CHEM2 – CHRYSLER ECM MODIFIER (2.0.0.7)

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USES

ChEM is used to alter Boost Goals, alter timing, and modify fueling for larger Fuel Injectors or modified engine flow characteristics (i.e. Manifold porting, Headwork, cam), or alternate fuels. The primary purpose of modifying the ECM program will be to maintain stock streetability while providing for increased power capability from hardware modifications. It is also possible to modify deeper down into the system.

Using ChEM is designed to be as simple and intuitive as possible, but I can't stress enough that you need to *pay attention* to what you are modifying. You can NOT take a stock engine, modify some tables, and gain fifty free horsepower, even though **some** custom calibration sellers claim this. Although stock calibrations do make a few performance trade-offs, for the most part they provide the best combination of power, economy, and behavior. What we want to do is maintain these desirable properties while adding support for enhancements that you make to vehicle hardware.

ChEM is supported and distributed at www.MoparChem.com

INTENDED AUDIENCE

ChEM is intended for Chrysler vehicles, generally from 1985 to 1993. The Engine controllers from these vehicles can also be used for other 4-cylinder engines. Both 2.2 and 2.5 liter American made Chrysler engines are supported immediately. Special attention is given to the Turbocharged engines.

You can also use these earlier generation Chrysler ECMs to operate other 4-cylinder engines. This might be useful for a current vehicle being operated by a secure or tamper-proof Engine Controller. It is possible to use these controllers on the Mitsubishi 2.6, or Daimler-Chrysler's current 2.0 and 2.4 engines (descendents of the 2.2 and 2.5), with their 16 valve variants you can make some serious gains.

ChEM is not a casual adjustment tool. It is designed for tuners who have some idea what they are doing. It IS possible to make changes that will destroy an engine, so don't just go in and make changes without reading up on the possible results.

It is the intent of this document to provide you with enough information to understand, for the most part, which values can be changed, and the safe or productive ranges to adjust them to.

PREPARATION

Before ChEM is of any use to you, you will need to make some modifications to your vehicle.

Specifically, you will need to socket the Read Only Memory chip in the ECM that the current program was burned onto so you can replace it with your modified version. Also, you will need to obtain a method to write new ROM chips, and erase the old ones. EPROM burners are relatively inexpensive, and blank chips are still available. It is also possible to get used EPROMs and reuse them.

Support is also provided for burning EEPROMs in SMECs. Since the SMEC is under the hood it is simpler to change the programming using a laptop computer inside the car. Also, you can use a ROMULATOR, which allows for real time calibration changes in a running engine both in Logic Module and SMEC cars.

THE CHEM SYSTEM

ChEM is not just the editing software, it is a system. Baseline calibrations are provided for Logic Module and SMEC computers, which should handle the majority of requirements. Complete source code with useful comments is provided for these calibrations, so you can make actual program modifications to the controller code (an example is my modification to allow rev limits while stopped, useful for holding your best launch RPM while staged, or the Check Engine Light modification that flashes the dash light whenever detonation is detected). A custom assembler and linker are also provided that process the source code into the actual binary for burning into the ECM, and generates a file that ChEM uses to help you make further changes.

As shipped, these baseline calibrations use mostly stock parameters, since the stock calibrations represent a huge investment in development time and testing. Some tweaks and enhancements were made, however, and might be important. For example, the cruise control tables were copied back to the 87 calibration from the 89, since the tables in the 87 T2 cal did not include the ability to handle turbo. Timing was retarded at higher boost levels. Some fueling and timing from the 89 SMEC were also brought back to the 87 LM in order to gain the benefits of two more years of corporate development.

Probably the *most* important modification is the ability to use a 3-bar MAP sensor in place of the factory 2-bar. By expanding the range of boost levels that the ECM can use, the 3-bar MAP allows you to surpass 14.5 psi of boost and go as high as 29. In a stock vehicle, boost begins to stack up in the intake manifold around 20 psi, but if you make (significant) intake manifold, head, turbo and exhaust modifications to allow better flow then you can potentially break the 500 HP barrier.

When you assemble one of the baseline calibrations, you select whether you are using a 2-bar or 3-bar MAP sensor. ChEM then uses this information to scale the appropriate tables while editing.

After you have edited a calibration using ChEM, it is highly recommended that you transfer the new numbers for your tables or constants into a new source file. Then, your calibration will be easier to share with others, and you can establish a new baseline for your own particular setup. To make this as easy as possible, just double-click a table name in the list on the left side to display the Object Dialog. Notice at the bottom right is a Copy button. This will place the numbers for the source code into the copy buffer, all you need to do is Paste this text into your source code at the proper location.

HISTORY

The original version of ChEM was started in 2000. As a first generation editor, it was passable. Unfortunately, other tasks took me away from developing ChEM for quite some time. In order to add more functionality, Derek Beland wrote D-Cal to duplicate the features of ChEM. When I had some time, I added many of D-Cal's features to ChEM so users could share data files.

After more study of the data in the ECMs, it became apparent that the old version was not properly designed to handle the editing features that would make ChEM as useful as possible, so ChEM 2 was developed. Specifically, the original ChEM didn't allow keyboard editing of table points, so adjustments to critical data was hit-and-miss at best. Also, the editing area was extremely small on larger displays, which made it almost impossible to adjust a point precisely.

The design goals for ChEM2 are:

- give the user the largest editing area possible for precision,
- give the user as much explanation of what they are changing as possible,
- give the user a pleasant visual experience, along the lines of Vista and other modern User Interfaces,
- establish three baseline or "starting point" calibrations for users to use as a starting point for consistent custom calibrations.

Hopefully, ChEM2 has achieved most or all of these goals.

ENGINE CONTROL PRIMER

Computerized engine control was begun on passenger cars in the 1970s as microprocessors became more practical for the purpose, and were probably a direct result of the massive government intervention in emissions and economy requirements. By removing mechanically complex components, and parts that were subject to wear resulting in unwanted emissions and poor economy, computerized engine control increased the overall efficiency of the global private vehicle fleet. More important, they gave people better performing cars that cost less to run.

The first attempts, including Chrysler's "Lean Burn" from the late 70s, were primitive at best. However, through the 80s a standard method of engine control was established that is, for the most part, still in use today.

In general, internal combustion engines still work on the same principle they have for over a century. Air mixed with gasoline is ignited in a combustion chamber, which pushes a piston, which turns the crankshaft, which turns the wheels. The challenge to automotive engine designers has always been the same: how much gasoline to mix with the air, and when to ignite the mixture to generate power. Carburetors were becoming increasingly complex through the 70s, distributors used lead weights to adjust advance, there were chokes, choke heaters, fast-idle cams, vacuum feedback, vacuum advance, and more, and the end result was prone to going out of adjustment.

Today, instead of carburetors, vehicles use a throttle body which is essentially a plate connected to the gas pedal that blocks or unblocks air from getting into the engine. Somehow the amount of air that is getting into the engine is measured, and the correct amount of fuel is sprayed in to mix with it. Virtually all engine controllers keep track of the position of the crankshaft so they can calculate the proper time to fire the spark plugs, igniting the mixture. All feedback systems then use an Oxygen sensor in the exhaust to determine if the mixture was too rich or too lean, and adjust the amount of fuel to compensate.

In order to control all of this, almost every car made since the 80s uses a small computer to operate the engine. At their simplest level, computers work by processing input and providing output. The input to an engine controller includes:

- Throttle Position sensor,
- crankshaft position sensor,
- airflow sensor (either a MAP or MAF),
- temperature sensor, in some cases also an air temperature sensor,
- voltage sensor, for charging and knowing how fast the injectors will operate,
- Oxygen sensor, to determine how accurate the fueling was,
- Speed sensor, for speed limiting and cruise control

All of the inputs in the world won't help if there are no outputs, and the computer controls at least the following:

- Ignition (Spark),
- Throttle body or multi-port Fuel Injectors,
- Alternator field (charging),
- Fan (to keep the engine within an operating temperature range),

There are more, but these are the most basic functions.

Essentially, here is how computerized engine control works:

Every time the engine passes Top-Dead-Center of cylinder 1, a signal is sent to the computer that interrupts whatever else it is doing and forces it to start over. *This interrupt is the most important function of the computer*, and cannot be avoided. The time since the previous TDC signal is measured, and from that the computer knows the engine speed. The amount of air flowing is determined, either from the throttle position or direct measurement using a Mass-Air-Flow or Manifold-Absolute-Pressure sensor, and from the known or estimated air the required amount of fuel to match is calculated. The fuel injectors are programmed to open for the amount of time it will take to inject that amount of fuel. The correct time to ignite the mixture is calculated, and a timer is programmed that will fire the spark plugs at that time. The Oxygen sensor is examined, and from its signal of either a too-lean or too-rich condition, slight adjustments are made for the next engine rotation.

The program that is running inside the computer is usually based on books worth of detailed mathematical formulas, built by engineers to be as precise as possible, and adjusted after track and street testing. To simply go in and make changes without understanding how it all works would not be good, you could end up doubling your fuel use or quite literally blowing up your engine if you don't understand what you're doing, so please study as much as you can before attempting any modifications.

CONTROLLER CONCEPTS

Although a detailed description of real-time controller technology is far beyond the scope of this document, a quick overview might be helpful.

In order to make it easier for developers to understand what they are doing, any controller will be broken down into a series of easily understood and achieved tasks.

Generally, one section of code will determine what a value *should* be. This is called a “High Level” function. Another section will perform actions to make it happen, and is called “Low Level”. For example, the Boost Control high level section determines the maximum allowed Boost given a variety of conditions, while the low level section will deal with the actual control of the wastegate to stay within the goal.

In the case of Boost control, the feedback into the ECM is the MAP sensor input. As the ECM sees boost approaching the goal it will apply control to slow the rise. Over time, the ECM builds a record of how the wastegate responds and adapts to any slop in the actuation mechanism, which increases precision of control.

The difference between high level and low level functions is that high level functions determine the *intent* of the controller, and you can generally ignore the low level functions.

For the most part, tuning is about adjusting high level functions, working with an intended boost goal, timing, and Air/Fuel ratios. While there may be times you need to work with low level functions, they will be rare.

Don’t get me wrong, the low level functions are what actually operate the engine. However, the ECM developers spent a significant amount of both time and money developing these, and we rarely need to change them because they are proven technology. Another parallel is any Windows program: the program itself is usually in control of literally billions of dollars worth of development (Windows) to do such things as display something on the screen, save files, or print a document, but the programmer only needs to worry about the actual *result* of his software.

Something else that is critically important to remember: an engine is a dynamic system, not steady state. NO engine controller will be completely accurate at any time. The best we can hope for is to generate results within a certain acceptable margin of error. Factory calibrations must account for clueless users, sloppy maintenance, winter and summer, unreliable grades of gasoline, people who put 84 octane into a tank when the label clearly states “Premium Fuel Only”, etc. Therefore in any case where a choice must be made they always choose the side of caution. Most drivers do not associate the sound of detonation with the serious engine damage it causes, therefore they ignore it. Factory calibrations will always run just slightly rich, and with slightly less advance than possible, for this reason. If you make changes that require a certain grade of fuel, you are committing to always using that fuel.

TERMINOLOGY REFERENCE

Throughout this document you will encounter phrases and abbreviations that may confuse first-time users. This section should be a useful reference for the terminology used both in ChEM and generally all computerized engine control.

ECM – Engine Controller Module (Generic term).

LM – Logic module. The LM was the name for the ECM in 1985 to 1987 Chrysler vehicles. It included a computer inside the car beside the passenger side kick panel, and a Power Module under the hood beside the battery. The power module contains the drivers for the high-current things such as Injectors and alternator field.

SMEC – Single Module Engine Controller. The SMEC was the name for the ECM in 1988 to 1990 Chrysler vehicles, and has also been used to describe other ECMs of other brands. The SMEC combined the Logic Module and Power Module circuit boards into one package, under the hood beside the battery.

SBEC – Single Board Engine Controller. The SBEC was the name for the ECM in post 1990 Chrysler vehicles, although it is important to note that many people still consider this a SMEC, since it is still a single module. The SBEC combined the Logic and Power boards into one, supposedly to increase reliability.

MAP Sensor. The **Manifold Absolute Pressure** sensor is connected to the intake manifold through a standard vacuum hose and measures the actual pressure there. Since airflow rates at a given RPM are constant, using the MAP sensor allows relatively simple calculation of the actual amount of air flowing into the engine. ECMs that use a MAP are called Speed-Density systems.

MAF Sensor. Chrysler vehicles did not use a **Mass Air Flow** sensor, but it is included here to explain the difference. The MAF sensor uses a laser to determine the *actual* amount of air going through it, which can increase accuracy of airflow calculations. One major downside of a MAF system is that your engine will always be limited to the amount of air that can go through the MAF sensor, and higher flowing MAF sensors are expensive. One advantage is that if you make modifications to your intake that increase flow, the MAF system automatically takes that into account.

TPS – Throttle Position Sensor. This is a simple variable resistor that the ECM uses to determine how open or closed the throttle is. Increasing throttle opening on a carbureted vehicle actuates an accelerator pump that literally sprays more fuel into the engine, and an ECM simulates this by tracking the TPS. It is also used to determine if the vehicle is at idle or Wide Open Throttle.

CTS – Coolant Temperature Sensor. This is a variable resistor that the ECM uses to determine the actual operating temperature of the engine.

CTS – Charge Temperature Sensor. Just to add confusion, there is another CTS. Air density is different at different temperatures, and this sensor allows the correct fuel metering to match the more dense cold air or less dense warm air.

BTS – Battery Temperature Sensor. This is a temperature sensor inside whichever module happens to be beside the battery, and is used to determine ambient air temperature. Battery charging can depend on this temperature.

Hall Effect Pickup. This is the sensor inside the distributor, and is used to determine the exact location of the crankshaft. This sensor is responsible for generating the signal that interrupts the ECM and begins a cycle of fuel and timing calculations. The reason it is called a Hall Effect sensor is the actual sensing element is a semiconductor device that measures magnetism. Metal Shutters inside the distributor alternately block or unblock the sensor from a small permanent magnet.

AIS – Automatic Idle Speed. This is a stepper motor that opens and closes a small bypass passage in the throttle body around the throttle plate. The ECM uses this to actually control idle speed, and can rapidly open it when the engine seems about to stall. In addition, AIS opens or closes slightly when the AC or Fan are switched on or off to maintain a constant idle speed even as loads are applied or removed.

Wastegate. The ECM provides a signal to actuate the wastegate solenoid, which allows boost pressure to open a small bypass valve in the turbo, reducing boost. The ECM is able to anticipate when the desired boost goal will be reached and will begin controlling the wastegate prior to this to prevent overshoot, also known as Boost Spike. When properly set up, wastegate control will be as rapid and precise as possible.

EGR / Canister Purge. EGR is a valve that feeds a small amount of exhaust gases into the intake. This is not used on all turbo cars, and was apparently an emissions requirement in some states and countries. The vapor canister holds fuel vapors from the gas tank and allows them to be drawn into the engine through the throttle body to prevent evaporative waste and emissions.

Fuel Injectors. The device that allows fuel to flow into the engine is a Fuel Injector. At a given pressure (55psi on our cars) they will flow a certain amount of fuel per second. The predictability of flow quantity from time is the basis of our fuel calculations. Higher flowing injectors will allow more fuel into the engine when opened for the same amount of time as lower flowing injectors. Our vehicles require Low Impedance injectors, 63.5mm (2.5 inch) with 14mm (0.55 inch) upper and lower O-ring dimensions, which are fairly standard injectors and should be available almost everywhere.

AutoCal. In order to more precisely measure fuel, the ECM keeps track of the O2 sensor feedback at various RPM and MAP ranges called ‘cells’. As engine operation enters these cells, the previous value is loaded and worked with, and any changes are saved in the onboard memory.

Feedback. Any control system usually monitors what it is controlling. If there is a problem with feedback, or no feedback, a system is said to be operating in Open Loop mode. The controller can control something without direct feedback on the effect of this control. A system that is actively adjusting something based on feedback is operating in Closed Loop mode.

Hex. Computers work with binary numbers, which means each bit doubles the value. This is different from our normal base 10 numbering system, which is most likely derived from the number of fingers we have. Binary values go like this: 1, 2, 4, 8, 16, 32, 64, 128, 256, and so on. In order to make it easier to work with raw computer values, we use base 16 numbers, where each 4 bits is a character. This means we run out of digits, so we use some letters: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. In order to let you know when you’re working with Hex numbers instead of decimal, hex values are prefixed with a $. The Windows calculator, in scientific mode, has the ability to convert between Hex and decimal. Since we are dealing with microcontrollers, it is more convenient to work with hex numbers in most cases.

FUEL INJECTORS

Here is a bit more information about fuel injectors. Chrysler used several different types of injectors, and although we say “size”, they are all the same physical size (63.5mm long, or 2.5 inches, with both O-ring ends at 14mm, or 0.55 inches). It is almost impossible to tell what the flow rating is of an injector by looking at it, you would need to examine the part numbers to be sure.

As mentioned above, one of the purposes of ChEM is to recalculate the fueling to handle different flowing injectors. The stock injectors that come with a vehicle typically flow just enough to handle the amount of fuel required at maximum boost, plus a small amount more for a safety margin. If you modify the car to allow more boost, or increase flow, there will be more air entering the engine. Obviously, you need to match increased air with increased fuel to maintain a proper air/fuel ratio. The potential problem is, if you simply put higher flowing injectors in without modifying the fuel tables, you will run too rich at idle and in the lower power ranges.

Appendix A – Fuel Injectors has a list of all stock Chrysler fuel injectors, their flow rates, and the expected horsepower per cylinder that the injector can support given the various BSFCs (efficiency of flow). Use the .52 BSFC table for a reasonable approximation for a stock 8 valve engine. As an example, the 33 lb/hour injectors in the .52 column can support 50.8 HP per cylinder, or just over 200 HP, and Chrysler rates the Turbo 2 engines they come in at 174 HP.

Injectors are available from several sources, and a decent online catalog is at www.injector.com – just remember you need low impedance, 63.5 x 14 x 14.

ALTERNATIVE FUELS

The stoichiometric (chemically correct) air/fuel ratio for gasoline is 14.7 to 1, or 14.7 parts of air for every one part of fuel. The best power for gasoline is achieved at a richer air/fuel ratio, typically between 12-13 to 1. The presence of excess fuel ensures that all available oxygen will be burned, and the extra fuel going out the exhaust carries with it more of the combustion heat. Dipping below 12 to 1 will result in reduced power, but we accept this power loss at high boost to prevent detonation and overheating.

Adding oxygen to fuel is one way to reduce the requirement for air, allowing richer mixtures to generate more power. Oxygenated compounds, including MTBE which is 18.2% oxygen, are sometimes blended into racing gas to allow richer mixtures to generate more power, and also to reduce detonation. Since air contains 23% oxygen, any addition of oxygen to the fuel can help generate significantly more power. This is why people use Nitrous Oxide, its 36% oxygen is easily liberated when combusted with gasoline, and a 5% mix can increase power by 9%.

Let me rephrase that so the advantage is clearer: In a stock engine, part of the limiting factor in generating power is how much Air you can get into the engine. However much that is, we add fuel to match it at the proper A/F ratio. Increasing power, then, requires increasing air flow, which we do with a turbocharger or by porting the head and intake manifold. If you add oxygen to the Fuel, you reduce the need for air, and you can generate more power with less air, and with fewer hardware engine modifications. **It is easier to modify the fueling system and deliver more liquid fuel using larger injectors than to modify and tune the hard air components**. However, as with anything else, there is a trade-off. For vehicles used only for racing, this is great. For street vehicles, you *must* take the availability and cost of fuel into account.

Alcohol is an Oxygenated Compound, and thus increases the available oxygen for combustion. Ethanol is blended with gasoline to make a compound with characteristics as close as possible to gasoline alone, which is good, and some areas have E85 which is 85% ethanol instead of the currently available E10, which can allow you to generate more power by tuning the A/F ratio (Ethanol *WILL* require more liquid fuel than gasoline, be aware of the impact on cost and mileage). If you want *serious* power gains you will go with Methanol, which is 50% oxygen.

The stoichiometric (chemically correct) air/fuel ratio for methanol is 6.45 to 1, or between two and three times as much fuel for the same amount of air. Also, methanol has an octane equivalence of 115, which allows FAR higher compression ratios and higher boost. Maximum power for methanol is obtained at an A/F ratio of 4:1, which is three times more than gasoline. In order to run methanol, then, you would need to use MUCH larger injectors and keep track of the desired A/F ratios while modifying the fuel tables, however with ChEM this is now actually very simple. While stock turbo injectors are usually 33 lb/hour, you can also easily get 72, 83, 96, and even 160 lb/hour injectors that plug directly into our cars.

If you do a conversion to either pure or blended methanol as a fuel, you will need to modify the fuel system to ensure none of the metal or sealing parts will be eaten away by it. This means a new fuel rail, since the current aluminum one will not fare well running pure methanol. There are internet resources to help you calculate the actual A/F ratio required and Specific Gravity of a gasoline/methanol blend.

Notice also, if you are using an alternative fuel that requires significantly more liquid at pressure, you will probably need a fuel pump with more capacity than the stock one.

It is also possible to use any of a number of other alternative fuels, including hydrogen, natural gas, and propane. We won't be going into gaseous fuels, though, since the delivery systems are beyond the scope of our studies here.

It would be interesting to see a Liquid Oxygen system adding oxygen to the intake air at a metered rate, which would change all of the stoich calculations. I bet it would be very possible to create a serious increase in power using it… if you can obtain it and plumb your engine to use it.

Appendix B – Stoichiometric Values for Ethanol Blended Fuel contains tables that will help you determine the appropriate fueling values for Ethanol blended fuels. Note that I am concentrating on Ethanol throughout this document since we are probably ALL going to have to deal with Ethanol blended pump gas, which requires slightly more volume (but *can make more power* due to its oxygen content).

SECTIONS

The ECM divides its controls into various sections, to break down the program to logical groupings. ChEM recognizes these sections and allows you to work with them separately. There are no hard and fast rules, ChEM allows any calibration to have any named sections, however the included calibrations have the following sections:

Baro Read. From time to time the ECM samples the ambient air using the MAP sensor. Air is thinner at higher altitudes and when it is warmer, so the ECM grabs this approximately every 180 seconds to use as a constant in some of the fueling calculations.

Boost Control. This section includes the boost goals which the ECM will attempt to achieve, and some of the mechanical controls used to achieve it. Generally speaking, you only want to modify the Goals, not the other tables, unless you have a good idea what your changes will do.

Cruise Control. Most ECMs operate the cruise control, which is a very useful street accessory.

Deceleration AIS. When decelerating, idle is usually controlled to increase idle speed to provide additional vacuum for the power brake booster, and to prevent stalling during stops.

Fan. Fan switch-on and switch-off temperatures are different when the vehicle is stopped or moving. Balancing the temperature is important to ensure that fueling requirements are constant.

Idle Control. Contains tables for desired idle speed based on temperature (so you get a faster idle on a cold engine, which then decreases to the desired 900 in neutral, or lower in Drive), also contains anticipatory idle changes when AC or the fan is engaged or disengaged.

Knock Retard. Contains tables and constants for retarding timing when detonation is detected. This allows the use of lower octane fuels without damaging the engine. These ECMs are still fairly primitive in their octane adaption, so don't rely too heavily on them for this.

Load Enrichment. Contains tables and constants for handling fuel enrichment under load, especially when cold, and Transient enrichment, as you hit the throttle.

Rev Limits. You can adjust the engine RPMs at which the ECM shuts off the engine for various events, and control my own modification that allows you to sit at the exact desired RPM for launch.

Running Fuel. The main fuel tables for once the engine is running. Also, the volumetric efficiency table for adjusting fuel based on the airflow at various RPMs.

Starting Fuel. Starting fuel is dramatically different from running fuel. Most importantly, at the slower rotational speed there is 100% filling of the cylinder, and usually the engine will be cold, requiring much more fuel than a warm engine. Once the engine is started, the fuel "fades" smoothly from starting to running.

Start Run Transfer Points. This is where you can adjust the engine RPMs where the ECM switches between Starting and Running modes. There are two Start/Run phases, one is for fuel and one is for timing.

Timing. Tables and constants related to timing. This is where you can balance high advance at low boost to accelerate the engine quickly, low advance to spool up the turbo, and decrease the advance as boost increases. There are three main tables: cold, warm part throttle, and warm full throttle.

FUNCTIONAL DETAILS

The two most important functions of the ECM, as mentioned, are fueling and timing. Within the fueling section are also two major sections, AutoCal and O2 Feedback. We'll examine both, since understanding these can greatly improve your understanding of tuning. Also, understanding the O2 controller and AutoCal will be very useful if modifying an ECM to handle a Wideband O2 controller.

AUTOCAL

AutoCal is the way that the ECM handles variations in flow between different injectors, flow rate change caused by wear of injectors, and errors in the original fueling tables. Over time the ECM stores a record of the fueling error in a range of cells. There is a fairly limited range of adjustment, only a few percent, so AutoCal is inappropriate for handling radically different injector sizes.

The AutoCal cells are defined by an RPM value, and five MAP sensor values. Anytime the RPMs are below the R1 value, the bottom row is used, anytime the RPMs are above R1, the top row is used. If the MAP sensor is below MP1, the leftmost column is used, if it's above MP1 but below MP2, the second column is used, and so on. It is important to note that AutoCal is not for full power turbo use, but is intended to get the best efficiency below boost.

Cell 1	Cell 3	Cell 5	Cell 7	Cell 9	Cell 11
Cell 0	Cell 2	Cell 4	Cell 6	Cell 8	Cell 10

In addition, there is an idle cell, number 12, used only when the throttle is closed and the engine speed is below a certain value.

If you have ever watched an Air/Fuel gauge displaying the signal from an O2 sensor, you know that it is constantly bouncing up and down. The goal of the ECM's fueling control is to "toggle" the fueling between slightly lean and slightly rich. One reason for this is that the stock O2 sensor has a very precise range, and even though it is toggling around these slight variations it is actually very close to the ideal fueling. Another reason is that by forcing toggles, the ECM can constantly test the O2 sensor and know that it is functioning properly.

Every time the engine is operating in one of the cells (in other words, not in boost), the actual amount of fuel that needs to be added or removed is stored in a memory variable. The next time the engine operations enter that cell, the ECM can simply use the stored value to know how much fuel to start with to be in the general zone of proper operation.

AutoCal constants include the RPM cell boundary (R1), MAP cell boundaries (MP1 to MP5), some hysteresis values to avoid excessive switching between cells, and the number of bits changed per update within a cell (CELCHG). The number of Engine rotations (EPPs) that must pass between AutoCal memory values are updated (AMUPDT for open throttle, AMUPDI for closed throttle), the absolute highest MAP reading that results in an AutoCal adjustment (MAPLIM), and the highest RPMs to allow an AutoCal adjustment (RPMLIM). Also, the overall range of authority (AMLIMH and AMLIML) is the maximum fuel that can be added or removed based on the cell contents.

One other benefit of understanding the AutoCal cell values: you can examine these cells and see the level of adjustment being applied, and use that to fine tune the base fuel tables. For example, if all of the cells are showing negative numbers, then your base fuel is too rich.

O2 CONTROLLER

AutoCal is a high level monitor for the low level O2 controller function. There are actually 2 completely different O2 controller parameter sets, called the Primary and Secondary Ramps. These are also split into cells, three different RPM ranges and three different MAP ranges, plus an idle cell.

Cell 2	Cell 5	Cell 8
Cell 1	Cell 4	Cell 7
Cell 0	Cell 3	Cell 6

Instead of storage, these cells are used to determine how much fuel to add or remove each time. As the cells from an O2 controller Ramp overflow and can no longer adjust enough, the AutoCal is kicked up or down and the O2 Ramp begins again.

Most sensors operate from 0 to 5 volts, only the O2 sensor operates from zero to one volt. As a result, the numbers are slightly different when dealing with it. With a 5 volt sensor, values are scaled from 0 to 255 (8 bits of data), but with a 1 volt sensor the values will be scaled from 0 to 51, or about $32. In the 1989 SMEC, a reading of $16 or below is considered lean, while $17 or above is considered rich. In the 1987 LM they used $18 and $19. The most likely reason for this difference is that the 89 used a slightly different model of O2 sensor, which had a more efficient heater to get it to return valid information quicker. If you are using an 89 O2 sensor in an 87 vehicle, you *should* modify the toggle numbers to account for the change. Also, it is possible to get the engine to run slightly richer or leaner overall (below boost) just by adjusting these values, but the benefit of this is probably not worth the effort.

TIMING

Timing is possibly the most misunderstood aspect of controlling an engine. The goal of timing is to ignite the mixture before power is needed, since there is a slight delay between ignition and sufficient expansion to make power. If ignition is too soon, the expanding gases will push against the piston while compression is still happening, which can and will damage engine parts. If ignition is too late the expanding gases push against an already receding piston, which does not generate much power. As an added complication, you can spin a turbo more quickly by slightly retarding timing. The energetic exhaust gases that are not pushing against the piston will happily spool up the turbo, at the expense of some mid-range power.

Ignition timing is controlled as degrees of engine rotation, which is actually misleading. If you assume that the time delay between ignition and actual power being produced is constant (it's not, but follow along here), then as engine speed increases the number of degrees of advance must also increase. This is why there is "mechanical advance", which is obtained from a table called "GOVNER" from the RPMs. Higher engine speed returns a higher advance. It is also important to remember that each engine rotation's timing will be based on the previous engine rotation's speed, so virtually *all* timing calculations during acceleration or deceleration will be imperfect. If you are tuning for a strictly race application, you can assume that timing will always involve acceleration, but for most street purposes this can create poor running.

There are three main tables for timing: CLDMAP is used whenever the engine temperature is below TMPSWP. Notice that there is a significant amount of advance into boost using CLDMAP. This is because the Boost Goal tables *should* be limiting the amount of boost allowed on a cold engine. If you increase the amount of boost allowed when cold, therefore, you should reduce the CLDMAP advance into boost. But don't. You should not be pulling large power out of a cold engine. All parts need to expand from heat to reach their design clearances, and it only takes minutes for an engine to warm up.

Next, HOTMAP is used for all idle and part throttle operation when the engine temperature is above TMPSWP, and WOTMAP is used at Wide Open Throttle when engine temperature is above TMPSWP. Both HOTMAP and WOTMAP have significant advance in vacuum and significant retard at higher boost levels. Although you can tweak and adjust these tables, it is highly recommended that you avoid adding large amounts of advance in boost. In fact, some retard is beneficial in the boost building area, since retarded ignition will pass more energetic exhaust through the turbo, spooling it quicker.

The last important table in Timing is SPKLMT, which is the absolute Advance Limit from RPMs. If other calculations exceed the value returned from this table, then the SPKLMT value will be used instead.

The Logic Module uses the Throttle Position Sensor to control retard, but the SMEC does not. Therefore, on a LM ECM you will also see several tables related to TPS Retard that don’t exist on a SMEC.

KNOCK RETARD

If detonation is detected using the Knock Sensor, the ECM will pull back some advance, so technically the Knock Retard section is still a part of Timing. Knock Retard was included to allow the engines to operate on various octane fuels, however you should know that this capability is primitive at best. Knock detection can also cause boost to be reduced.

One important thing to know is that the knock sensor table, DLTKNK, uses a different RPM scale between LM and SMEC ECMs. The SMEC requires a higher signal before it will identify a knock event. If you modify this table, you should only adjust the voltages, not the RPM range. Raise the points to make the sensor less likely to detect a knock event. Also, be aware that other mechanical noise can cause false knock detection, including a loose power steering mounting bracket or fuel rail mount. MOST important, DO NOT OVERTORQUE the knock sensor mounting bolt or it will detect knock constantly.

STARTING FUEL

Starting and Running fuel requirements are significantly different. At the slower speed of cranking, there is no need to consider air flow, since all cylinder-filling will be 100%. What is more important in Starting Fuel is air temperature and barometric pressure to determine air density. A cold motor requires a deliberately rich mixture to fire, since there will likely be poor vaporization of the fuel as it is sprayed from the injector. Within a second of actually attaining a running speed the ECM begins to transition the fuel calculations to Running Fuel, which take flow into account.

Starting Fuel also watches the TPS. If the driver is holding the gas pedal to the floor the injectors will not fire during cranking, which can clear a flooded engine.

The only table used for both Starting and Running fuel is BATOFF, which is the amount of “lag” time between a signal being applied to the injector and it opening to its rated flow. Since lower voltage in the battery will cause the injector to open very slowly, this is an important table during starting, and the injector lag is an important part of fueling. As a general guideline, larger flowing injectors almost always take longer to open, so you will probably be *increasing* the return values from this table when switching to larger flowing injectors.

RUNNING FUEL

Running Fuel uses three main tables, the only three tables that are stored in a different format. Whereas all of the other tables return a value from 0 to 255 (8 bit), the fueling tables return a value from 0 to 65535 (16 bit). In practice, fueling rarely exceeds 30,000 microseconds, but the extra bits are there for extra precision. The LM and SMEC store these values in different formats, which is important. ChEM attempts to determine which is being used and scales the results so they make sense, but you might want to know that the end result from a Logic Module is doubled, where the end result on a SMEC is quadrupled. This makes it difficult to directly compare the table values between the two types of ECM (although ChEM does).

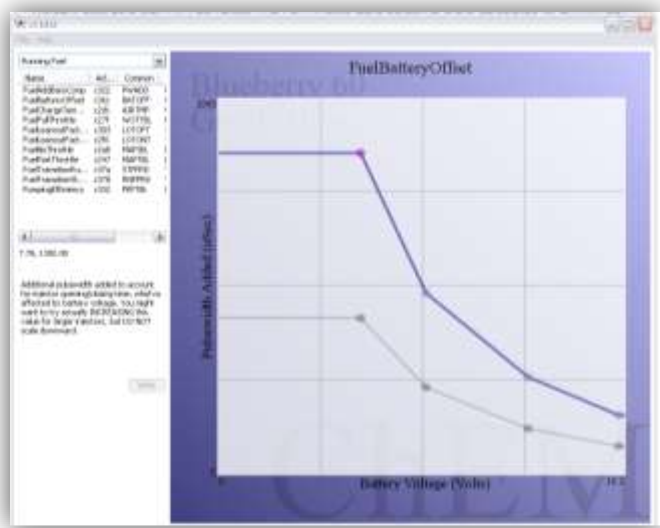
The three fueling tables are MAPIDL for off-throttle (both idle and deceleration), MAPTBL for part throttle operation, and WOTTBL, or Wide Open Throttle Table, which is also used as the maximum fueling for part throttle.

It is important to know that MAPIDL will never be used in boost, so any value above zero boost will effectively be ignored.

Part Throttle and idle fueling will have some fuel added and removed by other sections of the system, so they are to be considered guidelines. This is why ChEM allows you to pre-calculate these tables based on typically desirable lean Air/Fuel ratios. The Full Throttle table guideline is pre-calculated for an Air/Fuel ratio that goes from about 14:1 at 20 inches of vacuum to about 12:1 going into boost, then consistently to about 11:1 at 25 psi. Remember that the Full Throttle table is used without any further processing at full throttle, so getting it right is very important.

On a turbo vehicle, it is important to increase richness at higher boost levels. More fuel cools the charge, resulting in less detonation, but it also reduces the possible power output. The goal of tuning is to find the best compromise between the richness required to prevent engine damage and the leanness required to generate the most power. The intent of the fueling guidelines in ChEM is to make it easier to find this sweet spot, since when you find it you will notice a *dramatic* increase in power.

If you have adjusted the main WOTTBL table to values you know are appropriate but your O2 sensor is reporting excessively rich or lean mixture, the culprit could be the Injector Latency (BATOFF). This is the only way to accurately adjust the BATOFF values other than removing the injectors and having them tested. Having an accurate BATOFF table will make all aspects of fueling more accurate, including cold, warm, idle, part and full throttle. For most running conditions, your voltage will be between 13.2 and 13.8, so that range of the BATOFF table is where you should focus adjustment. Using a voltage meter during tuning might be helpful. Note that the BATOFF table uses a different range between the LM and SMEC.



Another important table in Running Fuel is Pumping Efficiency. This table returns a value from zero to one from engine RPMs, and is the final multiplier for fuel. At different RPMs, the intake manifold, head and valves created differing levels of restriction to airflow. If you have 12 psi of boost, the amount of air flowing will be different between 3500 RPM and 5000 RPM. The PEFTBL table reflects the *actual* amount of air that will be entering each cylinder at a specific RPM relative to 1.0, which is the calculated volume of a cylinder.

Typical pumping efficiencies will range from 0.84 at lower RPMs to a peak of 0.91 at 4000 RPM (maximum efficiency of a stock one-piece intake) to 0.70 at extremely high RPMs.

To make this make sense, consider a 2.2 engine. Each cylinder is 0.55 liters. During starting, with guaranteed 100% filling, you need to provide enough fuel for 0.55 liters of air. While running at 2400 RPM, inefficiency in the intake only allows 0.87 times 0.55, or 0.478 liters of air into the cylinder, which must then be matched with an equivalent reduction in fuel to maintain the desired ratio.

You will need to modify the Pumping Efficiency table to account for head or intake manifold changes, such as porting, or camshaft changes. There are two ways to get this completely accurate: flow testing at a shop, and watching the Air/Fuel ratio during a full throttle acceleration run when you know the WOTTBL and BATOFF tables are close to accurate. During the run you will see the Air/Fuel ratio increase and decrease through the RPM range, and can smooth out these changes by modifying PEFTBL.

LOAD ENRICHMENT

This encompasses both Cold Load Enrichment during warm-up, and Transient Enrichment, the equivalent of the old carburetor accelerator pump. During constant running the air and fueling requirements are straightforward, but during an increasing throttle or MAP event the ECM adds more fuel to handle the extra air you are giving the engine.

Cold Enrichment is accomplished using three curves, A, B and C. A and C are phased out after warm-up, but B remains in operation.

Transient Enrichment has two sections: TPS and MAP. Both TPS and MAP, in addition to having their immediate value, also track the average value over the last second or so. If the current value is above the average then a transient event is triggered and fuel is added to handle that.

Logic Modules use a relatively simple model to reduce fueling during deceleration, but the SMEC introduced a much more accurate set of tables. Logic Modules never achieve zero fuel delivery even when coasting down a hill with zero throttle, but SMECs are capable of completely turning off fuel after a certain time of no throttle. Note that Blueberry60 does, in fact, achieve zero fuel during deceleration.

During a Part Throttle Enrichment event, no matter how it was triggered, AutoCal and O2 controller updates are inhibited, and O2 controller control is limited to rich values only. When Part Throttle Enrichment is maxed out, EGR and Purge are disabled, Curve A and Curve C are not used, Fuel enrichment resulting from AutoCal and PTE are discarded, and the Full Throttle timing and fuel tables are used.

Load Enrichment is one of the ECM functions optimized over time by the factory. There is probably very little that we as tuners can gain by modifying it.

MAP SENSOR

Manifold Absolute Pressure is an important value for ChEM, since the entire engine control system uses it to estimate flow.

OPERATION

Load a calibration file (CALX files are used, which are XML representations of the data inside of a calibration, and a link to the calibration ROM image file).

You will see a list of items in the calibration on the left side, along with a dropdown box to select only the items in a particular section. As you click on items or scroll through the list, a description will be displayed at the left, and the actual data will appear in the section to the right.

Double clicking an item in the list to edit the information related to that item, but not the data itself.

You can also load a Comparison calibration, which will show its data behind the main one you are editing. This is extremely useful for seeing what changes were made between years. Items are linked together using their "Common" Name, so no matter what the descriptive name is you can properly compare the actual items. You can even compare data between LM and SMEC calibrations, very handy for seeing the running changes made by Chrysler as their development program proceeded.

In the case of constant values, such as temperatures, there is a slider that allows you to choose the exact value required, scaled to the proper range. For Word values, you can type values directly in hex. Make sure you read the description on the left side to help you understand what each value is for, and how to calculate the required values in some cases.

Tables are the real goal of ChEM, since most useful alterations to a calibration will be in the tables. These use an interpolation method unique to Chrysler in the 80s, and pack an amazing amount of data into a surprisingly small space.

All tables accept an input value, and provide an output. Obviously, these would be meaningless without knowing the scale and purpose of these values, and ChEM was designed to give you as much information as possible.

You can either do the most intuitive thing and click and drag points around using the mouse, or use the keyboard arrow keys. For precision, it is *highly* recommended that you use the keyboard.

While using the keyboard to edit points, remember these tips: Use the mouse to click on a point to select it. Use Tab to select the next point, Shift-Tab to select the previous point. Use Shift-Arrow to move a point farther. For fueling tables, use Ctrl-Arrow for fine movement. Points should never "overlap", if they do the calibration will not work properly. I decided to not constrain points for you since it is a lot easier to drag them around in whatever order you are most comfortable with, and as long as you understand that they must all be in sequence it was inconvenient having the software prevent you from editing the way you want to.

To add a point between points, right-click on the line between the points. This MAY OR MAY NOT WORK, depending on the availability of empty space after the table in the calibration. The calibrations included with ChEM contain extra blank space behind all tables that might need more points, but you should avoid doing this. Each point in a table requires a small amount of processing time, and it is possible that if you load up all tables with extra points the ECM will be unable to keep up at higher RPMs.

Notice that as you move the mouse around a table, the coordinate display shows the current position on the table, in the proper units. If you move near a point, the exact value of that point is captured momentarily to help you see the actual value. As you move a point using the keyboard arrow keys, the coordinate display shows the exact value, which is extremely useful for precision, especially needed for tables controlling boost, timing, and fuel.

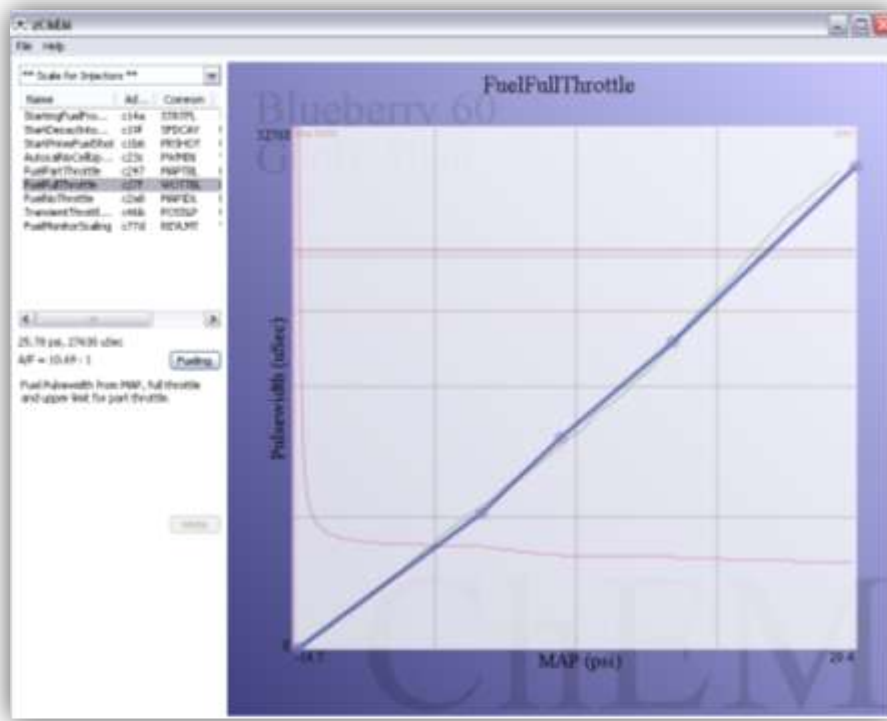
Notice also that if you have a comparison calibration loaded, your bold editing line is partly transparent so you can see the line behind.

FUELING ASSISTANCE

While working with one of the three main fuel tables, you will see a few extra lines in the background. These are guidelines, designed to help you get the most accurate fueling possible.

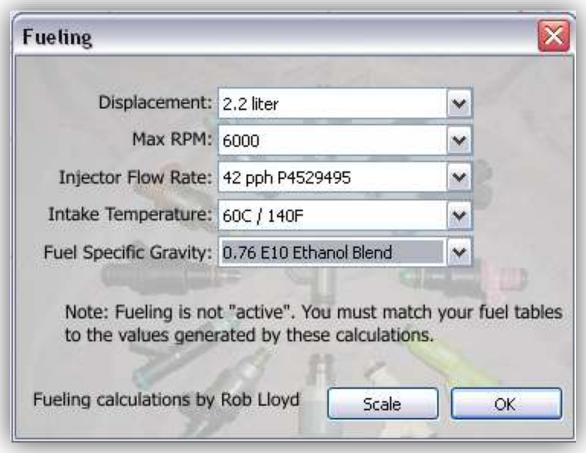
First, there should be a squiggly green line moving generally from the bottom left corner to the top right. This is a precisely calibrated "ideal" fuel curve, calculated on the fly from input you provide using the Fueling dialog. Pop up the fueling dialog using the "Fueling" button under the item list.

This green line comes from a range of "ideal" Air/Fuel ratios based on the MAP pressure, calculates the amount of air that would be present in a cylinder at that MAP value (NOT taking into account the volumetric efficiency) and determines the amount of fuel required to match that calculated air at the desired Air/Fuel ratio. Generally, you should match your calibration data to that calculated curve, since that will provide a reasonable starting point for AF Ratio.



Using the Fueling dialog, you can adjust the parameters that create this ideal curve. You can select a 2.2 or 2.5 liter engine, which model of fuel injectors are installed in the vehicle (flow rate), the intake temperature (you should leave this at 60C / 140F unless you know what you're doing), and the specific gravity of the fuel you are using. Included are some reasonable defaults that probably apply to the vast majority of calibrations.

On the main fueling table is also a pair of Max RPM lines. These DO take volumetric efficiency into account at the selected maximum RPM to determine the absolute maximum amount of time that is available for an injector opening at that engine speed. The pale red horizontal line represents the



absolute maximum time available at 100% injector duty cycle, and the pale yellow line represents the absolute maximum time available at the recommended 85% duty cycle.

Generally, **the point at which the calculated green line intersects the pale yellow line is the Absolute Maximum Safe Boost level**, at which there is enough fuel to support that level of boost at your selected Maximum RPM. In order to maintain a safety factor, you should set your overboost shutoff to a boost level just below the red line intersection, and your maximum boost level to the yellow line intersection. You should also adjust your Boost Goal to decrease after about 5500 RPM, since that is when a stock engine will start running out of time to deliver fuel.

Remember also, below 5000 RPM you should have enough fuel to go significantly higher than these guidelines. A set of +20 injectors on a 2.2 will easily support 24psi of boost below 5000 RPM, falling to about 21psi at 5200. As long as you modify the Boost Goal from RPMs to lower boost above 5000, you should easily have enough fuel to handle significant boost through the actual power band.

Notice the generous use of the word “should” in the preceding paragraphs. If you have improved flow by manifold, head or cam modifications, you will probably have higher volumetric efficiency and could run out of fuel much sooner. This is not a bad thing, it means you will be making a lot more power with lower boost. However, it also means you will be limiting your fueling ability at higher boost levels. Just remember that you have more time to inject fuel at lower RPMs, therefore if you can improve flow between 3500 and 5000 RPM you will get the best gains since you can provide more fuel at lower speeds. If you are only increasing flow at high RPMs, you will run out of injection time there and will probably have to drop your boost to match.

GUIDES

In addition to fueling guides, ChEM2 has a library of timing and pumping efficiency tables from various calibrations. These can be selected from the Guides menu. Further information forthcoming.

The Guides menu also has three option settings:

- Show Guides is the overall guide display setting.
- **Show Interpolation** is used to confirm that the slope lines on all tables are set properly. Earlier versions of ChEM had a bug in the slope calculation that could result in unintended table output. If the grey line behind your blue line doesn’t follow along properly, move any point to recalculate the slopes for the entire table.
- **Show ComparePoints** determines whether or not the actual points are displayed from the comparison calibration, if one is loaded.

3 MINUTE QUICK-START

Let's say you're going to create an 87 Logic Module calibration for 3-bar MAP sensor and +20% injectors. These are the steps you will take:

1) Load Blueberry.asm in a text editor, double check that "Map3Bar" is 1 and "Map2Bar" is 0. Make any other source changes at this time, including author and description if you want.
2) Save your asm file and double click "BB60.bat" to assemble the source into your bin and calx files.
3) Run ChEM2, and load Blueberry.calx
4) Optionally, you can load another .calx file as a comparison. As an example, you could load Ladybug and change some of the 87 values to match the 89 values (this has already been done, by the way).
5) Don't change any fueling numbers until you have made your other changes.
6) Pull down the File menu, select "Scale Injectors…"
7) Select the injectors you are going to be using, in this case the +20% injectors are 42 pph. Click the Ok button. Things should flicker around for a moment as your changes are made, the files saved, and reloaded.
8) If you want to make fine fueling adjustments, you can do so now
9) Pay extra attention to the AF ratio. On fuel tables you can fine tune the up/down location of the points using Ctrl-Up and Ctrl-Down for more precision. The goal here is to get a smooth curve for A/F, not to follow the green guideline exactly. For Ethanol blends, go slightly richer.
10) When you are finished, click the Write button.

Now, the .bin file contains a calibration that you can burn onto a chip, flash into the LM, or Romulate into the LM, and you are done. If you are using a 32K chip in the LM (27C256) you might find it useful to double up the chip. The provided double60.bat file will do that for you.

More on the fueling guidelines: Full throttle is also the limit for Part throttle + modifiers, such as Load Enrichment and O2 feedback, so Full throttle fueling should always be richer than Part throttle. Gasoline makes the most power between 12 and 13 to one, so get the curve to 13:1 close to the left side, and around 12:1 at 0 psi. As you move into boost, you will need to go richer, and if you can make the AF curve smooth that is best. By the time you get to 20 psi boost you could even be richer than 11:1. When using Ethanol blend, it is fine to go to 10.5:1 at 20 psi, since the extra oxygen in Ethanol blended fuels will help to make more power. Pure gasoline should probably not need to be below 11:1.

APPENDIX A – FUEL INJECTORS

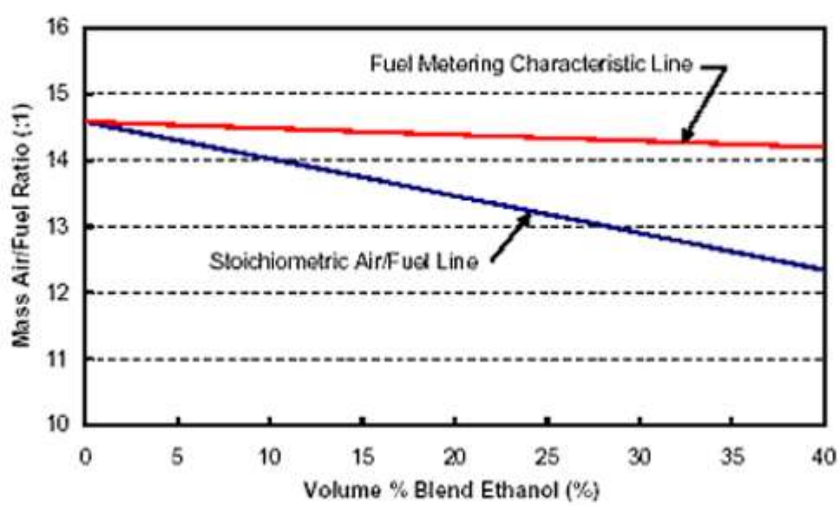
Part Number	Flow lbs/hr	Flow cc/min	.42 BSFC - Est. HP Duty Cycle 80%	.42 BSFC - Est. HP Duty Cycle 95%	.47 BSFC - Est. HP Duty Cycle 80%	.47 BSFC - Est. HP Duty Cycle 95%	.52 BSFC - Est. HP Duty Cycle 80%	.52 BSFC - Est. HP Duty Cycle 95%	.57 BSFC - Est. HP Duty Cycle 80%	.57 BSFC - Est. HP Duty Cycle 95%	Impedance	Application
4275312	27.0	283.8	51.4	61.1	46.0	54.6	41.5	49.3	37.9	45.0	Low	2.2 Turbo
4306018	32.0	336.3	61.0	72.4	54.5	64.7	49.2	58.5	44.9	53.3	Low	2.2 Turbo
4306024	27.0	283.8	51.4	61.1	46.0	54.6	41.5	49.3	37.9	45.0	Low	2.2 Turbo
4418213	33.0	346.8	62.9	74.6	56.2	66.7	50.8	60.3	46.3	55.0	Low	2.5 l
4418258	33.0	346.8	62.9	74.6	56.2	66.7	50.8	60.3	46.3	55.0	Low	2.5 Turbo
4418474	27.0	283.8	51.4	61.1	46.0	54.6	41.5	49.3	37.9	45.0	Low	2.2 Turbo
4418475	27.0	283.8	51.4	61.1	46.0	54.6	41.5	49.3	37.9	45.0	Low	2.2 l
4504322	33.0	346.8	62.9	74.6	56.2	66.7	50.8	60.3	46.3	55.0	Low	2.2 l, 2.5 Turbo
4532586	52.0	546.5	99.0	117	88.5	105	80.0	95.0	73.0	86.7	Low	2.5 l
5277895	34.0	357.3	64.8	76.9	57.9	68.7	52.3	62.1	47.7	56.7	Low	2.2 l
P4452204	35.0	367.9	66.7	79.2	59.6	70.7	53.8	63.9	49.1	58.3	Low	Mopar Performance
P4452803	29.0	304.8	55.2	65.6	49.4	58.6	44.6	53.0	40.7	48.3	Low	Mopar Performance
P4452804	34.0	357.3	64.8	76.9	57.9	68.7	52.3	62.1	47.7	56.7	Low	Mopar Performance
P4529495	42.0	441.4	80.0	95.0	71.5	84.9	64.6	76.7	58.9	70.0	Low	Mopar Performance
P5249452	52.0	546.5	99.0	117	88.5	105	80.0	95.0	73.0	86.7	Low	Mopar Performance

APPENDIX B – STOICHIOMETRIC VALUES FOR ETHANOL BLENDED FUEL

Property	Gasoline	E10 - 10% Ethanol/Gasoline Blend	E85 - 85% Ethanol/Gasoline Blend	Ethanol
Specific Gravity @ 15.5 °C	0.72 - 0.75	0.73 - 0.76	0.775 - 0.785	0.79
Heating Value (MJ/kg) (BTU/lb)	43.5 18,700	41.9 18,000	29.5 12,665	27.0 11,600
Heating Value (MJ/litre) (BTU/gal)	32.0 117,000	30.9 112,900	24.1 84,000	21.3 76,000
Approx Reid Vapor Pressure @ 37.8°C (kPa)	59.5	64.0	< 30	17
Stoichiometric Air/Fuel Ratio	**14.7**	**14**	**9.9**	**9**
Oxygen Content (% by weight)	0.00	3.5%	29.75%	35%

http://www.environment.gov.au/atmosphere/fuelquality/publications/review-non-automotive/changes.html

1) Reid Vapor Pressure refers to how easily the liquid fuel evaporates.
2) Stoichiometric is ideal combustion, maximum power will be achieved at richer ratios.



APPENDIX C – DISCLAIMERS

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It is the intent of the author that this software be used to calibrate vehicles in a lawful and safe manner, to NOT increase emissions, to NOT make excessively loud vehicles, to NOT create a dangerous situation of any sort, BUT IT IS SOLELY THE RESPONSIBILITY OF THE USER TO ENSURE THAT THESE INTENTIONS ARE MET.

IT IS POSSIBLE TO DESTROY AN ENGINE USING THIS SOFTWARE. IT IS POSSIBLE TO CREATE A CALIBRATION THAT GROSSLY VIOLATES EMISSIONS LAWS. IT IS POSSIBLE TO CREATE AN ENGINE THAT EXPLODES OR SMOKES OR IS EXCESSIVELY LOUD. IT IS POSSIBLE TO CREATE A CALIBRATION THAT MAKES TOO MUCH POWER FOR THE VEHICLE TO BE SAFELY OPERATED.

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