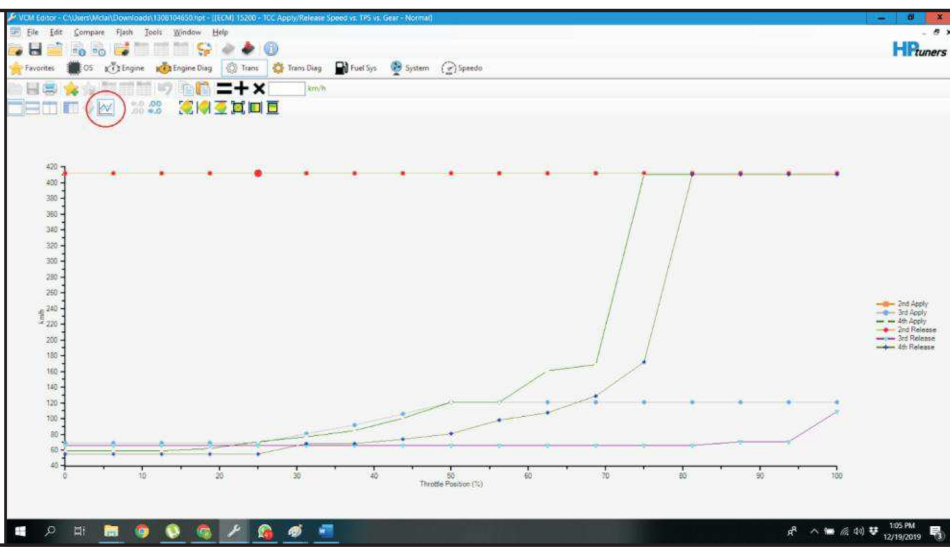
In this tab we get several options to determine more TCC lockup parameters.



First the "speed" button. Again, we have multiple modes. Lets look at the two buttons of the normal mode. Under the first button we can control the speed the TCC applies or released based on our Throttle position. It's clear that in 2nd gear there will be no apply at any TPS as we can never achieve 412km/h in that gear.

By changing the speeds you have full control of your Converter clutch. But keep in mind to change both apply and release speeds if needed. If your apply speed is lower than your release speed, you could have no apply in the best case, or a TCC that continuously apply and release in the worst case.

For this you can also use the "2D" chart mode to get a better view.



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This will give you a better view if there is enough "Room" between the apply and release.

The other button will control the release of the TCC Release TPS based on speeds.

You can tailor this table to your needs if you wish the TCC to release based on a specific TPS value in a certain region. But changes are you don't need to touch this table as the normal table has enough control on its own.

The Minimum throttle release parameters in the middle. With these numbers you can control the TCC strategy even further. If you dont want the TCC to release during coast, or wish to release earlier when backing of the throttle, you change these values to help you tailor the TCC control. This is only to enable or disable the "minimum throttle" mode. The additional information in the lower bar gives you additional information when hovering above the values. By changing the disable value to 0% for example, you could keep the TCC locked during coasting in most cases. This will help with engine braking.

The next tab is manual. In here you can define your reverse lockout for example, but also CASG, Computer Aided Skip Shift. For the 4L60-E its not a valid option, but for 6L80 this is an option.

Last tab we can modify is Torque Management.

In order to keep our transmission alive, we ask the engine to reduce its torque by "XX" % during the shifts. This will keep the transmission from working against the engine torque and help the clutch packs to clamp faster.

A lot of people will just zero them out as this table "RIPS" away their power. And they are right, it does limit the maximum torque during shifts. On the strip you can get allot of improvement in time by modifying this Zeroing them out gives a great firm WOT shift the first time. After a few times on the strips you will most likely change the cluster into this:

Torque management isn't there to rob you from time, but it protects your transmission.

If you build the 4L60-E with some heavy duty stuff, you can start to change torque reduction to get better strip times, firmer shifts without getting a bunch or neutrals.

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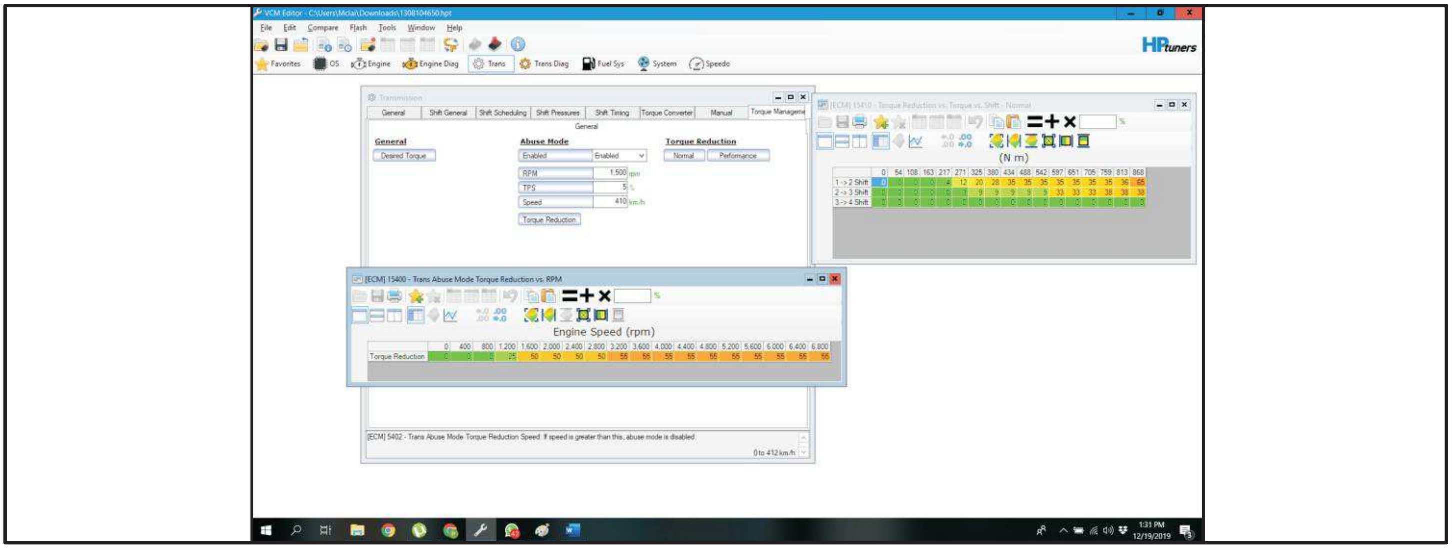
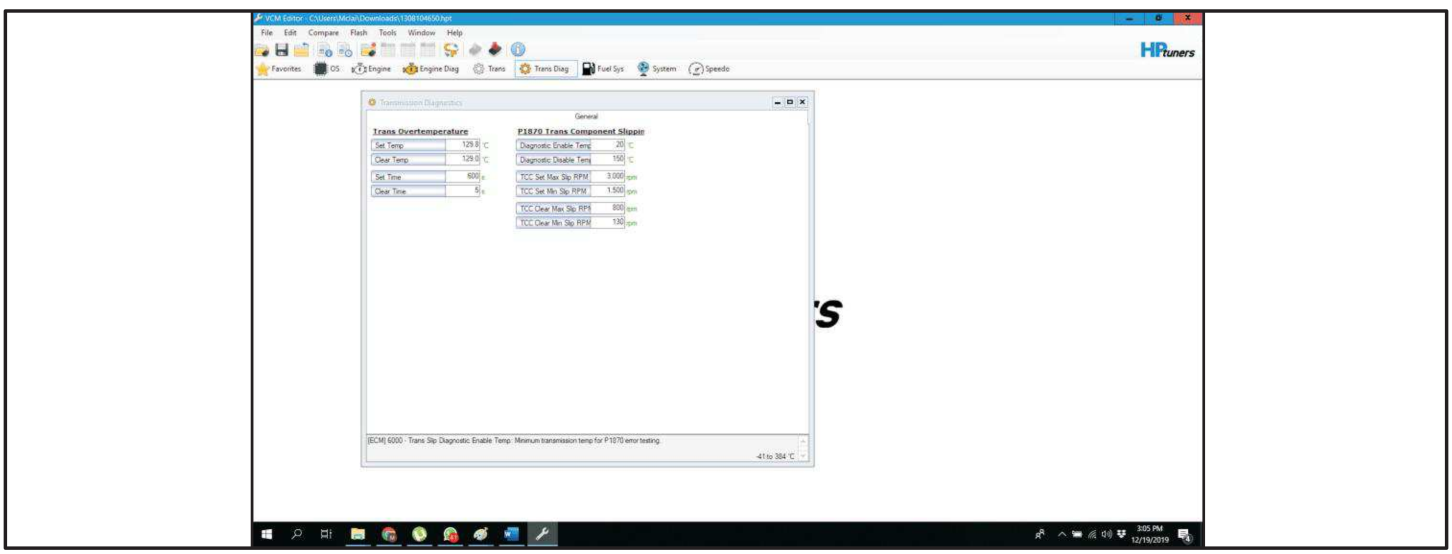


There are two "modifiers" in there. One is the "Abuse Mode," and the other is shift based.

You can define engine speed, throttle position and speed when ever Abuse mode should be active. The other option is based on shifts. You can instantly see that you could disable abuse mode completely and base everything on the shift map, but be cautious when changing these modes and values. Its very easy to kill the transmission by "abusing" these torque limiters.

So you now have a good idea on the 4L60-E tuning options. That leaves only diagnostic codes and bigger tires or complete different diff ratio.

First the diagnostic page of the transmission. In this case it's a bit limited as you can see.



The options here are pretty much self explaining and hardly need any changes. In the newer 4L65-E with ISS that's a different story. If the transmission is fine but its just a sensor issue, you can help your customer with a tune.

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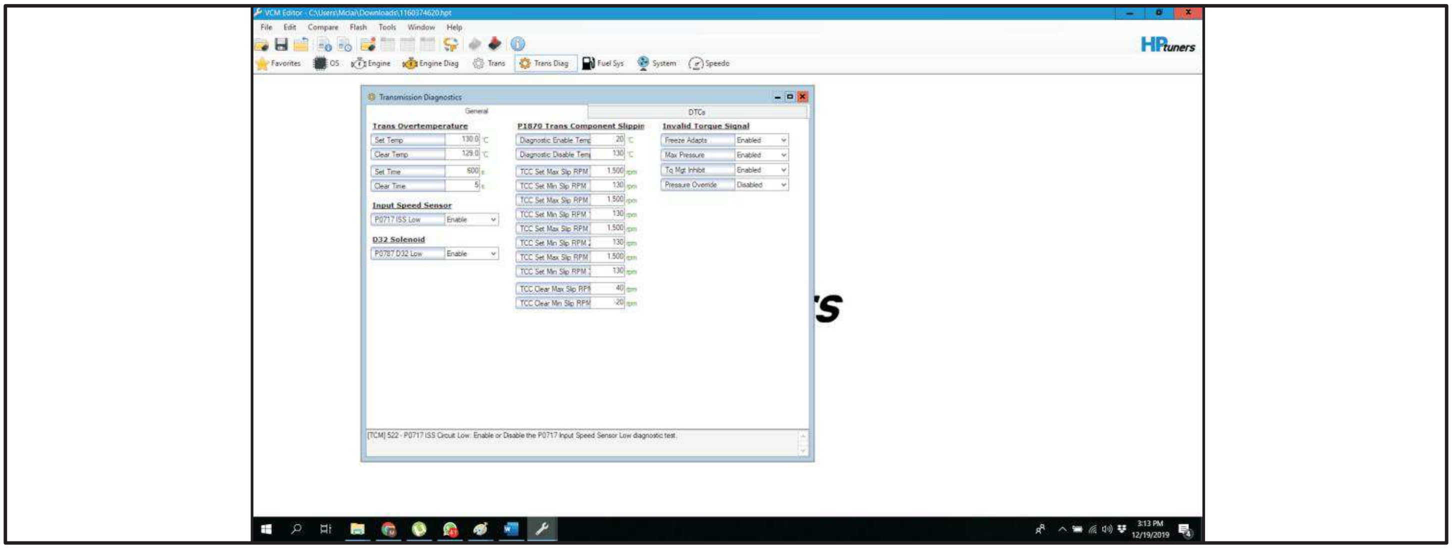
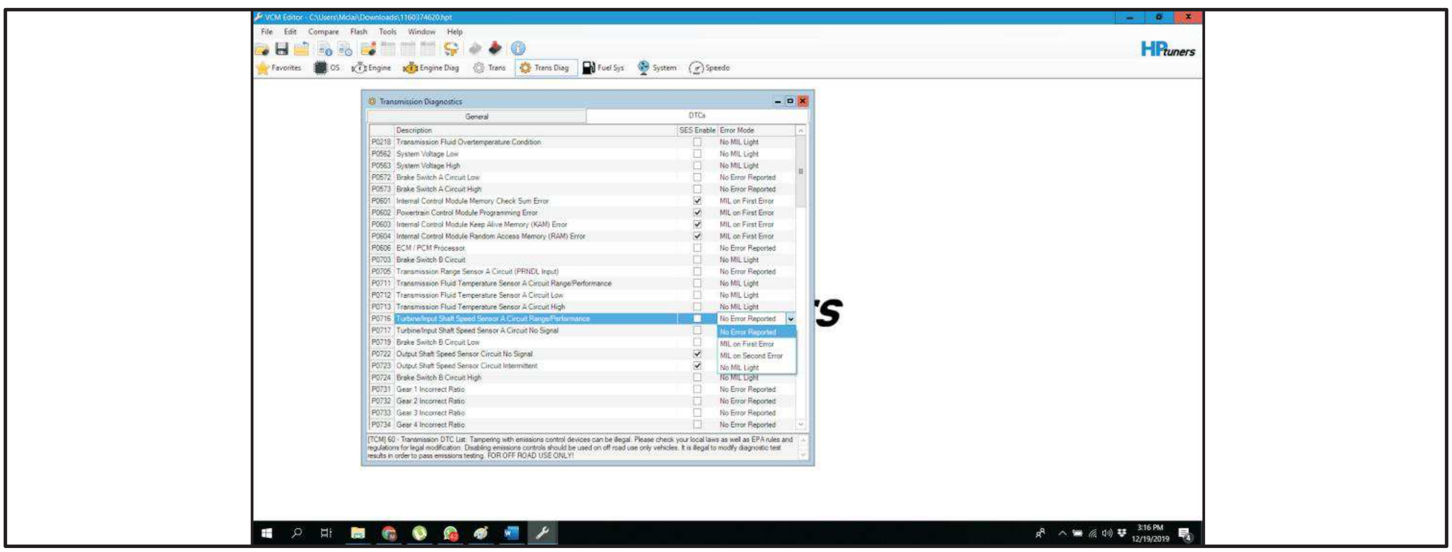


You can disable the input speed sensor in the diagnostic tab and delete the DTC's in the other tab by just clicking on the drop down menu of that code, and select “No error Reported.”



This is also available for most engine codes, but only change these things if you are 100% certain what you are doing and trying to achieve. Its not a fix for everything.

What if we put on bigger tires or a complete different Diff ratio. You could manually correct each table and you fixed the issue. But HPtuners made it easy for you. By going to Edit and opening the Gear / Tire wizard, you can change all the parameters “linked” to this with a simple procedure.

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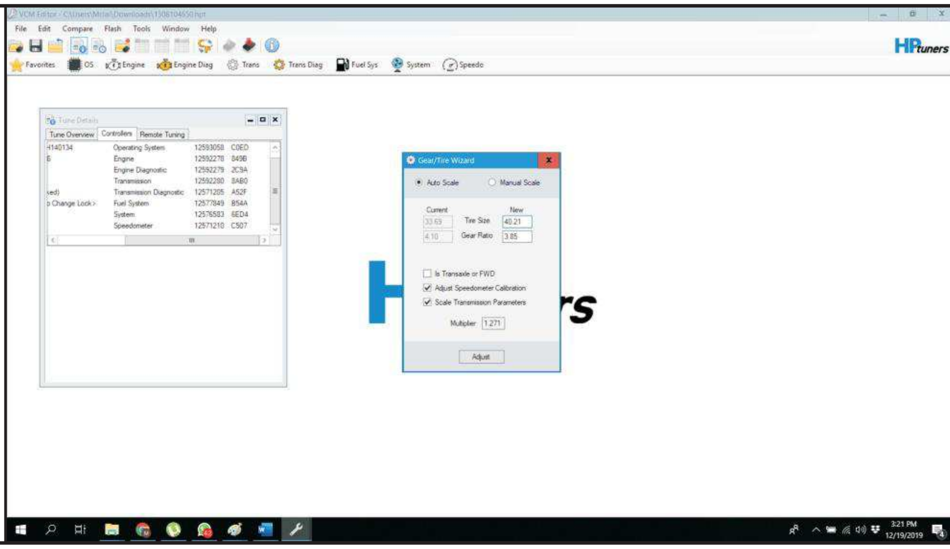
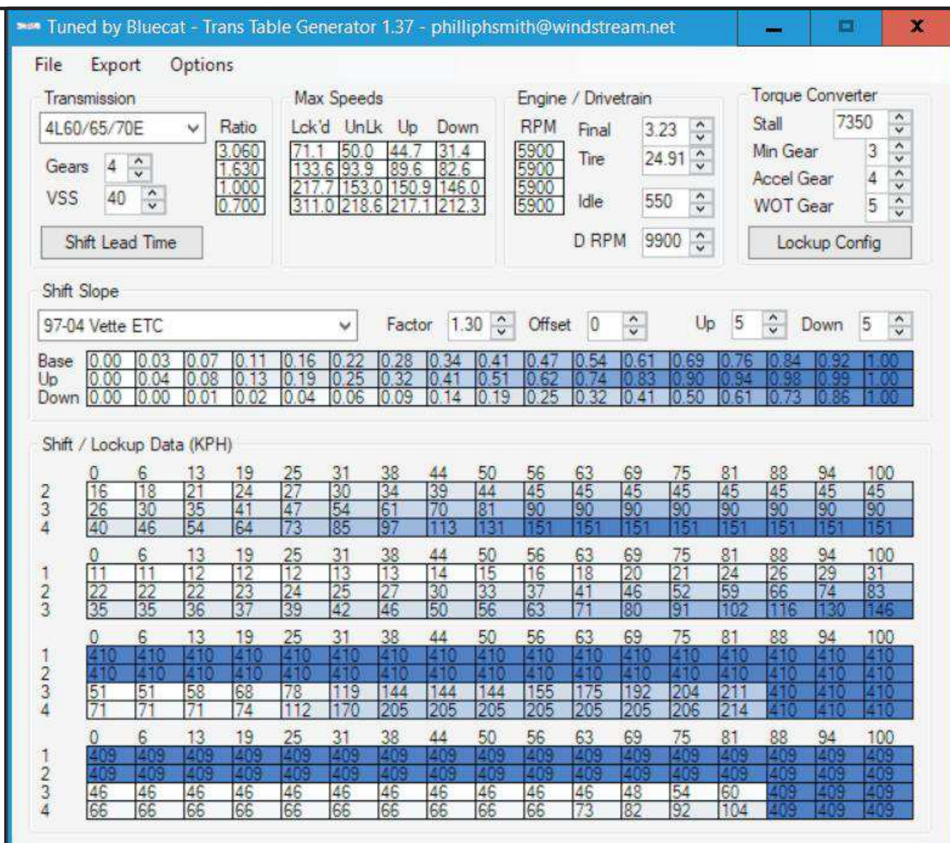


You will see that the program calculates the multiplier needed to correct all the values to suit the new setup. This saves a huge amount of time.

So if we can do this automatically, tuning should be just as easy right. It actually can be up to a certain point. I could have started with this, but then you would just enter numbers and don't know what you are changing exactly.

Search for Bluecat Transmission Table Tool. This tool will give you some good basic tables on transmission tuning based on your input.



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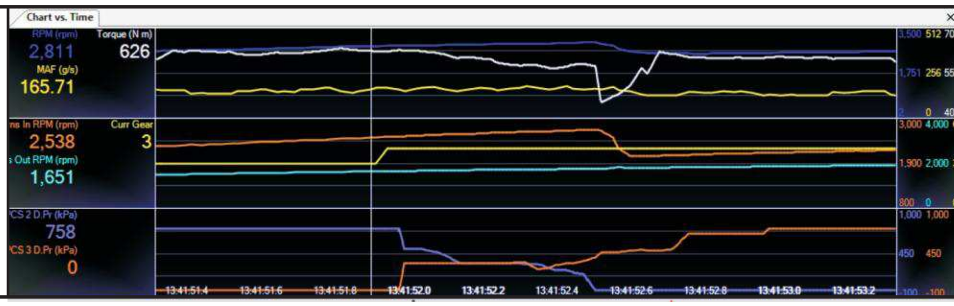
Although I won't be discussing this tool, it has some great advantages, especially when you just start. It will help you setup a base when you are totally new and the vehicle changes drastically. For this one the same caution remains, use it at will, but look at the data and don't just copy paste. Look over the changes, and try to understand it.

Lets head into some 6L80 tuning.

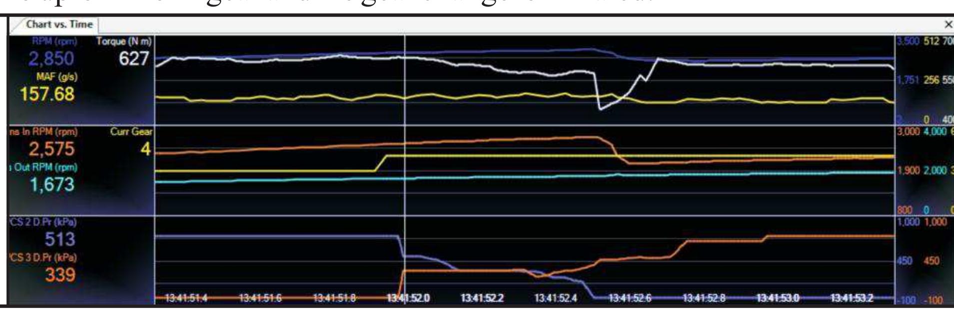
The 6L80E differs quite allot when comparing it to the 4L60-E. It is a complete different beast mechanically as well as clutch control and electronics.

In the 6Lxx we have a different clutch strategy. When a shift is initiated, The upcoming clutch is pre-filled, then the pressure of the off-coming clutch is reduced while its still holding that gear. The upcoming clutch is filled and is ready to take over. The off-going clutch is lowered even further as the upcoming clutch pressure is pushed up, engine torque reduces, the clutches overlap and we have a different gear. Torque reduction is canceled and we are on our way again.

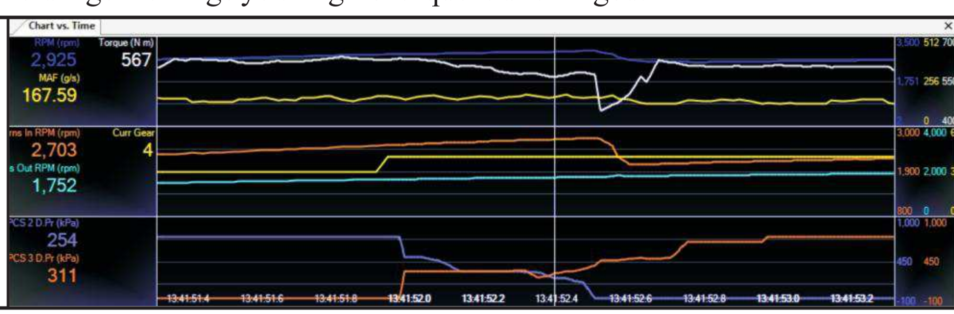
Let's look at this using a log file in VCM Scanner.



We are in 3th gear, torque is at 626nm and we are cruising along nicely. The transmission controller programming determines it's time to up-shift to 4th gear and the gear change is initiated.



You can see that the controller is now reducing PCS2 pressure while the PCS3 pressure is upped to 339kpa. This is the start from our 3-4 up-shift. If you look closely to the Transmission Input speed, you see that it's still rising slowly, so we don't have an actual gear change yet. Engine torque is unchanged.



Few milliseconds later and we are approaching the actual shift. The upcoming clutch is filled and the off-going clutch is ready to let go. We are still in 3th gear here if you look at the input speed rpm, but you can see that the engine torque is being reduced by about 10% at this point.

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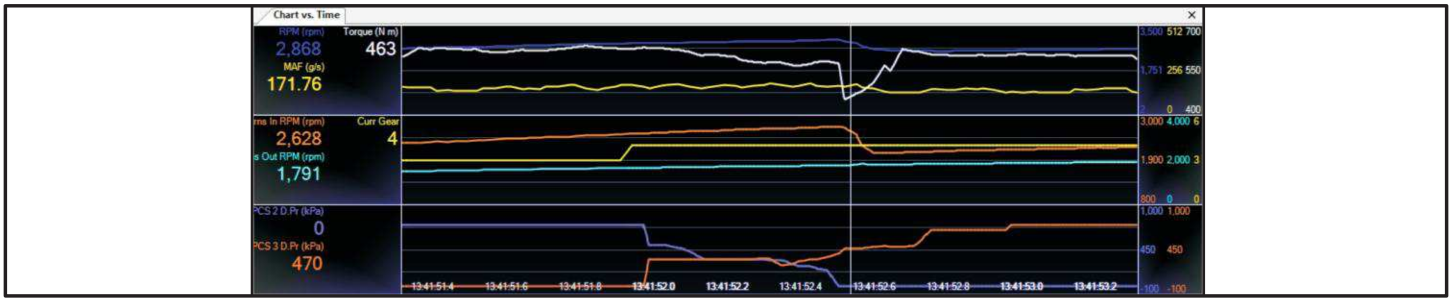
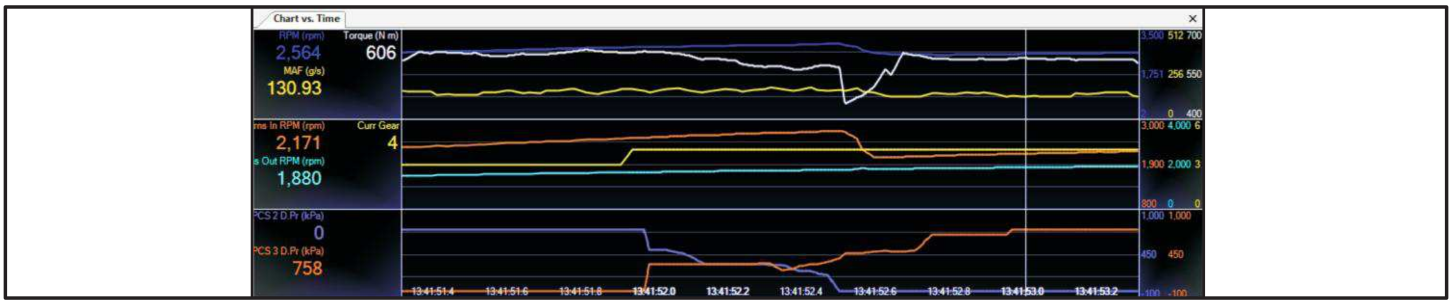


We are shifting. You can see that the upcoming clutch pressure is being increased gradually while the commanded pressure of the off-going clutch is 0kpa. The engine torque is massively lowered for a smooth shift and a prolonged transmission life.



Clutch control is maxed and the shift is completely done and we are already a few milliseconds in our new gear.

By monitoring this data very extensive, the TCM (as well as you) can detect flairs or bind ups really easy. If you even did a 6L80 clutch relearn, you might have figured out the trick for that procedure.

The TCM will lock the transmission completely after it purges all the clutches. Input shaft is standing still at this point and the engine is at a fixed rpm. The computer now starts to decrease the pressure of the clutch it wants to adapt. At a certain pressure, this clutch lets go and the input speed rises. That “point” is what the tcm is looking for. That is the pressure it can apply to the upcoming clutch to fill it, but not engage it. A bit above that line is the minimum pressure it will hold, but can release as fast as possible.

By knowing these pressures, the overlap is made much easier for the transmission. If you changed the amounts of friction plates, pistons or anything else, chances are the fast adapt will fail and the transmission program has no idea about these changes, and cant use that info for its adaption procedure. Changing these numbers in the programming can help you “fix” the fast adapt

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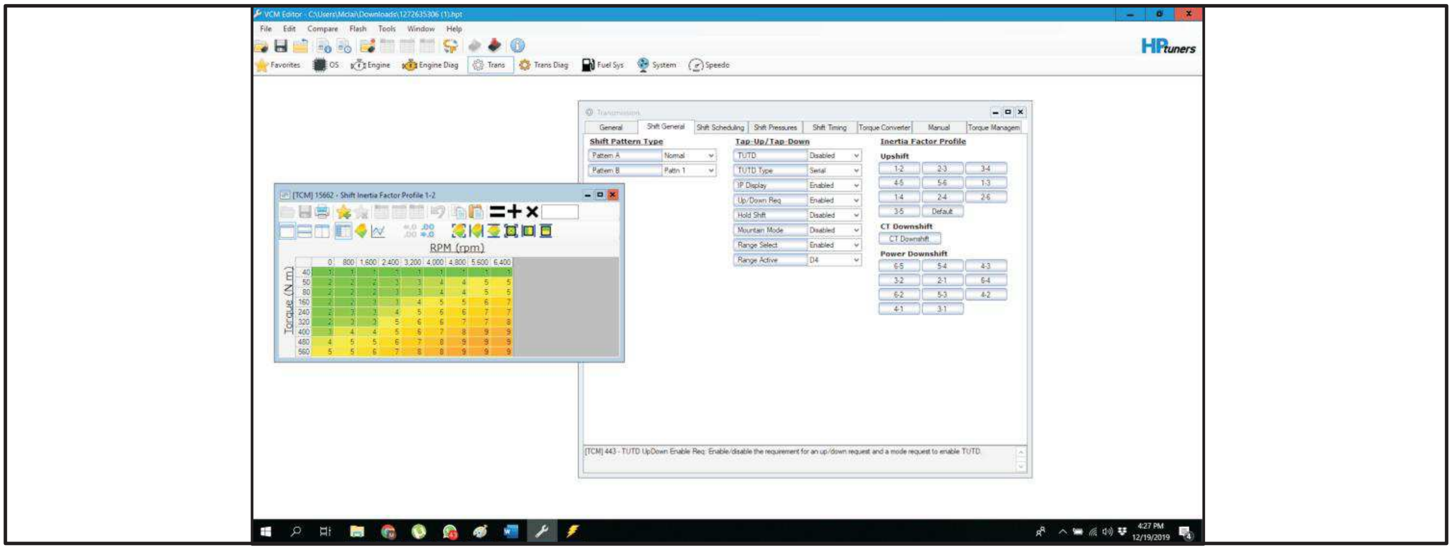
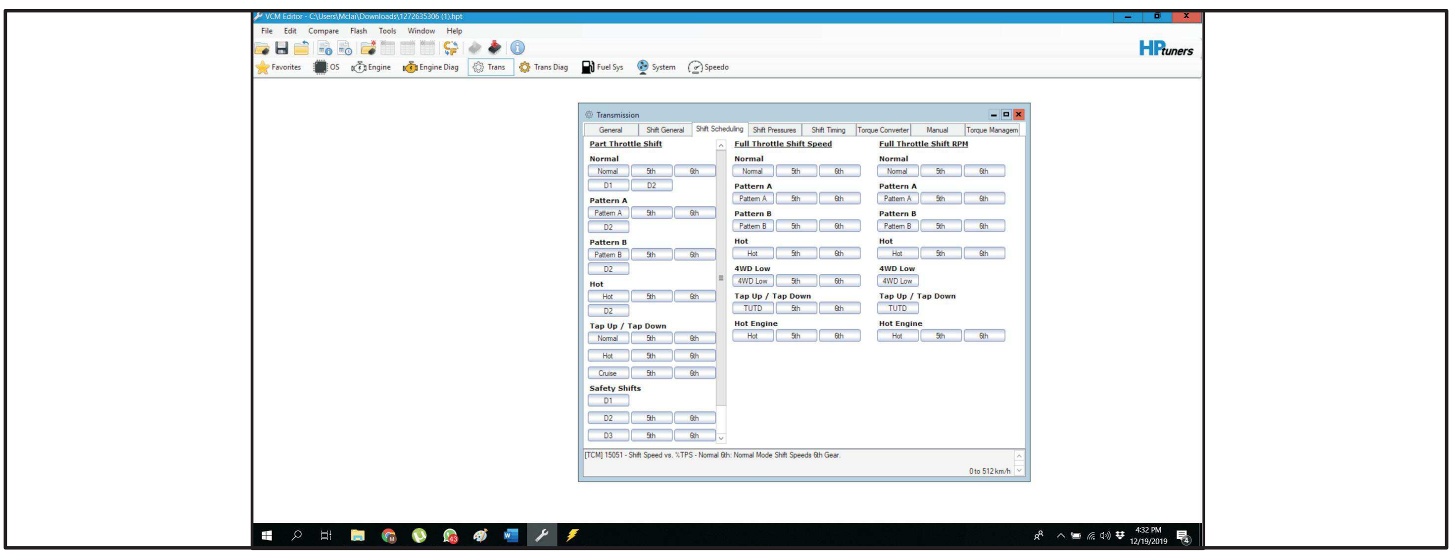


One other thing that is not seen with the 4L60-E is the Inertia Profile.

The programming uses this "inertia factor" to look up the right amount of values in other tables to finally control the shifts and the level of "Shift-Feel." Changing the shifts firmness can be as easy as changing this inertia factor.

There are also options to change the Tap up and down functions in this tab.



As with the 4L60-E, there is a way to change the shift speeds scheduling. Big difference is the amount of modes and patterns. Check your shift general tab to make sure you change the right pattern.

THE WORLD OF TRANSMISSION TUNING

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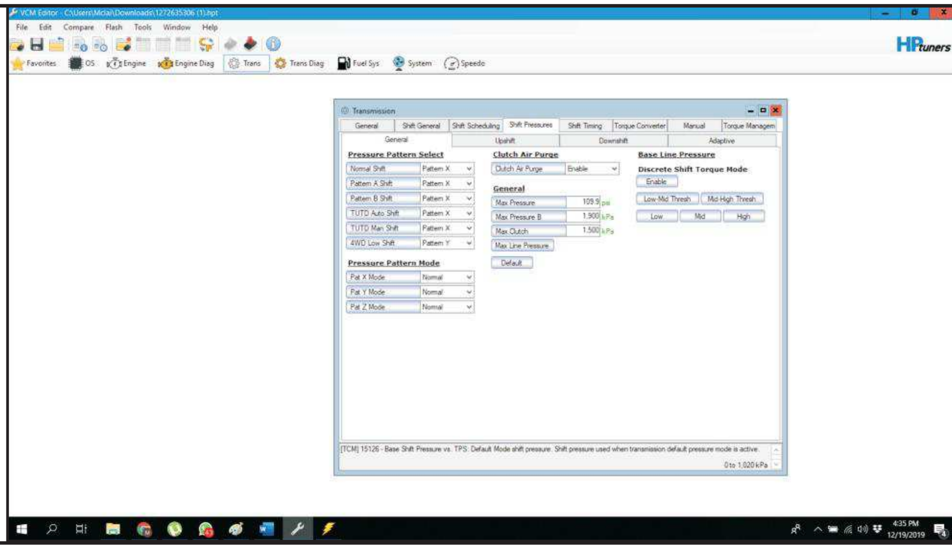
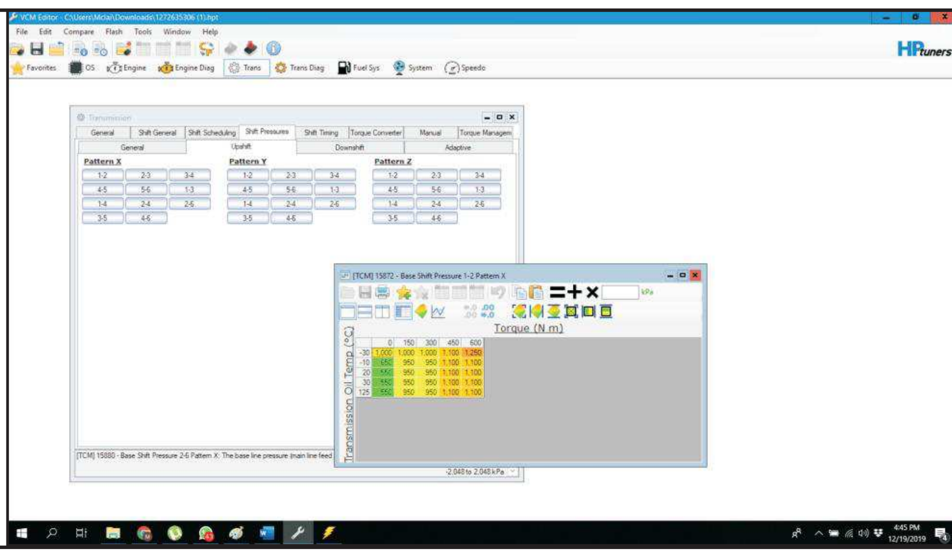


Shift pressure is also more extended as the 4L60-E. We have different patterns that might overwhelm you at first, but just take your time to get familiar with the pattern names and you will see that it actually makes perfect sense.

Like in the 4L60-E, you can change the maximum pressure in this tab. If you have a tuned engine and your transmission needs some additional holding power, change the max clutch pressure to give you additional clamping force for shifts. Unlike the 4L60-E, we do have more control about the maximum line pressure here. You can change the max pressure in this tab, and alter the line pressure vs RPM and Gear in the bottom table.

Use these tables with care and adjust this in little increments. Don't skyrocket the numbers and hope for the best, get some time to try what works and what not. The up and downshifts tabs show all the patterns the TCM works with, and you can change the pattern you are tuning for quite easy like in the 4L60-E.



If you are raising the pressure dramatically, make sure the overall limit is changed in the “general” tab, or that value will limit the pressure to that value, no matter how much pressure you are demanding in these tables.

THE WORLD OF TRANSMISSION TUNING
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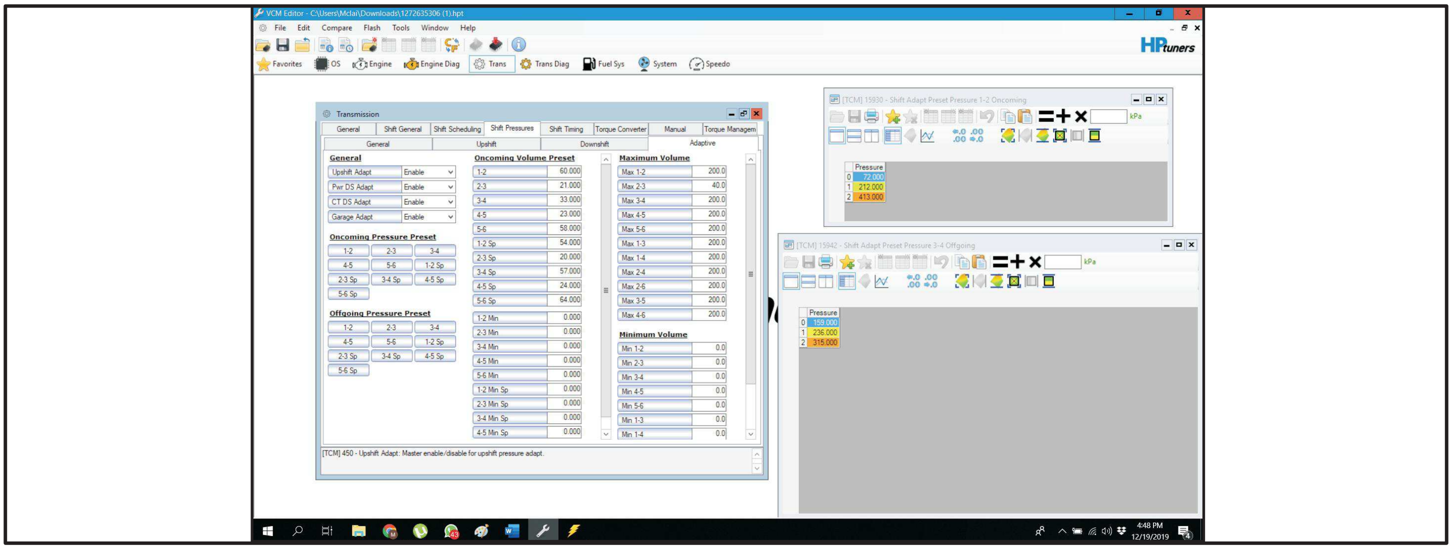
Adaptative

Now this is a tab that is brand new as we didn't have that with the 4L60-E earlier.



You can instantly see the oncoming pressure presets as well as the off-going pressure presets. If you changed anything in a clutch drum that would mean it needs more pressure to come on, you could try to change these numbers to make the program more "aware" for these changes.

Same for the Volume presets. If you closed the clearance significant, the volume before the clutch applies is reduced quite a bit. You can make it aware for this by changing it to a lower point. The controller then will take this into its calculation when it applies the clutch.

Just like our engine, the closer the calibration is true to the setup, the easier the controller can work with the transmission as the "Base" is perfect.

The outer right row is the allowed adaption volume. Raising this, might help you get through the fast adapt, as you give it more room to work with. I would suggest changing the 2-3 as well, as even unchanged transmissions fail the fast adapt way to often due to adaptation boundaries that are too tight.

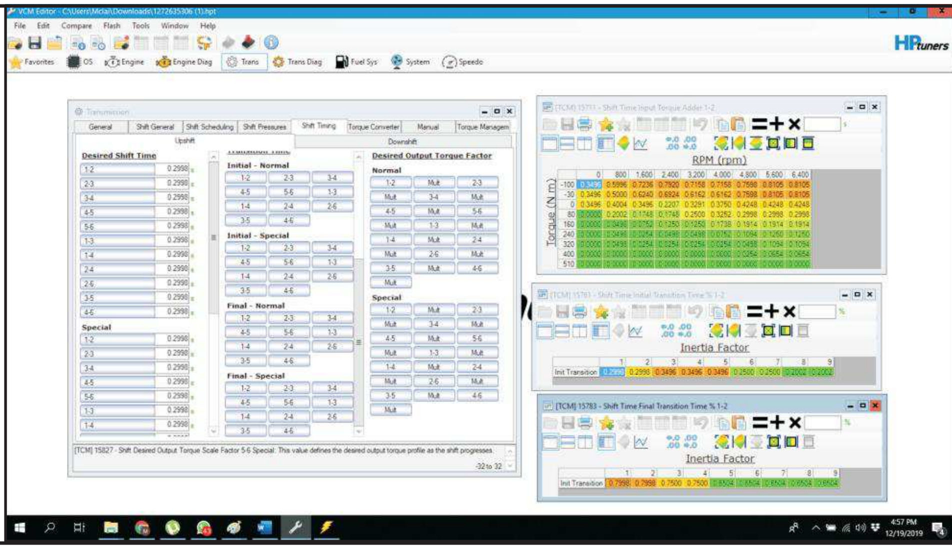
If you notice that the transmission works perfect from the beginning, but the adaptions make it work less effective or sloppy, you can disable the adaptations in this screen as well.

Now the biggest change, shift timing

THE WORLD OF TRANSMISSION TUNING

TRANSMISSION TUNING

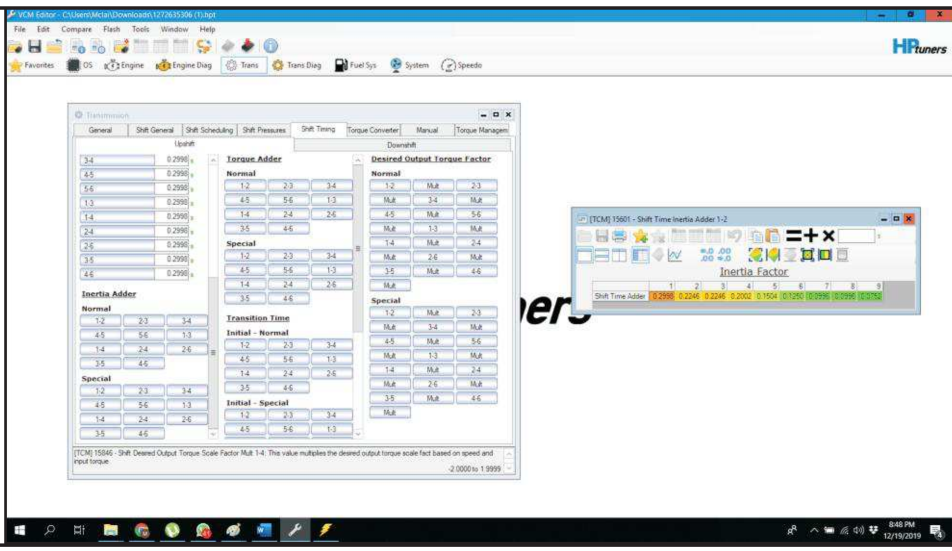
Now the biggest change, shift timing



And I say biggest change, as this is a real overwhelming tab.

On the left you see our BASE timing for a shift. The controller will start its "Shift Time Equation" with this base number.

If you scroll the left menu down to the bottom, you will find where there is an Inertia Time Adder.



The inertia factor we saw earlier comes into play here. You can see that there will be a lot of time added to the base number when we want a smooth seamless shift that you hardly feel. That shift is now already up to approximately 600ms.

Then in the middle we start with the Input Torque adder.

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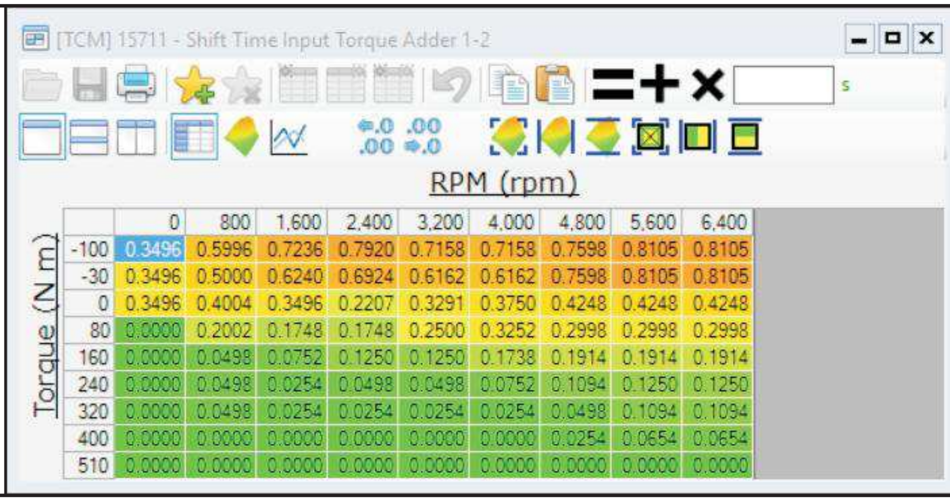
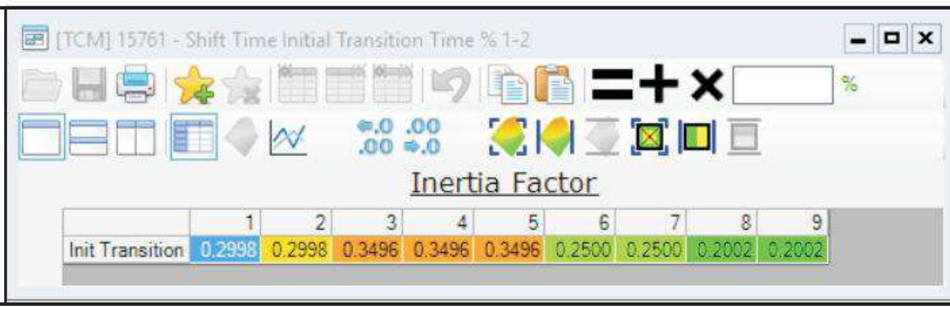


Torque (N m) \ RPM (rpm)	0	800	1,600	2,400	3,200	4,000	4,800	5,600	6,400
-100	0.3496	0.5996	0.7236	0.7920	0.7158	0.7158	0.7598	0.8105	0.8105
-30	0.3496	0.5000	0.6240	0.6924	0.6162	0.6162	0.7598	0.8105	0.8105
0	0.3496	0.4004	0.3496	0.2207	0.3291	0.3750	0.4248	0.4248	0.4248
80	0.0000	0.2002	0.1748	0.1748	0.2500	0.3252	0.2998	0.2998	0.2998
160	0.0000	0.0498	0.0752	0.1250	0.1250	0.1738	0.1914	0.1914	0.1914
240	0.0000	0.0498	0.0254	0.0498	0.0498	0.0752	0.1094	0.1250	0.1250
320	0.0000	0.0498	0.0254	0.0254	0.0254	0.0254	0.0498	0.1094	0.1094
400	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0254	0.0654	0.0654
510	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

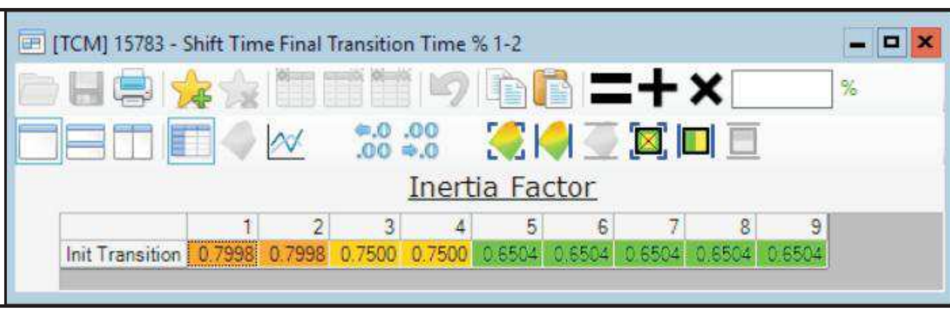
So next to our Base time and inertia time, we will "add" a certain time based on the Torque and RPM at that given time.

With low torque and medium rpm's, we see that we add up to 0.3 seconds to our base timing. That can bring the total time well above 750ms which is very high. But shift timing here is different then with the 4L60-E as it consists out of phases. This doesn't mean we have a clutch that is slipping 750ms on each shift. But it does make our job harder as we now have a base timing plus two adders we need to deal with.

Since our shifts are now in multiple phases, we now also have some control over the amount of time a phase can take.



	1	2	3	4	5	6	7	8	9
Init Transition	0.2998	0.2998	0.3496	0.3496	0.3496	0.2500	0.2500	0.2002	0.2002



	1	2	3	4	5	6	7	8	9
Init Transition	0.7998	0.7998	0.7500	0.7500	0.6504	0.6504	0.6504	0.6504	0.6504

With these two tables you have some more control over the shift . They basically work like a ramp in and ramp out on the shift. When you just start working with the 6L80, its best to leave these tables as they are to start with. You probably only need to change these value's if you are looking for the last milliseconds on the track or have a setup that wont work properly without changing these values.

So you see, the shift timing isn't just a number like it was with the 4L60-E. But there is a way to simplify the "shift timing" for the user. This can even be the Default setting on some vehicles. With the setup above, we have to take in account the base timing and then check how much time is added.

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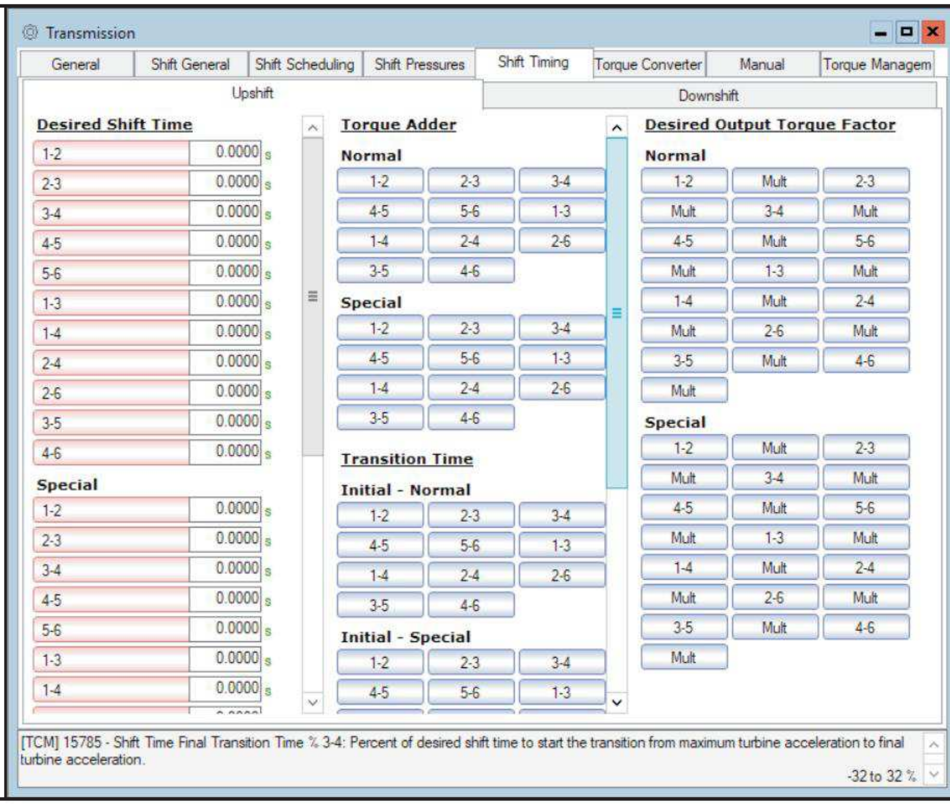
By zeroing out the base timing, you are now controlling the actual shift timing with the Adder table. So let's say you want to approach shifts like that. Zero out all the base timing to start with.



So now our equation start with 0 seconds. If we also delete the inertia adder as well, we are left with one table that will be the entire timing. Select each inertia shift table and zero it out.

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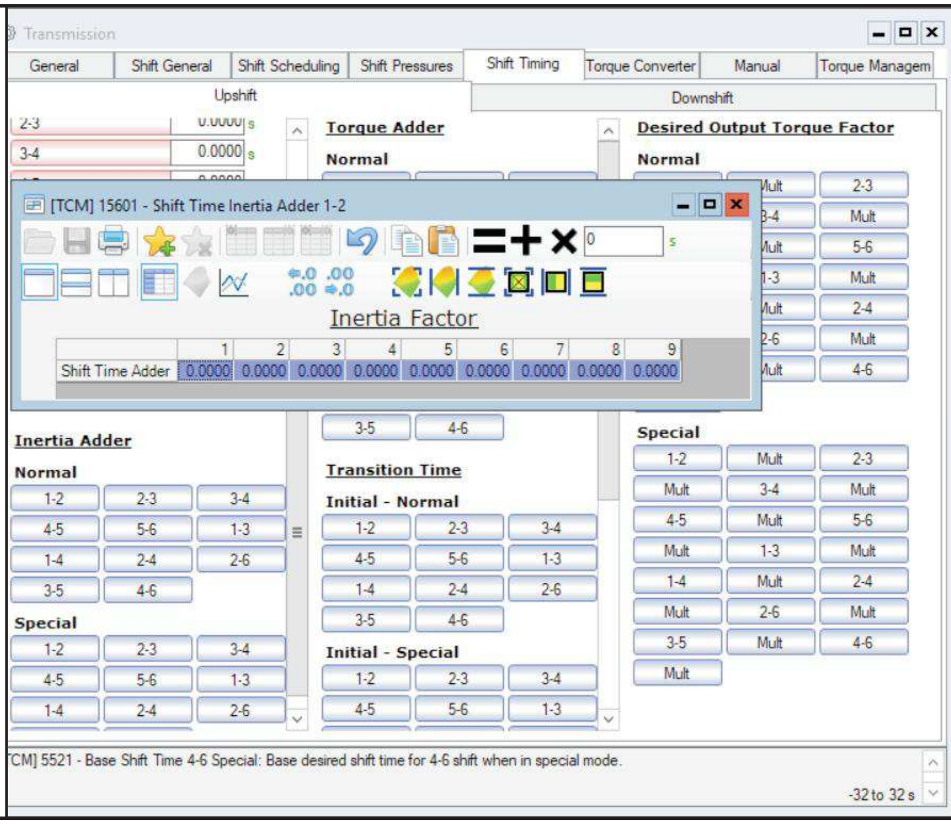
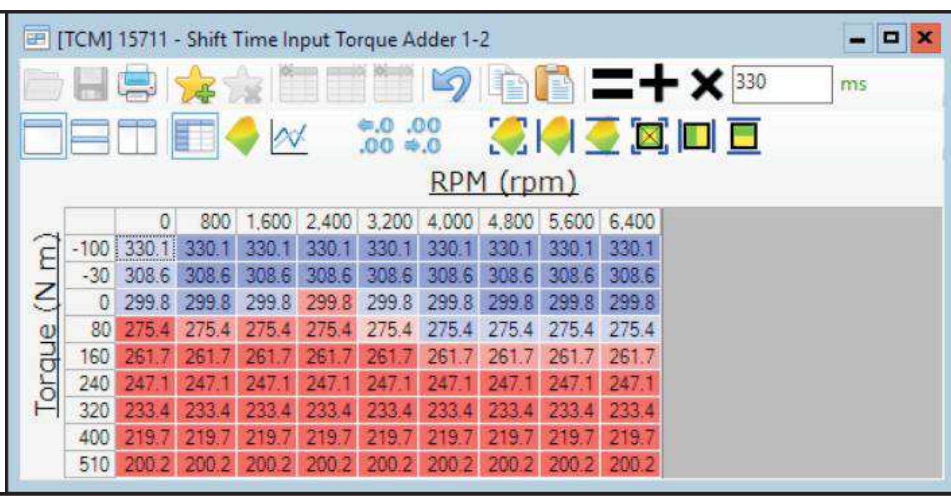


Now the only table active will be our Torque adder table.

We can fill this table with reasonable numbers and have only this table determine our shift timing.

So let's start Filling the entire 80nm row with your longest desires timing for low load, lets say 275ms, and the entire row 510Nm with the shortest time of 200ms at high load. With 2 rows occupied as valid shift timing numbers, you can now interpolate vertically between those rows.

For the negative torque rows, put some higher acceptable number. Lets say 330ms. Interpolate between that row and the 80nm row again and you now have a base table that looks something like this.



	0	800	1,600	2,400	3,200	4,000	4,800	5,600	6,400
-100	330.1	330.1	330.1	330.1	330.1	330.1	330.1	330.1	330.1
-30	308.6	308.6	308.6	308.6	308.6	308.6	308.6	308.6	308.6
0	299.8	299.8	299.8	299.8	299.8	299.8	299.8	299.8	299.8
80	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4
160	261.7	261.7	261.7	261.7	261.7	261.7	261.7	261.7	261.7
240	247.1	247.1	247.1	247.1	247.1	247.1	247.1	247.1	247.1
320	233.4	233.4	233.4	233.4	233.4	233.4	233.4	233.4	233.4
400	219.7	219.7	219.7	219.7	219.7	219.7	219.7	219.7	219.7
510	200.2	200.2	200.2	200.2	200.2	200.2	200.2	200.2	200.2

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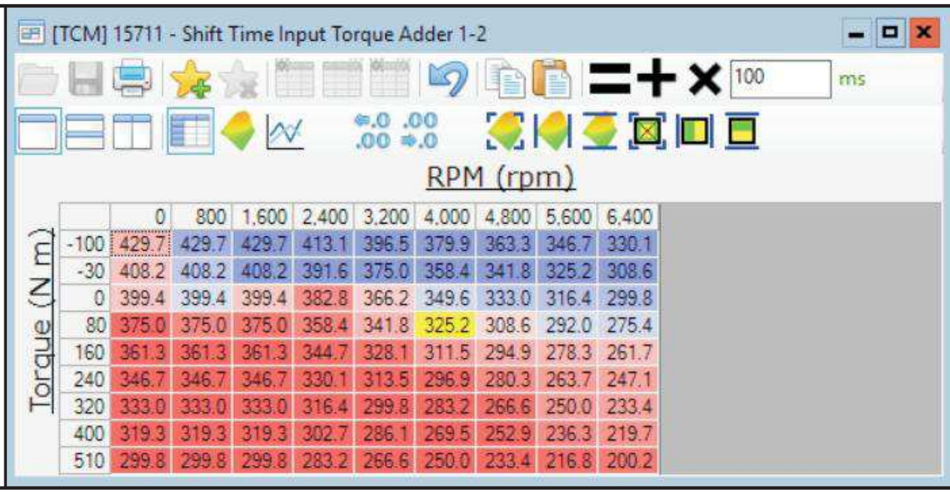
These values are now used by the controller as the desired shift timing. At this point only the Torque will influence the shift timing. If you want to take in account the rpm as well, select the columns 0, 800 and 1600 rpm and add some time, lets say 100ms. Select row 1600 and 6400 rpm and interpolate horizontally.

It should now look something like this:



Torque (N m) \ RPM (rpm)	0	800	1,600	2,400	3,200	4,000	4,800	5,600	6,400
-100	429.7	429.7	429.7	413.1	396.5	379.9	363.3	346.7	330.1
-30	408.2	408.2	408.2	391.6	375.0	358.4	341.8	325.2	308.6
0	399.4	399.4	399.4	382.8	366.2	349.6	333.0	316.4	299.8
80	375.0	375.0	375.0	358.4	341.8	325.2	308.6	292.0	275.4
160	361.3	361.3	361.3	344.7	328.1	311.5	294.9	278.3	261.7
240	346.7	346.7	346.7	330.1	313.5	296.9	280.3	263.7	247.1
320	333.0	333.0	333.0	316.4	299.8	283.2	266.6	250.0	233.4
400	319.3	319.3	319.3	302.7	286.1	269.5	252.9	236.3	219.7
510	299.8	299.8	299.8	283.2	266.6	250.0	233.4	216.8	200.2

Now you have a Base table that is progressive in both RPM as Torque. This is just a way you could make a base map for yourself. You need to drive the car to actually get an idea of what's good for this particular car. But by doing this, you have a rough base table. Take some time to polish these numbers to suite a certain type of car, or a certain time of driver.

Once you put in some good work, you have a real good timing map you can use on future projects or other tunes. You can have the next 6L80 “Tune” up and running within an hour with a very happy customer, and cash in your hands once you have done the hard work on these maps once.

You can then simply copy and paste your work, take it for a drive, maybe polish the tune a bit here and there and be done. After the hard work is done, the next tune normally only takes 2 or 3 tries to get is just right.

This is not only with the shift timing, but also shift pressure, scheduling and TCC. You can copy the numbers once you have dialed them in.

You can even use the Bluecat as a nice base to start from.

TCC Tab

Apply and release speeds are pretty much the same as with the 4L60-E, only the amount of patterns differs. So disabling TCC in lower gears can be achieved easy by filling in the rows for those gears with un-achievable speeds. This will effectively disable tcc for that gear.

It's recommended to have the TCC only enabled for 5th and 6th gear. This will “free-up” the transmission and make the car and transmission feel more alive.

But let's look at the options we have in the General Tab. Especially the TCC Apply Ramp is an interesting table.

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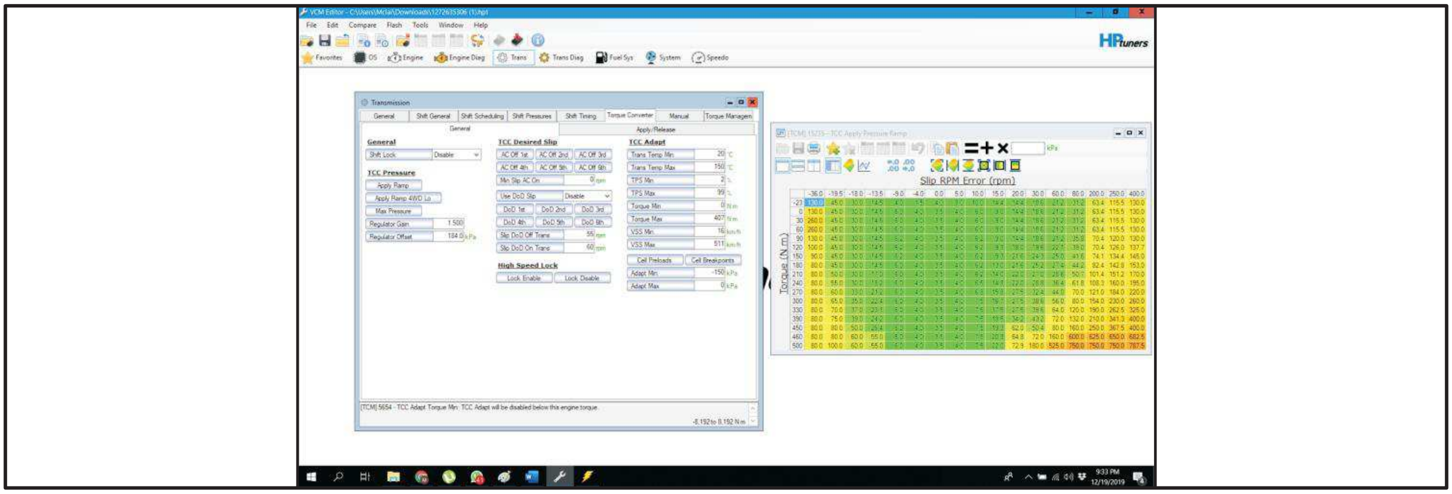
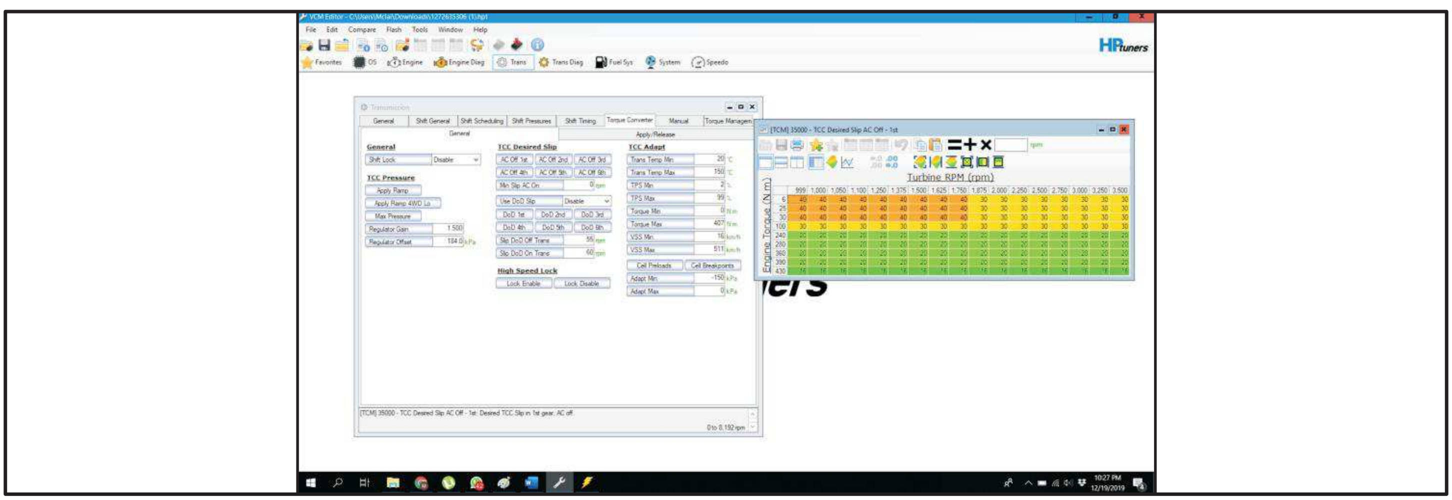


GM really did a lot of testing and calibration to fill out a table like it is. They have now based the ramping apply pressure of the TCC based on the amount of torque and the slip error. This gives you a very dynamic table that is able to catch the TCC at any given time with almost the same "feel". GM did a great job on this, and unless you are having an issue, or don't like the "TCC feel," I would leave it stock at the time being. But you could raise the pressure in this table to start with a higher pressure.

Desired TCC Slip

As with most modern transmission, the converter clutch is designed to "survive" an amount of constant slip. With 20 rpm, this slip is very slow. That's one full rotation of "slip" every 3 seconds.



You could change the desired slip table and zero it out totally to get an ON/OFF clutch idea.

But for that to work well, you need to raise the TCC pressure as well.

This can be achieved by modifying the Regulator Offset. This is your minimum pressure for the TCC. Raising this to lets say 620 kpa, effectively raises the base pressure to a pretty high apply pressure. This will make the TCC engage more like a clutch and it will hold quite some torque.

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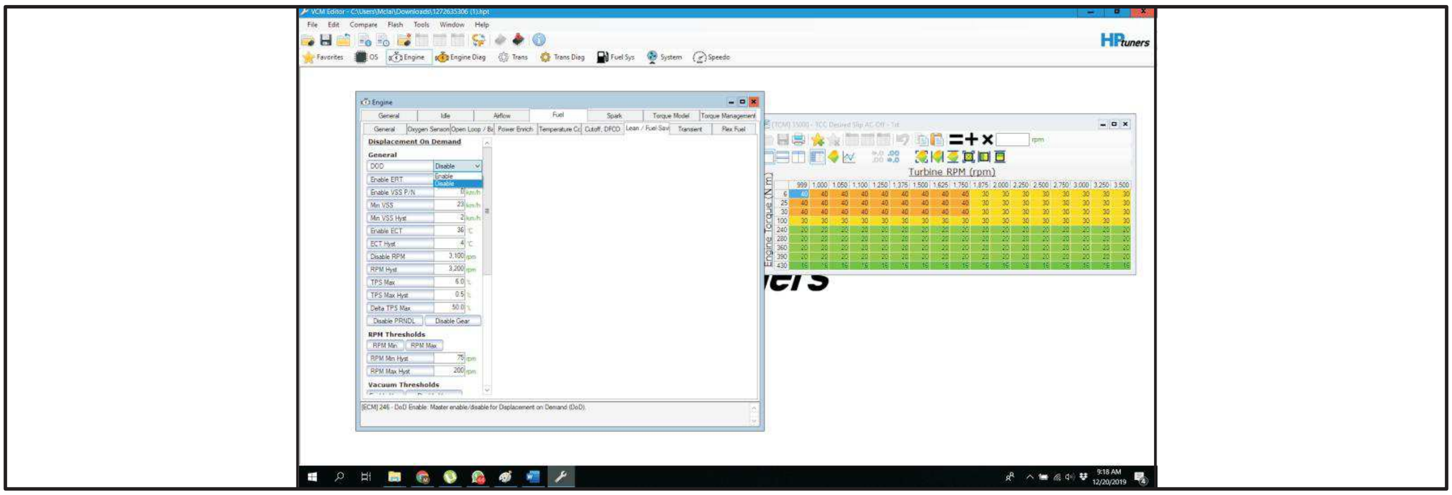
This can be very handy when you are dealing with aftermarket converters that aren't built like OEM. The friction plates in those might not be so forgiving when slipping, or they have a “friction value” that's not very stable under pressure. This might “over-activate” the converter clutch, and fail prematurely. Changing this strategy can reduce come backs, or help a customer who has issues with the TCC apply.

Underneath the collection of desired slip for AC-OFF, there is the option to set the parameters of TCC slip during DoD, which is your Displacement on Demand.

The controller will “shut off” cylinders in low load to preserve Fuel. This off course will affect the engines smoothness and could cause an issue when using lockup.

On this engine the DoD TCC strategy is disabled. If its enabled and you are experiencing a TCC issue because of it, you can either disable the TCC strategy here, or disable the DoD strategy completely in the engine setup.



Changing this setting to Disable will automatically inhibit DoD in the future.

The outer right column in the TCC tab lets you setup the TCC adaptation parameters.

If you are converting to an On/OFF strategy, and you are happy with how its working, you could inhibit the controller to adapt the TCC strategy any further. The adaptation can be inhibited by oil temp, vehicle speed, throttle position or torque. Putting one of these “minimal” values to an unreachable number, automatically sets the adaptation off. For example, putting the minimal torque to 4000Nm makes sure the adapt strategy is disabled completely.

One of the last taps is “manual".

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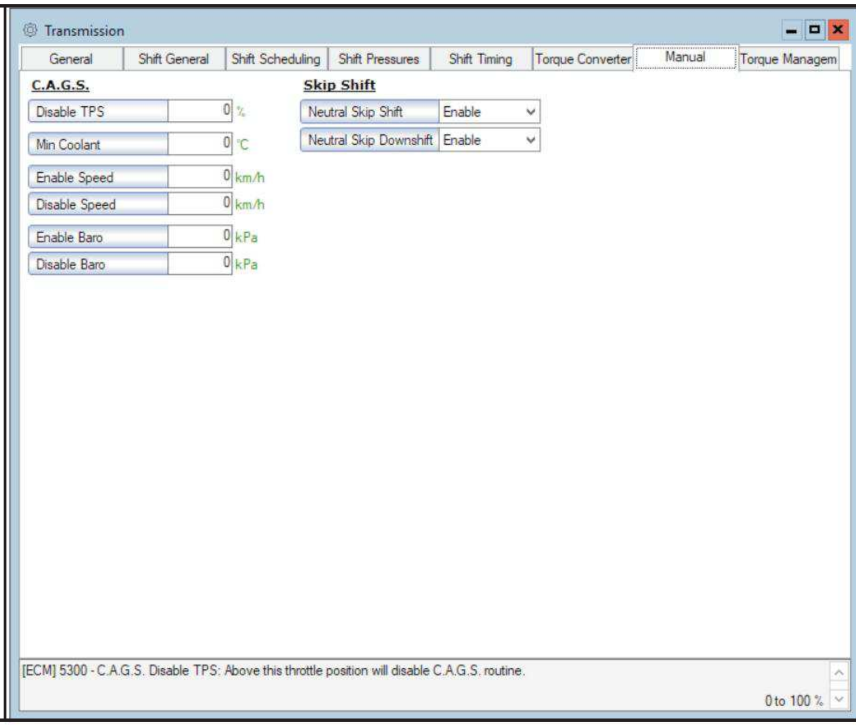
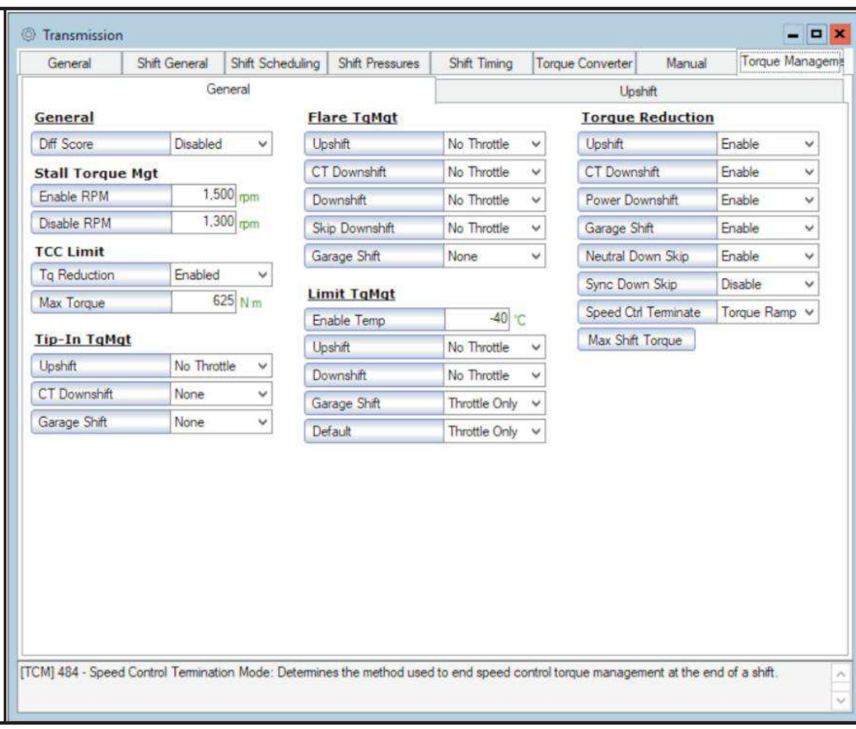


Here we can setup C.A.S.G. and get two additional options when skip-shift is enabled. In this particular vehicle the Skip shift strategy is disabled. Enabling the Neutral skip shift options, allows the transmission to revert to Neutral while skip shifting.

Like in the 4L60-E, we end with Torque management.



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As you can see, the options here are pretty big.

In the left section we can put in our stall rpm when torque management is allowed. If you have equipped the transmission with a high stall converter, you can raise this rpm to make sure torque management isn't taking away torque when you start driving.

TCC limit will try to protect your converter from too much torque and potential damage because of it. This is done by reducing Torque. You can change the Apply/release speed for both normal and Full throttle to disengage the TCC as well. This will prevent the converter ever being locked when the torque is this high.

Tip-in, flare and limit torque Management

These are all different strategies that will help reduce torque during that “type” of phase.

You can setup how you want the controller to achieve the torque management. We will keep those stock as they work pretty good like that.

Torque Reduction

Here you will see several “transitions” where the torque management can help.

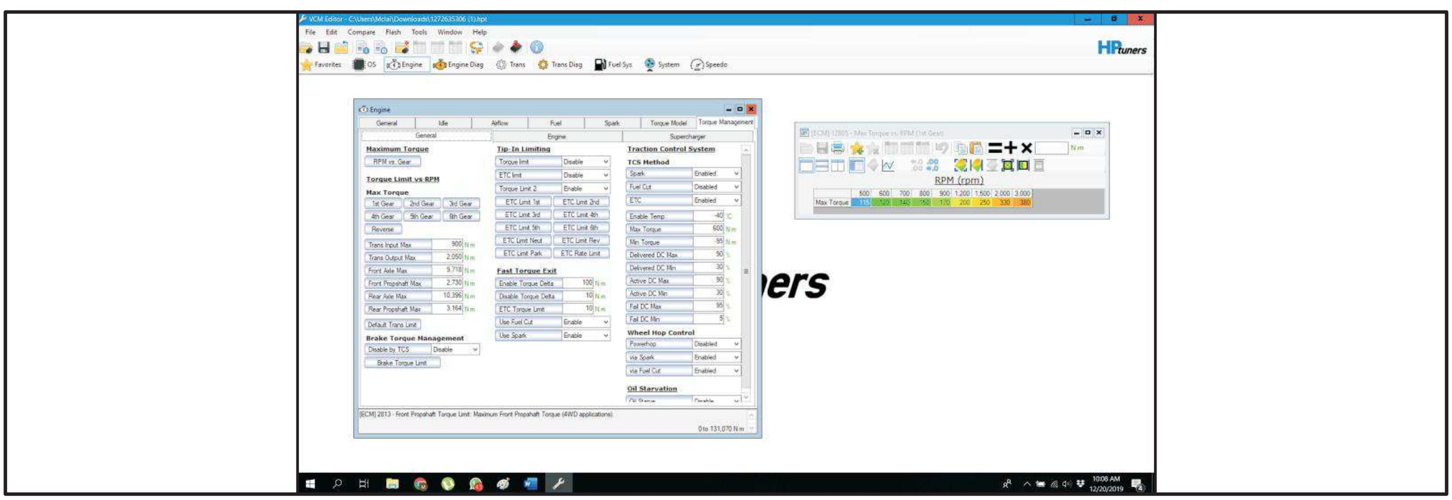
Some will disable things like Garage shift, to make the engagement a bit “firmer”. But like with the 4L60-E, it's a pretty fast way to kill a transmission if you throw every Torque management option overboard. So I wouldn't advice to disable the torque management on up or downshifts completely. If you tune your shifts, the time this Torque management is active, is also reduced significant. That way you still have a firm and fast shift, while still having the protection from the torque management.

If you want to tweak the torque management, this is possible in the up-shift tab. There you can find Torque Factor, Adder, cold multiplier and adder multiplier.

The Final Torque reduction is done with a formula using all these inputs.

My final Torque Factor = (Shift Torque Factor + (Shift Torque Factor Adder * Shift Torque adder multiplier) * Torque Factor Cold)

So you see, it's not just putting in a number, but it's a spiderweb of Values. You can lower the factors by a percentage to get less Torque Reduction during up-shifts, but remember that these values work together with the Torque model in the engine. Which also lets you set different parameters on when and how much torque is permissible on the transmission.



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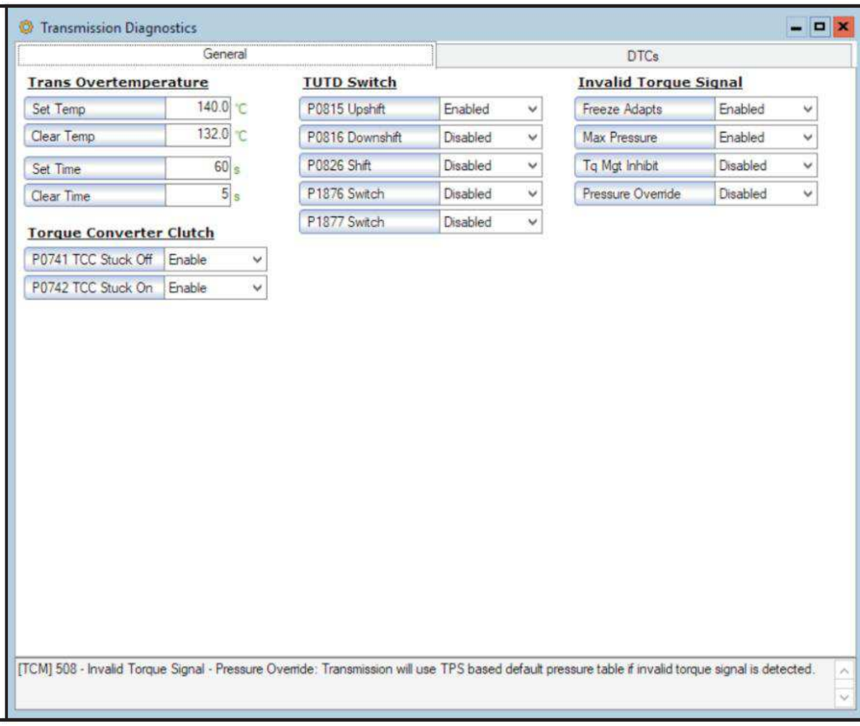
In my experience, there is often no real need to change the torque reduction. Modifying the shift timing and pressures is often enough to get crisp and firm shifts while not ripping of the splines of the shafts.

But if you feel that there is still some power and drag strip time left, start reading multiple threads on the HPtuners forum about this as it's a pretty complex system. Knowledge is power. Better to read a few hours, then killing a transmission or 2 during the learning curve.

The Trans Diag page looks similar to the 4L60-E, only with much more options.



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Transmission Diagnostics

General | DTCs

	Description	SES Enable	Error Mode
P0601	Internal Control Module Memory Check Sum Error	✓	MIL on First Error
P0602	Powertrain Control Module Programming Error	✓	MIL on First Error
P0603	Internal Control Module Keep Alive Memory (KAM) Error	✓	MIL on First Error
P0604	Internal Control Module Random Access Memory (RAM) Error	✓	MIL on First Error
P0606	ECM / PCM Processor		No Error Reported
P0608	Powertrain Control Module Vehicle Speed Output A		No Error Reported
P0609	Powertrain Control Module Vehicle Speed Output B		No Error Reported
P062F	Internal Control Module EEPROM Error	✓	MIL on First Error
P0634	PCM / ECM / TCM Internal Temperature Too High	✓	MIL on First Error
P0650	Malfunction Indicator Light Control Circuit		No Error Reported
P0658	Actuator Supply Voltage A Circuit Low	✓	MIL on First Error
P0659	Actuator Supply Voltage A Circuit High		No MIL Light
P0667	PCM / ECM / TCM Internal Temperature Sensor Range/Performance		No MIL Light
P0668	PCM / ECM / TCM Internal Temperature Sensor Circuit Low		No MIL Light
P0669	PCM / ECM / TCM Internal Temperature Sensor Circuit High		No MIL Light
P0685	ECM/PCM Power Relay Control Circuit/Open		No Error Reported
P0689	ECM/PCM Power Relay Sense Circuit Low		No Error Reported
P0690	ECM/PCM Power Relay Sense Circuit High		No Error Reported
P069E	Fuel Pump Control Module Requested MIL Illumination		No Error Reported
P06AC	PCM / ECM / TCM Internal Temperature Sensor B Range/Performance		No MIL Light
P06AD	PCM / ECM / TCM Internal Temperature Sensor B Circuit Low		No MIL Light
P06AE	PCM / ECM / TCM Internal Temperature Sensor B Circuit High		No MIL Light
P0700	Transmission Control System (MIL Request)		No Error Reported
P0705	Transmission Range Sensor A Circuit (PRNDL Input)		No Error Reported
P0711	Transmission Fluid Temperature Sensor A Circuit Range/Performance		No MIL Light

[TCM] 60 - Transmission DTC List: Tampering with emissions control devices can be illegal. Please check your local laws as well as EPA rules and regulations for legal modification. Disabling emissions controls should be used on off road use only vehicles. It is illegal to modify diagnostic test results in order to pass emissions testing. FOR OFF ROAD USE ONLY!

As you can see there are allot of DTCs defined for you as well as certain "boundaries".

You can use this to disable certain fault codes, or change the boundaries real easy, but remember, this is not a fix. If you have a faulty speed sensor, disabling the code will not fix the root problem. You might not have an error anymore, and maybe even get the transmission out of a limp mode situation, but it wont fix the cause. So use it with care and common sense.

So now you have a good basic understanding about the programming behind some automatics found in the GM vehicles. As you have seen, the basics of the 4L60-E are applied to the 6L80 as well, but that one is just more complex.

If you would look to any other transmission, even Ford or Chrysler, you will see that they all follow a similar approach. Names may change and they might have more or less options, but the principal basics are the same.

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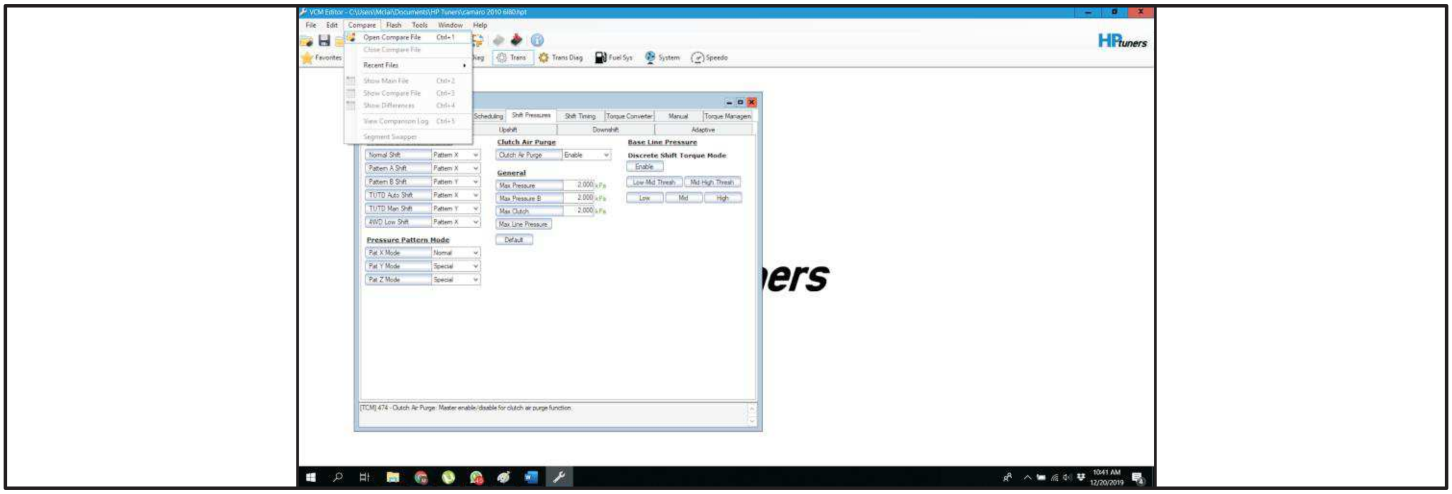
Once you have tweaked and tuned a car to your liking and put in some long hours of logging and adjusting the programming, you have a good base for the next car with the same transmission.

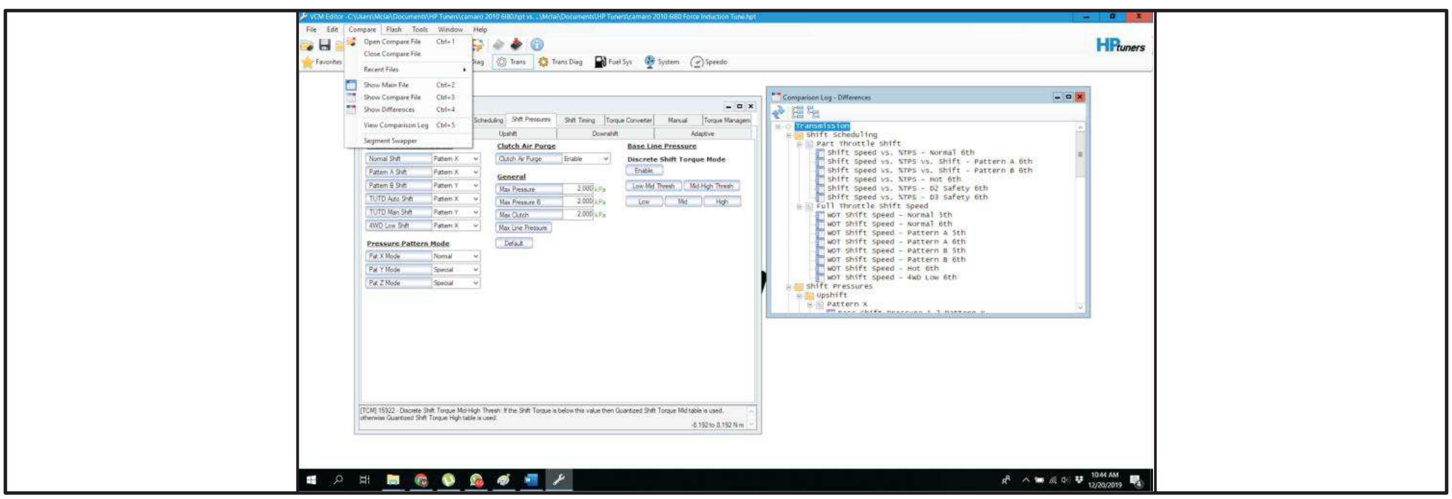
Copying the maps from one to another is done easy with the Editor.

Open the file of the car you are editing and click on Compare in the menu on top.



Now open a compare file, which off course is your tuned file.

The editor now has both files in its memory and with simple key combinations you can switch between them, or let the program show you the differences.



So CTRL+5 will show you the screen on the Right. This gives you a great overview.

If you want to copy your tuned tables to the file of the “to-tune” car, go to the Table you want to copy and press CTRL+3. You are now viewing your tuned files. Select the complete table and Copy that to the clipboard (CTRL + C). With the combination CTRL+2 you now switch to the file you want to edit. Past the data with CTRL+V and do this for all tables.

Once you are done, save the file, flash it and you are ready to test drive the next car to tune.