MegaManual 3.30

for

MegaSquirt

(2.2 Hardware / 3.0 Code)

www.bgsoflex.com/megasquirt.html

www.megasquirt.info

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Credits

This manual has been assembled from the documents of many people. Most important of these is the website of **Al Grippo** and **Bruce Bowling** who are the inventors, developers, group buy hosts, and general gurus of *MegaSquirt*, *MegaRelay*, *MegaJolt*, *MegaView*, and all things Mega!

Eric Fahlgren has not only written the *MegaTune* software, but also the *MegaTune* help file, which is the basis for many sections of this manual. **Darren Clark** has supplied the information for *MegaTweak3000*, as have **Roger Enns** (for the *EasyTherm* and *MS Palm)* and Mike Robert (for the *MegaSquirt Logfile Visual Viewer).* By providing support for the hardware they have developed, **Jeff Clarke** (*MegaStimulator*), **Jim Willette** (*Willette programmer*) have contributed much material to this manual.

Many knowledgeable replies on the MegaSquirt Yahoo! list have been incorporated into this manual. These replies came from the people above, as well as **Perry Harrington, Bill Shurvinton, Colin Gebhart, Camden Lindsay, Mike Robert, Dave Andruczyk, Brad J., Ira Emus, Clare Snyder, Patrick Carlier, Mike Lough, Guy Hill**, and many, many others. Earlier versions of this manual have been edited by **Lance Gardiner, Patrick Carlier, Richard Lockhurst, and Dan Barnes**, with comments from Al, Bruce, and Eric.

This manual is provided as a convenience for those who wish to read about MegaSquirt while away from their computer. Please not that the most up-to date information is on the websites at:

www.bgsoflex.com/megasquirt.html

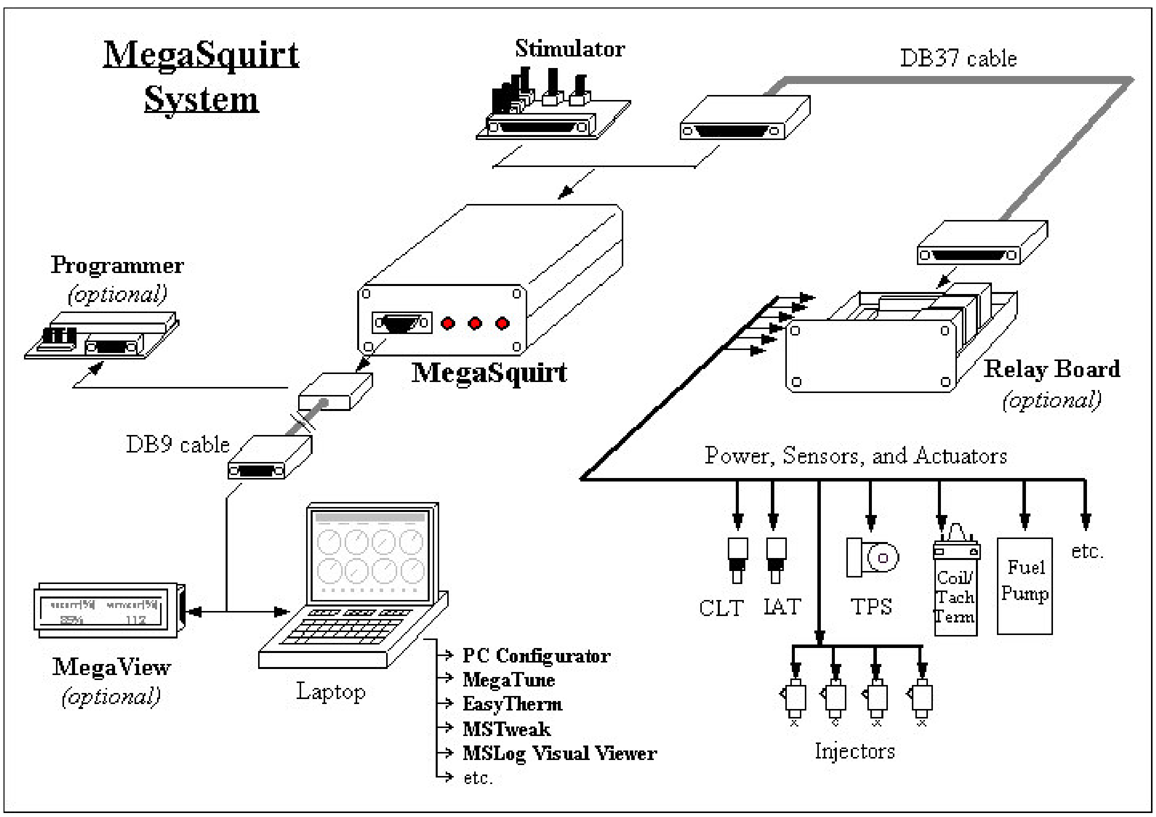
and

www.megasquirt.info

Introduction to MegaSquirt

MegaSquirt is an experimental Do-It-Yourself universal programmable electronic fuel injection controller for spark ignition internal combustion engines. *Experimental* means that YOU will be responsible for sorting out some details of your fuel injection that are specific to your application and equipment. In order to assemble, test, and install and safely use MegaSquirt, you must read, understand and follow this manual.

In general, there is a lot of assistance available on the MegaSquirt Yahoo! Web site, in the manual, and on the MegaSquirt FAQ, but ultimately YOU are responsible for the safe and reliable construction and operation of your electronic fuel injection system and its components, including the MegaSquirt controller. Before doing anything else, be sure to read and understand all applicable safety precautions for your vehicle, tools, and equipment.



MegaSquirt was designed by Bruce Bowling and Al Grippo.

MegaSquirt Features

MegaSquirt uses an 8 MHz Motorola 68HC908 processor and a Motorola MPX4250AP MAP sensor to provide electronic fuel control. MegaSquirt is based on the Motorola MC68HC908GP32 Flash-based microcontroller operating at an internal bus speed of 8 megahertz (this is bus speed - remember that most microprocessors specify their parts at external crystal speed, which is then divided down by four to yield internal bus speed). Many OEM and popular aftermarket EFI systems use older processor technology (like the MC68HC11 or Z80) that operates at 1 or 2 MHz internal bus speed. MegaSquirt has a faster clock speed, coupled with direct assembly language programming, which give MegaSquirt its power.

All of the embedded microprocessor code executed by MegaSquirt has been hand-written directly in assembler, not compiled from a high-level language, such as C. Working directly in assembler produces the most efficient and fastest-executing code possible. The result is that MegaSquirt can provide real-time fuel calculations up to 16,000 RPM! As well, the assembly code for MegaSquirt is available on the MegaSquirt web site, for anyone who wishes to view or customize it. A freeware compiler is available at that site too, so there are no extras to buy.

Additionally, the on-chip Flash memory makes this a true single-chip set-up, reducing cost and extending reliability. Using Flash technology allows the instant re-programming of constants, enrichments, etc. while the vehicle is running. The processor can even be re-loaded with other control code using a simple programming interface and no additional hardware. The flash can be re-written at least 10,000 times, and it will retain the data for at least 20 years.

Commonly available (from General Motors) coolant and air temperature sensors are used as default sensors, though you can substitute others. MegaSquirt provides either speed-density or alpha-N fuel control. MegaSquirt uses Windows9x/ME/XP-based PC Configurator (or MegaTune) software for firmware reprogramming, engine monitoring, and tuning. The tuning software is freely available at no cost. Even without a computer connected, the three LEDs on the MegaSquirt enclosure allow you to monitor injection pulse [commanded], warm-up enrichment, and acceleration enrichment at any time.

MegaSquirt is an open project. All software and hardware design is available at the MegaSquirt site for all to see. The MegaSquirt assembly code is available, and you are free to make modifications to suit your installation. Several modified versions have been developed for particular applications/features already. Other people have developed and shared helpful freeware for MegaSquirt, including:

- MegaTune - for tuning and datalogging MegaSquirt with a laptop computer running Windows 9x/ME/XP, (Eric Fahlgren)
- MegaTweak3000 - for refining your volumetric efficiency table from datalogged data, (Darren Clark) and
- EasyTherm - to simplify the substitution of non-standard temperature sensors and to upload software revisions. (Roger Enns)
- MegaSquirt Logfile Visual Viewer – for a graphical representation of datalog files (Mike Robert)
- MS Palm - to tune and datalog with a Palm (Roger Enns)

In addition, ancillary hardware has been developed, or is being developed, for your MegaSquirt. These include:

- MegaStimulator - to test your completed MegaSquirt unit before installing it. (Jeff Clarke)
- Relay board - to simplify wiring of the MegaSquirt. (Bowling and Grippo)
- MegaView - to provide a dedicated display for the MegaSquirt (Bowling and Grippo)
- As well, Jim Willette has developed the Willette programmer - for programming blank or corrupted processors, and the MegaProgrammer (.ZIP file) is also available for the same purpose.
- There are also ignition variants of MegaSquirt that can control various ignition modules. In general, if you have a working distributor, MegaSquirt*n*Spark is your best bet. For wasted-spark systems, MegaSquirt*n*EDIS is available.
  MS*n*EDIS - http://www.jsm-net.demon.co.uk/megasquirtnedis/
  MS*n*S - http://autos.groups.yahoo.com/group/megasquirtnspark/

The best feature of MegaSquirt is that you build it yourself! Since you assemble the controller, and all information about the design is available to you, you are able to troubleshoot the board if a problem arises, and, in almost all cases, repair the unit yourself. The system as it exists today is a complete “turn-key” solution. You solder it together, install in the vehicle or boat, tune, and use it. The complete source code is available for those who want to understand or even modify the control algorithms.

The Development of MegaSquirt

MegaSquirt came about because of the apparent need for an inexpensive, “turn-key” fuel injection controller by many individuals. Bruce and Al had design and offered the EFI332 system for Do-It-Yourself EFI enthusiasts. The hope was that the EFI332 project would result in a system that could ultimately be used for all applications, and this was one of the main reasons for offering their 4-layer MC86332 board as the EFI332 platform in 2000.

However, relatively few EFI332 systems had been built and installed on vehicles at first. Bruce and Al feel that one of the main reasons for the small number of operational systems was due to the complexity of the current EFI332 system. One has to be both a hardware and software expert, install and learn a bunch of software development tools, write embedded code, and become an expert in engine control algorithms. The EFI332 system is very powerful and flexible, but requires a tremendous learning curve, a wide range of skills, and many hours to install successfully. EFI332 is a powerful and complete unit. Bruce and Al thought that there is another group of people out there who want an EFI system in a more complete and turnkey state, and somewhat simpler. This was the idea behind the MegaSquirt EFI controller.

The philosophy for the MegaSquirt system is simple: provide a controller for fuel injectors which can be adapted to any application, without having to write embedded code or understand the details of engine controls. In addition, the plan has been to provide all the schematics, software, algorithms, etc. to everyone - keep nothing hidden. Provide enough information for anyone to duplicate the system with ease. This is not a commercial unit, but an experimental unit directed to Do-It-Yourself applications.

In short, MegaSquirt is a fuel injector controller. It controls fuel only, no spark control is provided (though some ignitions options have been developed by other people). MegaSquirt uses standard sensors (coolant temp, manifold air temp, throttle position, oxygen, and trigger from existing ignition system) to perform batch fuel injector (two banks) pulsewidth control. Not having ignition control makes this an ideal unit for replacing a carburetor - you can keep your existing ignition.

An early version of MegaSquirt was described in Circuit Cellar magazine in an article titled "*Building a Fuel-Injection ECU*" by Bruce and Al in January 2002.

MegaSquirt uses a flash-based Motorola microprocessor (MC68HC908GP32) for the calculation of fuel pulsewidth and injector control. Additionally, host software (Windows-based) was developed which allows the run-time adjustment of control parameters. All information for the system is available on the MegaSquirt web site at:

http://www.bgsoflex.com/megasquirt.

What you NEED to Install MegaSquirt

MegaSquirt is a universal electronic fuel injection controller that can be made to work on any spark ignition internal combustion engine, with the right external parts. However, the success of your installation depends on YOU. In order to make the MegaSquirt controller work on YOUR car, boat, chainsaw, or whatever, you will need:

- Tools and ability to assemble and test an electronic printed circuit board,
- Additional parts to suit your installation, including:
    - Coolant and air temperature sensors,
    - Oxygen sensor and bung is highly recommended (either narrow-band or wide-band),
    - Wiring and various connectors for the sensors, injectors, etc.,
    - Injectors and bungs/manifold,
    - Throttle body,
    - High pressure fuel pump and supply/return lines, and a
    - Fuel pressure regulator,
- Tools and ability to cut the aluminum case end-plates for connectors and LEDs,
- Knowledge and skills to install all of the necessary sensors and wiring,
- Knowledge and experience to be able install or adapt a complete high-pressure fuel system in your vehicle for MegaSquirt,

- Windows 95 (or better) laptop computer with a **serial port** to configure and tune your MegaSquirt, and
- Enough mechanical aptitude to know what to do to make the engine run right.

Installing the MegaSquirt controller in a vehicle that already has EFI means you will need to consider how you will run the ignition and any other devices the OEM ECU controls [such as the transmission, speedometer and other gauges, and emissions devices]. You will also need to figure out how you will interface the MegaSquirt to your existing wiring harness, and whether you can reuse your existing sensors.

Do YOU have enough knowledge, skills, money, and energy to complete your installation? The MegaSquirt is the fuel injection controller only, and YOU will have to figure out everything else you need for your vehicle. This manual covers much of the specific information you need for the MegaSquirt controller, and general guidelines for things like fuel systems, etc.

Generic information about electronic fuel injection can be found on the web in many forms, including SDS and the DIY_EFI message list. A good book on OEM and aftermarket electronic fuel injection systems is *Fuel Injection: Installation, Performance Tuning, Modifications* by *Jeff Hartman* (1993), published by Motorbooks International [ISBN 0-87938-743-2].

You will not be dealing with your MegaSquirt alone, however. Nearly a thousand MegaSquirt kits have shipped. There is a huge amount of collective experience and knowledge related to the assembly and installation of MegaSquirt in various vehicles available on the MegaSquirtYahoo! website.

<u>What You Do NOT Need</u>

- **Programming skills**. The assembly language software is already written and loaded, and the tuning interface is through a straightforward Windows application. You can, of course, conceive, write and load you own code if you wish.
- **PROM burner** to make tuning changes. A serial port connection allows adjustment of all the tuning parameters. Software updates can be uploaded through the serial connection as well.
- **Advanced electronic skills**. If you can solder and follow directions, or are willing to learn, you should be able to successfully assemble MegaSquirt. You do not need to know what every component does, as there is a comprehensive assembly guide to walk you through the entire assembly and testing process.
- **Latest laptop computer**. In fact, newer computer often do not have the serial port that is needed to communicate with MegaSquirt (instead they have USB ports). USB/Serial adapters can be used, but an older laptop is very cheap, and often a better solution. You may want a faster computer for processing datalogs with MSTweak3000, but these can be done separately on a faster desktop machine.

Purchasing a MegaSquirt

As of early 2003, MegaSquirts are available for order continuously. Your order will be shipped within a week or two of your payment being received (which can take up to a week for Al Grippo to receive).

The MegaSquirt ordering page can be found at:

http://www.bgsoflex.com/mspo1.html

The printed circuit board (PCB), programmed processor, MAP sensor (good for both naturally aspirated and turbo engines up to ~20 lbs/in of boost) and FET driver are sold in the **partial kits** from Bruce and Al. You order the remaining parts (called a component kit) from Digi-Key. An automated web-site order form has been set up for this purpose to reduce confusion and typing frustrations/errors. It is at:

http://www.megasquirt.info/bom.htm

It is strongly suggested that you purchase ALL of the following:

1) A partial MegaSquirt kit (described later) from the B&G site;
2) A MegaStim PCB from the B&G site;
3) A MegaSquirt component kit from Digi-Key;
4) A MegaStim component kit from Digi-Key; plus additional parts noted on the MegaStim order page
5) An LMB Heeger case or equivalent from any number of sources.

Full instructions are at the MegaSquirt Parts Order Page.

An optional unit that eases installation (especially on previously carburetted engines) is the relay board from B&G (and its component kit from Digi-Key, instructions are on the BOM web page). The Digi-Key parts ordering form does not include the enclosures and a few other components, which must be ordered separately. See the noted at the bottom of each order form for more details.

This means that you have to place 3 orders to get a complete MegaSquirt kit (PCB and some critical parts, Digi-Key parts, and the enclosure). Additional parts will be required from other sources for the MegaStim.

An on-going inventory of partial kits will be maintained and more will be ordered when stock goes below a certain point. This makes MegaSquirt kits available at all times, shortens delivery time, and frees up time for developing other useful ‘Mega” devices.

When you purchase a kit, it is your property. You can resell it on eBay, etc., for whatever amount you want. However, the seller assumes the responsibility of supporting the installation of the unit.

Bruce and Al do not support individuals who sell their own version of the PCB. A person may make a board for their own use, but producing them for sale is outside the spirit of the MegaSquirt project. Bruce and Al cannot assure the quality control for any such boards, and every issue become prefaced with "what PCB are you using..." Having a sole source for the PCB is important because it is very time consuming to troubleshoot problems arising from other PCB designs or production methods. With the current system, the quality of the boards is assured and the people on the MegaSquirt Yahoo! list can answer questions relating to them.

About this Manual

This manual has been produced for people new to MegaSquirt to assist them to assemble, install and tune the MegaSquirt EFI controller from the B&G partial kit and the specified Digi-Key parts. Unless noted otherwise, it is always assumed that:

- The reader is assembling and installing MegaSquirt hardware version 2.2, "standard" version 3.00 embedded software, and tuning software MegaTune 2.15 or higher,
- The reader has purchased a B&G partial kit and Digi-Key parts,
- The installation is intended to be the primary fuel controller,
- MegaSquirt will be installed on a gasoline-fuelled piston-engine vehicle,
- The engine, if supercharged, will see less than ~20 psi of boost (the limit of the MAP sensor),
- Prices are in U.S. dollars, and
- Part numbers are applicable to North American automobiles and parts suppliers.

However, many MegaSquirts have been installed on vehicles that do not conform to the above criteria. Many MegaSquirts have been built in countries other than the U.S., some have been built with "home-made" PCBs and other parts, and they have been installed on rotary engines as well. If your engine does not conform to the above list, read this manual first, and then check the Yahoo MegaSquirt message list for information specific to other configurations and locations.

This manual follows a sequence of tasks you need to follow to get MegaSquirt working for you. However, it will not tell you absolutely everything you must do. This is not a step-by-step guide to everything you need to accomplish to install your MegaSquirt (apart from the assembly guide for the unit itself). You will have to think some things through for yourself. This manual assumes you have some basic automotive, computer, and electronics background, or are willing to find, understand, and apply this information yourself. If you do not have such knowledge, you MUST consult a qualified mechanic.

Otherwise you might be unlikely to successfully assemble, test, install, and tune MegaSquirt. It is an experimental fuel injection unit, after all.

One of the reasons MegaSquirt came about was because Bruce and Al wanted to increase understanding of fuel control requirements for as many people as possible. In order to help the process of gathering knowledge, you need to understand your system thoroughly; something a step-by-step guide for everything is not conducive to. If you require a ‘turn key” EFI solution, one of the commercial controllers might suit your needs better.

To keep downloads to a reasonable size, a great many advanced topics have been left out of this manual, including: assembly language programming, the dual table code, the hi-resolution code, the many useful variations of the standard code and hardware, tuning rotary engines, running propane injection, etc. For information on these and other topics, see the FAQ and the Yahoo! message list.

Please report any errors, omissions, or clarifications to the MegaSquirt Yahoo List, so everyone will be notified.

Some Conversion Factors				
Inches	x 25.4	= millimeters	x 0.0394	= inches
Feet	x 0.306	= meters	x 3.281	= feet
Miles	x 1.609	= kilometers	x 0.621	= miles
cubic inches	x 16.378	= cubic centimeters	x 0.061	= cubic inches
US gallons	x 3.785	= litres	x 0.264	= US gallons
Pounds	x 0.454	= kilograms	x 2.205	= pounds
pounds per square inch (psi)	x 6.895	= kilopascals	x 0.145	= psi
pounds per square inch (psi)	x 0.068	= atmospheres	x 14.696	= psi
Horsepower	x 745.7	= Watts	x 0.0013	= horsepower
miles per hour (mph)	x 1.609	= kilometers per hour	x 0.0621	= mph
degrees Fahrenheit = (degrees Celsius x 1.8) + 32 degrees Celsius = (degrees Fahrenheit - 32) x 0.56				
miles per US gallon = 235/(litres/100km) litres/100km = 235/(miles perUS gallon)				

How MegaSquirt Works

Understanding how MegaSquirt controls the fuel injectors will help you to assemble, test, and tune your MegaSquirt for best performance.

MegaSquirt works on a number of levels to inject the correct amount of fuel into your engine. Most tangible is the hardware. This consists of:

- CPU (**U1**, the 68HC908) and clock section (**Y1**, the 32768 Hz crystal), that perform computations,
- Serial communications section (most notably **U6**, the MAX232 chip) to enable tuning software to read and write parameters to MegaSquirt,
- Power section (especially **U5**, the LM2937 voltage regulator) to provide a constant 5 volts for many of the other components,
- Various input conditioning circuits (consisting mainly of capacitors, resistors, and diodes, but also including: **U3**, the MPX4250 MAP sensor, and **U4**, the opto-isolator for the ignition signal, and
- A number of outputs to drive the injectors, relays, and LEDs. Significant components include **U7**, the 34151 FET injector driver, **Q2** and **Q7**, the two IFRIZ34N FETs (field effect transistors) for the injector banks, **Q1**, the TIP32C flyback transistor, and a number of other transistor, capacitors, and resistors.
- There are also a number of other associated parts, such as connectors, the case, cables, etc.

The MC68HC908 CPU is controlled by "embedded software". This is "burned" into the non-volatile memory (remembers data even when the power is turned off) of the CPU. It is written in assembly language. The embedded code and its variants are freely available. Another part of the CPU memory is burned with the "bootloader", which tells the CPU how to interpret and store new versions of the embedded code sent through the serial communications port.

The parameters that adjust the embedded code to your specific vehicle are configured using a laptop and tuning software, such as PC Configurator or MegaTune. These are Windows9x/Me/XP applications. They can read information coming from the MegaSquirt, as well as send parameters to MegaSquirt for use and storage.

The amount of fuel injected by MegaSquirt depends on several factors:

- The Ideal Gas Law that relates the amount of air to its pressure, volume and temperature, (this is a fundamental part of the embedded code).
- Measured values: manifold pressure, engine and intake air temperature, rpm, etc. (these are taken from the sensor measurements).
- Tuning parameters: REQ_FUEL, volumetric efficiency, injector open time, etc. (these are inputted and adjusted using the tuning software).

To understand these, we will start with the basics: the Ideal Gas Law, the REQ_FUEL value, and the fuelling equation.

The Ideal Gas Law

You might remember from high school physics classes that an ideal gas (which air is reasonably close to) obeys the relationship:

$$PV = nRT$$

Where:

> **P** = pressure,
> **V** = volume,
> **n** = number of moles (which is related to the mass of the gas, i.e. 1 mol = 6.023×10^{23} molecules of the gas, and n = mass (in grams)/molar mass(MM)),
> **R** = the ideal gas constant,
> and **T** = the absolute temperature.

What does this have to do with fuel injection? In order to know how much fuel to inject, we need to know how much air is going into the engine so the chemically correct mixture (called "stoichiometric") can be achieved. So for a fuel injected engine, we use sensors to determine the pressure in the intake manifold and the air temperature. However, the temperature in this equation is "absolute temperature" measured in Kelvins which is equal to degrees Celsius + 273°.

The volumetric efficiency (VE) is a percentage that tells us the pressure inside the cylinder versus the pressure in the manifold. We know the volume (V) from the displacement of the engine. Thus we can calculate the mass of air (M) in the cylinder (proportional to n) from

$$\begin{aligned} &\mathbf{n = PV/RT} \\ &\mathbf{\Rightarrow M = n \times MM = PV/RT \times MM} \\ &\mathbf{= (VE * MAP * CYL\_DISP) / (R * (IAT-32) * {}^{5}/_{9} + 273)) \times MM_{air}} \end{aligned}$$

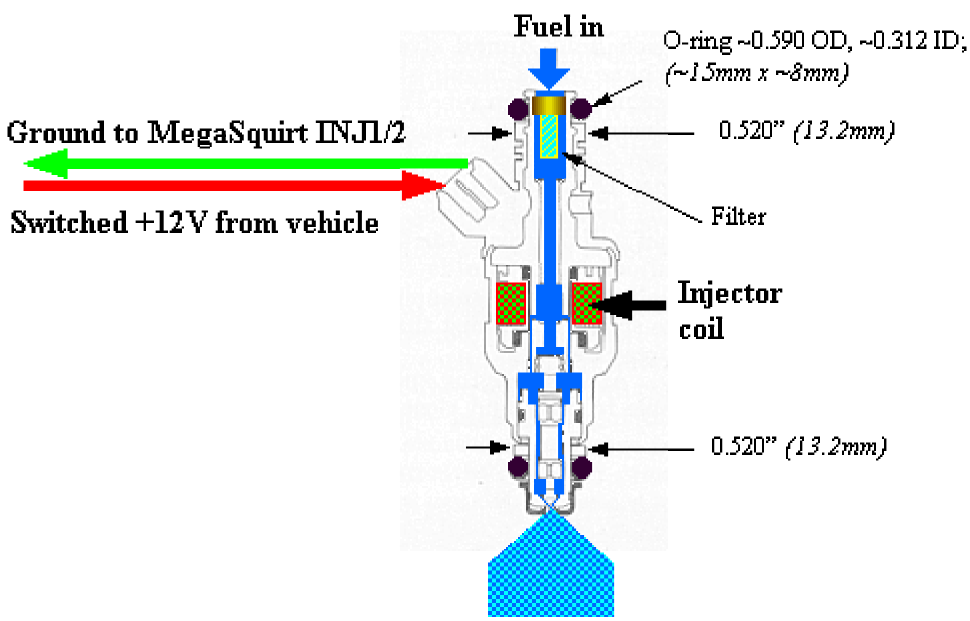
Since:

> **P** = VE * MAP (i.e. the pressure in the cylinder in kPa),
> **V** = CYL_DISP = the displacement of one cylinder (in liters),
> **R** = 8.3143510 J/mol K,
> and **T** = (IAT-32)* $^{5}/_{9}$ + 273 to convert IAT from °Fahrenheit to Kelvin.

Note that we can combine the constants R and MM_{air} into one, and we will ignore them from this point on since they can be hard-coded into the assembly language code and neglected after that.

Since we now know the amount of air in a cylinder from the MAP and IAT values and the tuned value for VE, we need to know the amount of fuel to inject. We specify this with a parameter called REQ_FUEL.

Injectors



Injectors operate by using a 12 volt supply source to operate a solenoid (via the *injector coil*) that opens a valve in the tip of the injector. In most electronic fuel injection installations (and all MegaSquirt installations), the opening and closing is achieved by the switching of the ground for the injectors. That is, the 12 volt supply is live to the engine whenever it is running, and the EFI controller opens the injector by providing a ground path for this 12 volts through the injector. Note the some injectors (called "low impedance" or "peak and hold") require some form of current limiting to avoid over heating the injectors. MegaSquirt has provisions for controlling and tuning the current through the injectors - see the Injectors and Fuel System section of this manual for more details. Except for the very brief periods when they are opening and closing (generally about 1 millisecond), injectors are either fully open (and flowing at their rated capacity for the applied fuel pressure) or fully closed and not flowing at all.

Injectors flow ratings are given in pounds per hour (lbs/hr) or cubic centimeters (milliliters) per min. You will need to find this number for your injectors to calculate your REQ_FUEL. See the Injectors and Fuel System section of this manual for more details.

REQ_FUEL

REQ_FUEL (short for "required fuel") is the part of the computation that tells MegaSquirt how big your injectors are, and what your cylinder displacement (CYL_DISP) is. It is the length of time in milliseconds [ms] that MegaSquirt should "squirt" to give the stoichiometric amount of fuel (14.7 Air/Fuel ratio for gasoline) at 100% VE, a manifold absolute pressure (MAP) of 100kPa, and an air temperature of 70 degrees Fahrenheit for a complete stroke cycle. A stoichiometric mixture is chemically correct for complete burning with no extra fuel **OR** air left over. *Note that it is not necessarily the ratio for most power or efficiency.*

Req_Fuel is calculated from the equation:

$$\mathbf{REQ\_FUEL*10} = {}^{36{,}000{,}000 * CID * AIRDEN(100kPA,\ 70^{o}F)}/_{(NCYL*AFR*INJFLOW)} * \mathbf{1/DIVIDE\_PULSE}$$

Where:

36,000,000 is the number of tenths of a millisecond in an hour, used to get the pounds per 1/10 millisecond from the pounds/hours rating of the injectors.
REQ_FUEL = Computed injector open time in tenths of millisecond.
CID = Cubic Inch Displacement.
AIRDEN = Air density (pounds per cubic feet) at MAP pressure of 100 Kpa, Air Temperature of 70
Degrees F, and Barometric Pressure of 30.00 In HG
NCYL = Number of Cylinders
INJFLOW = Injector Flow Rate in pounds per hour.
PULSE_DIVIDE = injection divide number for number of injections per engine cycle.

The **AIRDEN** function (used above) is defined by:

$$\mathbf{AIRDEN(MAP,\ temp)} = {}^{0.398568*\ (MAP*10-31.0)}/_{((temp+459.7)*1728)}$$

Where:

MAP = Manifold Air Pressure in kPa,
Temp = Air Temperature in Degrees F,
459.7 is used to convert from Fahrenheit to absolute temperature,
1728 is used to convert engine displacement from cubic inches to cubic feet.
Note that there is also a small adjustment for relative humidity, and AIRDEN(100,70) evaluates to ~1543 with this included.

Hence, the REQ_FUEL value is the amount of fuel (in milliseconds) required for a MAP reading of 100 Kpa, manifold air temp of 70 degrees F, and a barometer of 30.00 In Hg, for one complete filling of one cylinder (Volumetric Efficiency = 100%), without any enrichments.

For a 4-stroke, a complete stroke cycle is 720 degrees of crankshaft rotation (i.e. two revolutions); for a 2-stroke, it is 360 degrees (this is also factored in the REQ_FUEL value downloaded to MegaSquirt). (Technically, for MegaSquirt, a cycle is defined as nCyl ignition events.) In the tuning software, the upper REQ_FUEL box is the amount per cylinder, as noted above. The lower REQ_FUEL box is the downloaded value to the ECU - this is the REQ_FUEL number on top, but scaled by your injection mode (number of squirts and alternate/simultaneous). For example, if you inject simultaneous and one injection, and have the same number of injectors as cylinders [i.e. port injection], then REQ_FUEL on the bottom is the same as REQ_FUEL on top. The same applies with alternate and two squirts. If you put in simultaneous and two squirts, then REQ_FUEL is divided in half - because you squirt twice, you need to inject 1/2 the fuel on each shot.

<u>MegaSquirt Fuel Equation</u>

What MegaSquirt does is take this downloaded REQ_FUEL number and then multiply (or adds) values that scale this number, to come up with the injected pulsewidth [PW]. Therefore, pulsewidth is:

PW = REQ_FUEL * VE * MAP * E + accel + Injector_open_time

The "E" above is the multiplied result of all enrichments, like warm-up, after-start, barometer and air temperature correction, closed-loop, etc. - this is the scaling factor applied to the REQ_FUEL value, along with VE(RPM,MAP) and MAP. For all of the corrections, 100% means no enrichment/enleanment, since the value is normalized by 100 to get a fractional multiplier. Notice there are two other factors added to this - one is the acceleration enrichment, and the other is the injector open time.

Even if you set REQ_FUEL to zero you are still left with the injector open time (and accel enrichment if activated). The reason for adding in the open time is that it takes a finite amount of time to open the injector before one reaches a linear control state where injector time relates to fuel flow. The controller compensates for the open time by adding it to the applied total pulsewidth, otherwise the pulse would be too short.

The thing to note is that the REQ_FUEL is a pre-computed number downloaded to the MegaSquirt unit by the PC Configurator or MegaTune based on injector size, etc. MegaSquirt uses this by applying the ideal gas law to compute relative charge density based upon those conditions, then scales Req_Fuel accordingly to arrive at a pulse width. For changes in barometer and manifold air temperature, there are the lookup tables the values are run through (i.e. airdenfactor, etc).

To further understand the equations, read the VE Tuner document in the MegaSquirt Yahoo! File section. This document describes one implementation of the MSTweak that was not finished at the time that document was written. The top section has the equations for the MegaSquirt fuelling.

As we saw above the fuelling equation is:

PW = REQ_FUEL * MAP/100 * VE/100 * GammaE/100 + Inj Open Time

So to see an example of how MegaSquirt calculates pulsewidths, we will look at a low rpm cruise point data from a datalog file, with MAP=40 kPa, VE=74%, GammaE=97%, and a reported pulsewidth of 4.0 milliseconds, with constants: Req_Fuel = 10ms and Inj Open Time = 1.3 ms.

So: **PW = 10 * 40/100 * 74/100 * 97/100 + 1.3 = 4.17 ms in this case.**

The tuning software just reports what the MegaSquirt box is generating, 4.0 ms in the example.

You may not get exactly the number displayed reported by MegaSquirt in the datalogs. Remember that the serial transfer routine works asynchronous to the main calculation loop, so there is always the chance that you get readings where the VE, MAP, etc do not exactly match the pulsewidth. In other words, while the "math" is being done in the main loop (right after finding the VE, etc), MegaSquirt may transmit the pulsewidth before it has been calculated for this iteration. In fact, the main event loop will execute many times before the SCI has sent out one iteration of all of the 22 runtime variable bytes (at 9600 baud).

To verify the calculations, you need to run things steady state. For instance, run MegaSquirt on the stimulator, and then go through the exercise. Also remember that the resolution is 0.1 milliseconds for pulsewidth, and the intermediate calculation steps in MegaSquirt are held with 8 and 16-bit numbers, so if you want an exact match you need to manage the intermediate numbers the same way that MegaSquirt handles them.

Finally, note that the final absolute value of VE is not that important, as long as everything is repeatable for a given input parameter set (i.e. MegaSquirt yields the same PW for a given set of input values each and every time, i.e. repeatable). You tune the vehicle for best operation.

A fuel injection computer could use the cylinder filling efficiency (VE) relative to two points - the atmosphere, and the intake manifold pressure (as measured by the MAP sensor). If you use manifold absolute pressure (MAP) as your reference pressure to compute cylinder filling as MegaSquirt does, then a turbo motor is usually worse than a naturally aspirated (NA) motor, because of the added back pressure from the turbocharger exhaust manifold and the turbine. If you are referencing VE to ambient pressure, then "VE" goes way up as the boost builds.

Speed Density algorithms (like the one in MegaSquirt) usually use the first definition in their VE calculations, and then multiply the VE number by the MAP value to get an actual filling mass. However, VE values above 100% can be used in a turbocharged motor to cool the charge and prevent detonation by making the mixture richer.

Measured Values

As noted above, MegaSquirt uses several measured values in its computations. These include the Manifold Absolute Pressure (MAP) and Intake Air Temperature (IAT). The MPX4250 MAP sensor works by taking a 5 Volt reference (often abbreviated to 5Vref) supply from MegaSquirt, and returning a 0-5 volt signal whose voltage is a linear function of the absolute pressure at the sensor. Absolute pressure is the pressure compared to a total vacuum. Normal atmospheric pressure is about 101.3 kilopascals (kPa), or about 14.7 psi or 29.92 inches of Mercury ("Hg). Engine diagnostic gauges often use inches of mercury for measuring vacuum. So a vacuum of 15" (as read on a vacuum gauge) is equal to 29.92 – 15 = 14.92 "Hg = 101.3* $^{14.92}/_{29.92}$ = 50.5 kPa. MegaSquirt uses kilopascals exclusively for pressure measurement.

Lower pressures give lower voltages from the MPX4250 MAP sensor. MegaSquirt uses an analog to digital converter (ADC) to turn the MAP sensor voltage signal into a digital number between 0 and 255 (i.e. one byte = 8 bits). The "kpafactor4250.inc" is used by MegaSquirt to scale the "conversion" from volts to bits. MegaTune uses a similar file for its computations. MegaSquirt embedded code uses the variable "kpa" to store the measured manifold pressure value for use in its computations (when the assembling language code is compiled).

Note that MegaSquirt also uses the MAP sensor to grab a "barometer" reading at start-up to apply barometric corrections that compensate for reduced exhaust backpressure at high altitudes. This value is stored in a variable called "baro". The corrections themselves are in a variable called "aircor".

MegaSquirt also uses an analog to digital conversion to translate the varying resistance of the intake air temperature sensor to a digital value ("clt") between 0 and 255. The sensor resistance can range from 100,000 ohms at –40°F (-40°C) to 185 ohms at 210°F (99°). Other sensors can be used by recompiling the code using EasyTherm.

In addition to the measurements necessary to compute the ideal gas law, other sensors are used by MegaSquirt to compensate when the engine needs a mixture other than stoichiometric. These other sensors include a coolant temperature sensor for warm-up enrichment, and a throttle position sensor for acceleration/deceleration enrichment.

MegaSquirt has a coolant temperature sensor (CLT) that is electrically identical to the IAT sensor. It functions in exactly the same fashion as the IAT, but it is used only for warm-up enrichment, cranking pulsewidth determination, and controlling the fidle valve. At low temperature, fuel vaporizes poorly, and more fuel is needed to ensure enough vaporized fuel for adequate combustion. The variable "coolant", which is equal to "clt" + the offset of 40°F, is used to tell MegaSquirt when warm-up enrichment (variable is "warmcor") is needed. Cranking pulsewidths are determined by both the low temperature (-40°F) setting ("CWU") and the high temperature (170°F) setting ("CWH"). The actual pulsewidth is determined by a linear interpolation between these two settings based on the current coolant temperature ("clt"). The fast idle valve is activated whenever CLT is below "FASTIDLE".

The TPS sensor tells MegaSquirt what the current position of the throttle. This variable is compared to the most recent readings to determine if the throttle is opening or closing rapidly. If so, extra fuel can be added for an opening throttle to compensate for transient conditions. This functions the same as an accelerator pump in a carburetor.

The TPS also does two other important functions. First, if the throttle is open more than a specified amount during cranking, it invokes the "flood clear" mode by reducing the injected pulsewidth to 0.3 milliseconds. Second, if the throttle is open more than 70%, exhaust gas feedback is shut off.

The exhaust gas oxygen (EGO) sensor provides feedback to MegaSquirt if it is injecting the correct amount of fuel. The EGO sensor (also called an O2 sensor or oxygen sensor) measures the amount of oxygen in the exhaust gases, and sends a 0 to 1 volt signal (for a narrow-band sensor, more on wide band sensors later) to MegaSquirt (raw ADC count is "ego"). MegaSquirt then computes the adjustment that should be made in the fuel duration ("egocorr") for the next injection event. Lower voltages mean lean mixtures, and higher voltages mean richer mixtures.

However, the conventional narrow-band sensors are not particularly precise away from stoichiometric mixtures, so situations demanding richer or leaner mixtures must turn off EGO correction. MegaSquirt uses TPS measurements to shut off EGO correction at more than 70% throttle. MegaSquirt also gives you options to shut off EGO correction below a specified coolant temperature ("egotemp") and below a specified engine rpm.

Ignition Input

Okay, now that MegaSquirt knows how much fuel to inject, how does it know when to inject the fuel? That is a function of the ignition input circuit. A signal is taken from the distributor or negative terminal of the coil. Ideally, there is one "spike" each time a cylinder fires. MegaSquirt injects fuel on even multiples of these signals.

Considerable work has been done in the field to ensure clean ignition signals, with no dropped events and no false events. This is covered in more detail in the Ignition Triggering subsection of the Tuning section.

The timing of the injection events depends on the parameters you set using the tuning software (Injection Per Engine Cycle, Injector Staging, Number of Cylinders, etc.). These will be covered in detail in the Tuning section of this manual.

MegaSquirt does **not** perform sequential injection. Instead it does "**batch**" injection. Sequential injection means that the injection of fuel is timed to occur at a specific valve event, such as intake valve opening. Batch injection means that the fuel is injected for a number of cylinders at once, regardless of valve positioning. Sequential injection requires a camshaft position sensor to work, and adds complexity to the system.

Intuitively, it seems that the engine should run more efficiently if the fuel is injected when the intake valve is open.

Al Grippo has an EFI332 controller on his vehicle that can do sequential injection. As a real-world test, he programmed his ECU to start the injection when the exhaust valve closed (intake already open), but if the pulsewidth was such that injection could not finish by the time the intake closed, then the ECU advanced the injection timing so the injection would end when the intake closed. From this theoretical optimum, he varied the timing through the whole cycle and confirmed that what he picked as default was optimum based on the **highest rpm, lowest map reading**. This was all done at idle. There was a small but measurable difference if the timing was such that injection took place coincident with the exhaust being open.

At higher rpms, it becomes increasingly difficult to inject while the valve is open. For example, if your **req_fuel = 15.0 ms**, and your maximum duty cycle is **85%** then the interval between injections cannot be closer than 17.6 ms. The time available to inject during the entire 4 stroke cycle is:

$$\text{time}_{\text{cycle}} = {}^{120}/_{\text{RPM}}$$

The intake valve is typically open for less than 240° of 720° in an engine cycle, about 1/3 of the time for a complete cycle. So:

$$\text{time}_{\text{inject}} = {}^{40}/_{\text{RPM}}$$

and

$$\text{RPM}_{\text{max}} = {}^{40}/\text{time}_{\text{inject}}$$

Using the numbers above,

$$\text{RPM}_{\text{max}} = {}^{40}/_{0.0176} = \sim 2300 \text{ rpm}$$

Above this RPM, it is not possible to inject the entire amount fuel through the open valve at 100% VE and 100kPa. At idle, however, VE may be 30%, and kPa might be 35 kPa, yielding a pulsewidth of ~1.8 milliseconds, which certainly could be injected during the intake valve opening. So sequential injection is primarily effective at idle. It is not much different from batch injection, as pulsewidths get larger at higher engine speeds and loads.

In any case, when fuel is injected while the valve is closed, it will simply stay in the port until the valve opens. In some cases, this may allow enough heating of the mixture to better vaporize the liquid fuel, improving efficiency and emissions.

The Embedded Code

Version 2.986 is the current version of the embedded code, soon to be re-released as version 3.

This version has:

- Modified boot_r12 file to raise the LVI trip point.
- Fill unused RAM locations with $32, an illegal opcode to force a reset. Done to prevent flash erasure if code ever gets into a runaway state - for protection only.
- Put in interlocks to prevent VE/Constant section flash erasure unless specifically invoked by a flash burn command.
- Put in Odd-fire RPM averaging (Willette) for odd-fire engines.
- Added new calculation structure to code - same calculation as HI-RES code, but results are in 0.1 millisecond units. Calculation overflow fixed.
- Flyback damping code installed - jumper port X0 for INJ1 and jumper port X1 for INJ2.
- Fixed display of WARMCOR variable (no flickering).
- Inhibit PWM mode while cranking.
- Made "ADC" into "ADD in ADC interrupt section (Tom D) to properly perform the sum without a carry.
- Perform 12 ms time compare for re-enabling of tach IRQ interrupt (fix for random tach problem) - original trial time of 20 ms too long (Magnus Bjelk fix - also for high/low byte check).
- Moved after-start enrichment to increment after "N" tach pulses have occurred, with N being the number of cylinders. This will lengthen the after start enrichment time by an amount scaled by the number of cylinders (Tom).
- Fix display of barometer correction (no screen flicker if 100% barometer is selected).
- Fixed IRQ counter to work properly for NCYL above 8 cylinders.

The version 2.986 code is at:

http://www.bgsoflex.com/v2.98/megasquirt.asm
http://www.bgsoflex.com/v2.98/megasquirt.h
http://www.bgsoflex.com/v2.98/boot_r12.asm
http://www.bgsoflex.com/v2.98/megasquirt.s19

You only need the last file (megasquirt.s19) if you are not modifying the code.

Then download the program **download.exe**, included in the file *tools.zip* in the Files section of the MegaSquirt Yahoo! site.

Unzip the file to a convenient directory. Instructions for using download.exe are in DOWNLOAD.TXT in the zip file.

Note that V2.98 is required if you are using the Flyback Board.

There are a number of other specialized versions of embedded code for MegaSquirt. See the guide by Colin Gebhart (http://home.earthlink.net/~jcgebhart/mscompat.html) for compatibility and files.

Version 2.00 of the embedded code, shipped with the second group buy, is different from the version 1.01 code of the first group buy. It added the following features:

- Acceleration Enrichment Cold Multiplier added - now cold accel enrichment in form of a + b * x
- Barometer Correction Selection Mode put in Config13
- Bootloader Bug (lda vs ldx) fixed for this version
- RPM Calc made more efficient and bug fix for RPM exclusion values (Konstantin)
- Changed Flood clear value to 0.3 ms
- Added the "Guy ROM Offset" to fix the bootloader erase problem
- Added Embedded Code revision number SCI query command ("Q")
- Fixed SCI "C" transfer mode
- Added Alpha-N mode
- Added O2 target voltage constant and DIY-WB O2 sensor support, and bit for Odd-Fire Mode (no odd-code mode in embedded code yet).
- Fixed Battery voltage correction rollover problem.
- Fixed Lininterp problem with large negative numerator spans
- Fixed "sticky" decel bit
- Added both MPX4115 and MPX4250 KPA and Barofac tables in flash - selected by config register
- Prime Pulses and Adjustable RPM for entry into closed-loop added 4/2/02

All releases of the embedded software and tuning software are compatible in both directions. V1 (version 1.01) embedded works with the latest PC Configurator or MegaTune and the old MT and PCC releases work with V2 and V3 embedded code (but without access to newer features like priming pulse and WB support).

The hardware for both v1.01 and v2.2 boards looks the same from inside, so either code will work on either board.

Unless you have a specific reason to do otherwise, use embedded code that came on your CPU and the latest version of MegaTune, as they are the most robust.

SCI Communications

To communicate with MegaSquirt, you need to set the serial port parameters to 9600, No Parity, 8 bits, 1 stopbit (i.e. 9600, N, 8, 1). The PC Configurator or MegaTune does this automatically.

Communication is established when the PC communications program sends a command character - the particular character sets the mode:

- **A** = send all of the realtime variables via txport.
- **V** = send the VE table and constants via txport (128 bytes)
- **W**+{offset}+{newbyte} = receive new VE or constant byte value and store in offset location
- **B** = jump to flash burner routine and burn VE/constant values in RAM into flash
- **C** = Test communications - echo back SECL
- **Q** = Send over Embedded Code Revision Number (divide number by 10 - i.e. $21T is rev 2.1)

Look at the MegaSquirt assembly code near the section below for complete details on the mode commands.

Unless you want to edit and recompile the source code, you can upgrade to any version of the code by uploading the corresponding **.s19** file.

The files are:

- The **.asm** file is the human readable source code. Open it up with notepad and look it over. You may not understand it but it is very well commented.
- The **.inc** files are included by the compiler directed by command in the .asm file. In this case it is used to load tables. This can be read with notepad.
- The **.h** file is called a header file. It contains **defines** and **equates** (constants). Open it up with notepad.
- The **.s19** is called the "source record" or S record for short. This is the result of running the .asm through the compiler. This is not the program in binary form but

it is a text format that tells the loader where and what to write to the device memory. You can read this file if you understand Hex and op-codes.

All you really have to know is that you have to upload the .s19 file.

*To write modifications to the MegaSquirt assembly language code, s*tart by reading

http://e-www.motorola.com/files/microcontrollers/doc/ref_manual/CPU08RM.pdf.

(*Note that this link may change. Search the Motorola site (http://e-www.motorola.com/) if you get a dead link.*)

This document covers the architecture, resets and interrupts, addressing modes, and instruction sets for the MegaSquirt processor.

An outstanding book on micros is entitled Embedded Microprocessor Systems, by Jonathan Valvano, ISBN 0-534-36642-2. It ranks up there with Horowitz/Hill "Art of Electronics" and "Numerical Recipes". This one is destined to be a classic. It has info on programming Mot HC05/HC08/HC11/12 processors, and all of the hardware that people like us are interested (stepper motor driver circuits, sensor interfaces, etc). Not a lot of theory, just meat. Also there is a lot of info on algorithms like PID loops, how to make a real-time scheduler, etc. - things we are all interested in. In the front and rear cover, it has charts and tables on practical items (like different capacitor types, popular transistor types with relevant info, etc).

Get this book and you will be able to make MegaSquirt circuit and software changes yourself. It is expensive at $107.00, but it is worth every dollar if you will be extensively rewriting the code.

To compile modifications to the MegaSquirt assembly language code, you need the full P&E assembler/linker/simulator/IDE (http://www.bgsoflex.com/ics08asm.zip) that can be used to assemble, link, and program the MC68HC908GP32 part with the above files. Download the P&E Assembler tool set and extract it to a directory on your hard drive. The software has a short limit on the path to the executables director, so do not bury it in a sub-sub-sub-sub... folder! Something like c:\ics08asm*.* works well.

Use the WinIDE (Windows Integrated Development Environment), which is included in the above zip file. Note that you have to set the Environment [under *Setup Environment*] to match the directory to which you have installed the ZIP file so that WinIDE can find the compiler, simulator, etc.

Open File for the desired .asm file and make sure the associated files (*.inc, .h, Gp32.equ, etc.) are in the same directory. You can get these files from the MegaSquirt site. Then click on the "Assemble/Compile" button [leftmost], and the .S19 file is created. You can then download the .S19 files to the chip using the original bootloader or the

Willette programmer and the prog08sz, which will be the third icon from the left, if you have set the environment to the defaults.

Do not forget to let the Yahoo group know about your modifications, and the results! We are all interested in the experiments of others, and we will all benefit.

One example of modifying the code is to change the switch point for cranking. You may be cranking faster than the *cranking enrichment* cut-off speed of 300 rpm, and running off of the VE table while cranking. This can make it difficult to start your engine.

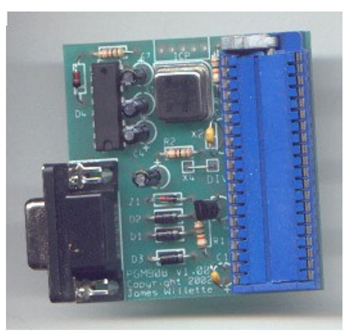
The cranking speed can be changed in the code to suit your application quite easily. Find a section of the code that has the following lines:

```
CHK_FOR_WENRCH:
cmp #$03 ; Check if we are cranking
bhi WARM_UP_ENRICH
```

This is where the cranking rpm check occurs. If rpm exceeds 300 (indicated by #$03), then it branches to the warm-up enrichment calculations, and assumes the engine is running. Change the $03 number to suit your cranking speed, and you have your own custom code version with a higher cranking/running transition point.

You can then compile your code using the ICS08ASM program mentioned above, and load the .s19 file to MegaSquirt using HyperTerminal, download.exe, or EasyTherm.

Willette Programmer



The Willette programmer is a standalone programmer for the MC68HC908GP processor. The power is obtained from a PC serial port. The board is 2.25 inches by 2.25 inches (57mm x 57mm). It has a ZIF socket for the processor and an ICP header for target board programming. More info is at the site: http://groups.yahoo.com/group/68hc908pgm.

Note that MegaSquirt partial kits come with the processor pre-programmed. You do not need the Willette program to run MegaSquirt or perform standard upgrades on these processors. However, if you purchase a blank chip from any other supplier than the group buy, or if you want to extensively rework the MegaSquirt code, you need this programmer. See the Yahoo 68hc908 group for more info.

Programming a Blank Processor

The steps to program a blank processor (i.e. not a group buy unit) are listed below. Make sure you have the latest version of the Prog08sz software. Get the latest version at http://groups.yahoo.com/group/68hc908pgm/ files/software/prog08sz.zip.

1. For MegaSquirt code (not Tomtek ignition), download the **megasquirt.s19** file(s) you wish to use **OR** assemble **megasquirt.asm** (or megasquirtDT.asm, etc.) into its respective ".s19" file. See how to do this in the "CODE" section of the MegaSquirt FAQ. (Tomtek ignition code, dual table MS code, and version 2 and later standard MegaSquirt code already contain the boot loader, so you only need to assemble the megasquirt.asm file.)

2. Start up **prog08sz**, you might have to retry several times to connect. If you cannot get a connection, read the 908 archives for some hints on debugging.

3. Often the connect problem is low voltage due to a wimpy serial port, so you might want to eliminate this problem by connecting an external power source. (e.g., a 9 volt battery) to the circuit. Connect the positive (+) side of the battery to the banded side of D2 (or D1) and the negative (-) side to a ground point (e.g., the mounting lug on the 9 pin connector).

4. Select the **908_gp32.08p** module when asked to "*Specify Programming Algorithm to Use*".

5. If this chip has been programmed before, you need to erase it (if in doubt, do this anyhow). Click on the button with the "pencil erasing" icon (6th from the left) to Erase Module. When this is done, it says "*Erasing. Module has been erased*" in the lower left corner of the screen, after which you should verify the chip with Blank Check Module (the button beside Erase Module). You should get a message saying "*Erased.*"

6. For version 1.0 of the code only, click on "*SS Specify S Record*" in the window on the middle left [or the 19diskette19 button in the menu], and select "**boot_r12.s19**". **Note that Version 2 and later .s19 files include the boot_r12 file, and this step should be skipped.** Click on "*Program Module*" [on the menu on the left, or use the button beside the "diskette"/ *Specify Record* button]. After a few seconds, it should complete. Then you can then click on "*VM Verify Module*" [on the menu on the left, or use the button beside the "Program Module" button]. You should get a message that the m odule was "*verified*".

7. Click on Specify S Record as above, this time selecting "**megasquirt.s19**" Follow this with "Program Module", then "Verify Module".

8. Disconnect the serial cable from the programmer, unlatch the ZIF lever, remove the chip, and you should be ready to insert the chip into a MegaSquirt controller and run.

This has been a brief introduction to the workings of MegaSquirt. You can learn more by studying the schematics, the assembly code, and the hardware datasheets, as well as by assembling and using a MegaSquirt.

Assembling Your MegaSquirt

When you purchase a MegaSquirt, (http://www.bgsoflex.com/mspo1.html) you receive a PCB (the printed circuit board), plus some essential components, called a partial kit. The partial kit includes:

- Printed circuit board (**PCB**),
- Pre-programmed 68HC908GP32 processor (**U1**),
- MPX4250AP MAP sensor, and the (**U3**),
- 34151 FET driver (**U7**).

Ordering Components from Digi-Key

When you buy a partial kit, you will need other parts. These are available for Digi-Key, and an on-line ordering form is at:

http://www.megasquirt.info/bom.htm

The components arrive from Digi-Key individually packed, with Digi-Key part numbers. MegaSquirt reference tags are printed on the packing list (and below). As a result, while you should verify that you have received all you ordered, it is not necessary to identify each item by color, markings, etc.

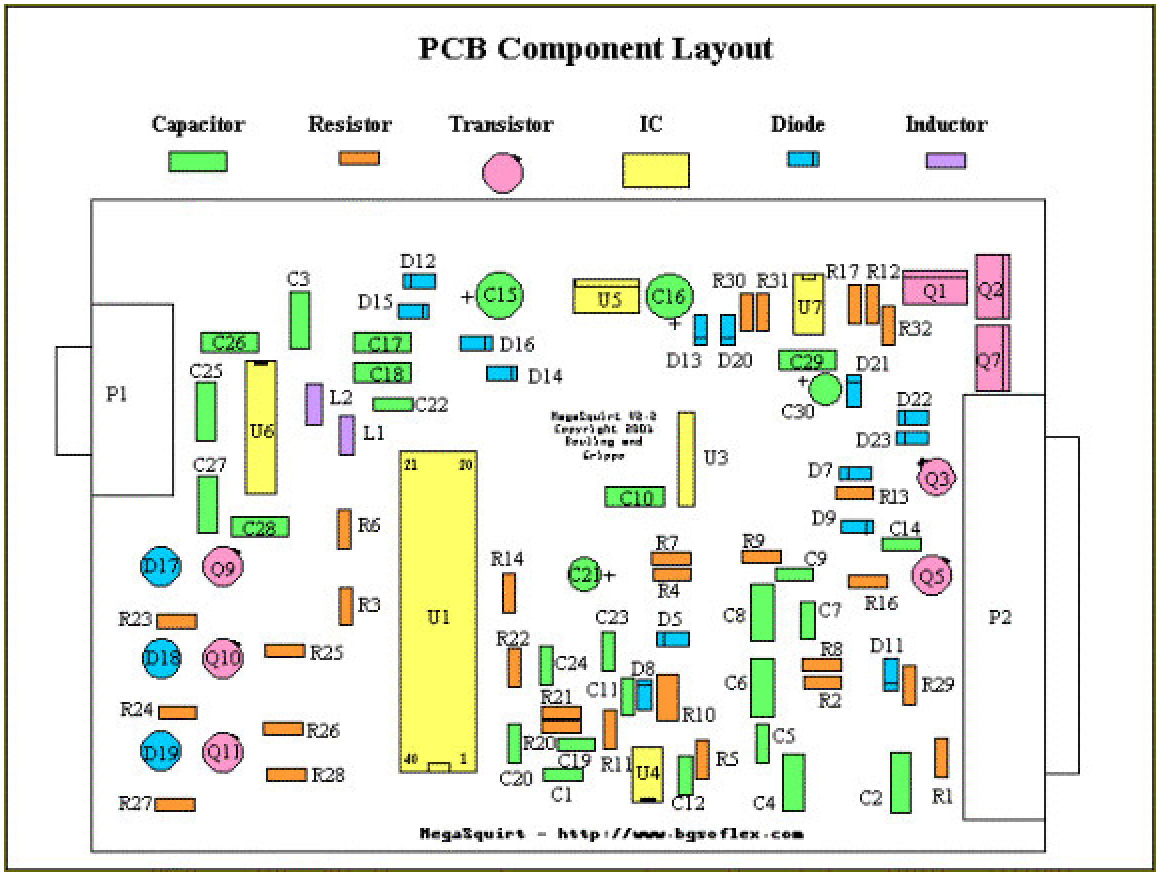
Here is a list of some of the major components used in MegaSquirt:

- 68HC908GP32 (processor),
- MPX4250 MAP sensor,
- 4N25 optoisolator,
- MAX232 serial chip,
- MC33151P / IXDI404PI FET driver,
- LM2937 voltage regulator,
- IRFIZ34N HexFETs,
- 1N47XX series diodes,
- 1N4001 diodes,
- TIP32 flyback transistor, and LEDs.

Below is a listing of all of the electronic components required for MegaSquirt.

Qty. (min. order)	MegaSquirt Reference	Description	Digi-Key Part Number
10	C1, C3, C17, C18, C22, C25 to C29	Capacitor 0.1uf	399-1880-1-ND
3	C2, C4, C10	Capacitor 0.22uf	399-1882-1-ND
5	C5, C7, C9, C12, C14	Capacitor 0.001uf	399-1818-1-ND
2	C6, C8	Capacitor 1uf	399-1887-1-ND
2	C11, C20	Capacitor 0.01uf	399-1868-1-ND
2	C15, C16	Capacitor 22uf tantalum	P2051-ND
1	C19	Capacitor 0.033uf	399-1877-1-ND
2	C21, C30	Capacitor 4.7uf tantalum	P2047-ND
1	C23	Capacitor 47pf	338-1053-ND
1	C24	Capacitor 20pf	338-1051-ND
6	D1, D2, D3, D4, D8, D11	1N4733 5.1V Zener diode	1N4733AMSCT-ND
9	D5, D7, D9, D12, D13, D14, D20, D22, D23	1N4001 Diode	1N4001DICT-ND
1	D21	1N4753 36V Zener diode	1N4753AMSCT-ND
1	D15	1N4749 24V 1W Zener diode	1N4749AMSCT-ND
1	D16	1N4742 12V 1W Zener diode	1N4742AMSCT-ND
3	D17, D18, D19	LED, red, T1-3/4 case	P301-ND
2	L1, L2	Inductor 1uH	M7010-ND
1	P1 Connector	DB-9 Female	A23305-ND
1	P2 Connector	DB-37 Male	A23289-ND
1	Q3, Q5, Q9, Q10, Q11	Transistor, ZTX450	ZTX450-ND
2	Q2, Q7	Transistor, IRFIZ34N	IFRIZ34N-ND
1	Q1	TIP32C	TIP32CFS-ND
8 (10)	R1, R2, R9, R13, R16, R25, R26, R28	1K ohm, 5%, ¼w,axial	1.0KQBK-ND
1 (5)	R3	51K ohm, 5%, ¼w,axial	51KQBK-ND
2 (5)	R4, R7	2.49K ohm, 1%, ¼w,axial	2.49KXBK-ND
2 (5)	R5, R8	2.2K ohm, 5%, ¼w,axial	2.2KQBK-ND
5	R6, R14, R20, R30, R31	10K ohm, 5%, ¼w,axial	10KQBK-ND
3 (5)	R23, R24, R27	330 ohm, 5%, ¼w,axial	330QBK-ND
1 (5)	R10	390 ohm, 5%, ½w,axial	390H-ND
1 (5)	R11	4.7K ohm, 5%, ¼w,axial	4.7KQBK-ND
2 (5)	R12, R17	22 ohm, 5%, ¼w,axial	22QBK-ND
1 (5)	R21	100K ohm, 5%, ¼w,axial	100KQBK-ND
1 (5)	R22	10M ohm, 5%, ¼w,axial	10MQBK-ND
1 (5)	R29	1M ohm, 5%, ¼w,axial	1.0MQBK-ND
1 (5)	R32	270 ohms, 5%, ½w,axial	270H-ND
1	U1 - Group Buy (pre-programmed)	68HC908GP32 Processor - 40 Pin DIP	MC68HC908GP32CP
1	U3 - B&G	MPX4250A Pressure Transducer	MPX4250AP
1	U4	4N25 opto-isolator - 6 Pin DIP	160-1300-5-ND
1	U5	LM2937ET-5.0 Regulator - 3 Pin T0-220	LM2937ET-5.0-ND
1	U6	MAX232CPE - 16 Pin DIP	MAX232CPE-ND
1	U7 - B&G	34151 FET driver - 8 Pin DIP	IXDI404PI-ND (replacement)
1	Y1	32.768 KHz Crystal	300-1002-ND
1	n/a	40 Pin DIP Socket	AE7240-ND (or A9440-ND)
1	n/a	Connector DB-37 Female	237F-ND
1	n/a	DB-37 Hood	937GM-ND
1	PCB - Printed Circuit Board - B&G	Double sided, plated holes, solder mask	n/a

Here is a color-coded diagram of how these components are located on the printed circuit board:



If you have questions about the specification or appearance of any item, check the part number at the Digi-Key site (www.digikey.com) first. Entering the part number in their search engine will give you access to both the catalog information and the datasheet from the manufacturer. You can also access this information from the ordering form at:

http://www.megasquirt.info/msbom.htm

The datasheet is available by clicking on the part description.

When you get your parts kit from Digi-Key, it will contain the components listed above (minus the PCB, U1, U3, and U7). Note that you will have some extra parts. These are the result of Digi-Key minimum order quantities for some items, notably the resistors. The resistors are generally less than $0.06 each, so the total cost of the extras is minimal.

Schematics for MegaSquirt are available on the MegaSquirt site at:

http://www.bgsoflex.com/v22/megasquirt_ShemV2.2.pdf

Before plugging in your soldering iron, be sure you read and understand the assembly instructions that follow. If this is your first time soldering, read the deployment guide thoroughly. It is in a file called "deploy_guide_DRAFT_040302.pdf" in the Files section of the MegaSquirt Yahoo! list. You do not need to use silver solder for MegaSquirt. Regular 60/40 or 63/37 solder is fine.

Note: The semiconductor components in MegaSquirt are sensitive to **electrostatic discharge** (ESD). To reduce the potential for damage from ESD, some care is needed. Interestingly, you cannot even feel an ESD shock unless the voltage exceeds 3,000 volts, far more than enough to destroy some of the MegaSquirt components. ESD events do not always destroy an electronic component immediately on the first occurrence, making the eventual failure of your MegaSquirt very difficult to troubleshoot. Where possible, make use of anti-static controls and material handling techniques, i.e., wrist-band grounding straps, anti-static foam and anti-static bags, grounded workbenches, anti-static mats, etc. Avoid handling semiconductor components more than necessary. If you are not wearing a wrist-band grounding strap, discharge yourself by touching grounded metal before handling ICs and equipment. This is especially important in the winter after taking off or putting on any garments, for example, sweaters and coats. The material of your clothing also has an effect, as materials like silk and some artificial fibres produce a lot of "static electricity". Most commercial carpets contain a high percentage of artificial fibres, which are prone to producing static. Where possible, try to keep the room humidity at 50% or higher to reduce static problems, or use a product such as "Static Guard".

Assembly Guide for Version V2.2

The following is a step by step assembly guide for the V2.2 MegaSquirt partial kit. Read all of these directions first. Be sure to check off each step as you complete it - this way you can take breaks and know where you left off.

The first time assembler of average skill can count on spending 4 to 5 hours assembling and testing the MegaSquirt if they follow the instructions below.

To assembled your MegaSquirt, you will need:

- A MegaSquirt PCB and all associated B&G and Digi-Key parts,
- A digital multi-meter (DMM) or a voltmeter and ohmmeter,
- A DB-9 serial cable that is "straight-through" (not a null-modem cable, see step 22a). Most computer shops will have these. You need a female connector on one end and a male connector on the other end.
- A Windows PC which has HyperTerminal (hypertrm.exe) (normally supplied with the Windows operating systems),
- The MegaSquirt PC Configurator (called PCC or just Configurator) OR MegaTune - download one of them from:
  PCC - http://www.bgsoflex.com/megasquirtpcdown.html

MT - http://not2fast.wryday.com/megasquirt/mt/2.16/
and install it on your computer,

- A MegaStimulator will make these checks, and several other tasks, much easier.
- General electronic kit assembly tools (screwdrivers, pliers, soldering iron, etc.). Also, if you are unsure of a resistor value (sometimes it is hard to pick out the color on a resistor), then use an ohmmeter to determine resistance - remember that most of these are 10% tolerance devices, so your readings may not be exactly as designated.
- Proper mounting of the larger heat-producing components requires the use of heat-sink compound. You can find a small tube of it at your local electronics store for under $2.
- A drill, file, and 1/8" and ¼" drill bits for cutting the end plates.

Do not let this be your first electronics kit. If you have not assembled such a kit before, go purchase another simple kit (like from Velleman) and practice, or assemble the MegaStim, relay board first. Do not let MegaSquirt be your first kit building experience. For tips on good soldering technique and electronics assembly hints, see the draft deployment guide by "Neon" John De Armond in the Documentation section of the MegaSquirt Yahoo! Files section.

Getting Questions Answered

When you have problems with assembly or testing, post your questions to:

megasquirt@yahoogroups.com

Make sure to mention the step number and be as specific as you can with regards to components, voltages or resistance values, temperatures, PC Configurator gauge numbers, LED flashing rates or any other information that you think might be related.

If you have all of the above items on hand, and a few hours of spare time, you can begin to assemble your MegaSquirt.

Assembly proceeds in functional blocks, with testing after each block. These blocks are:

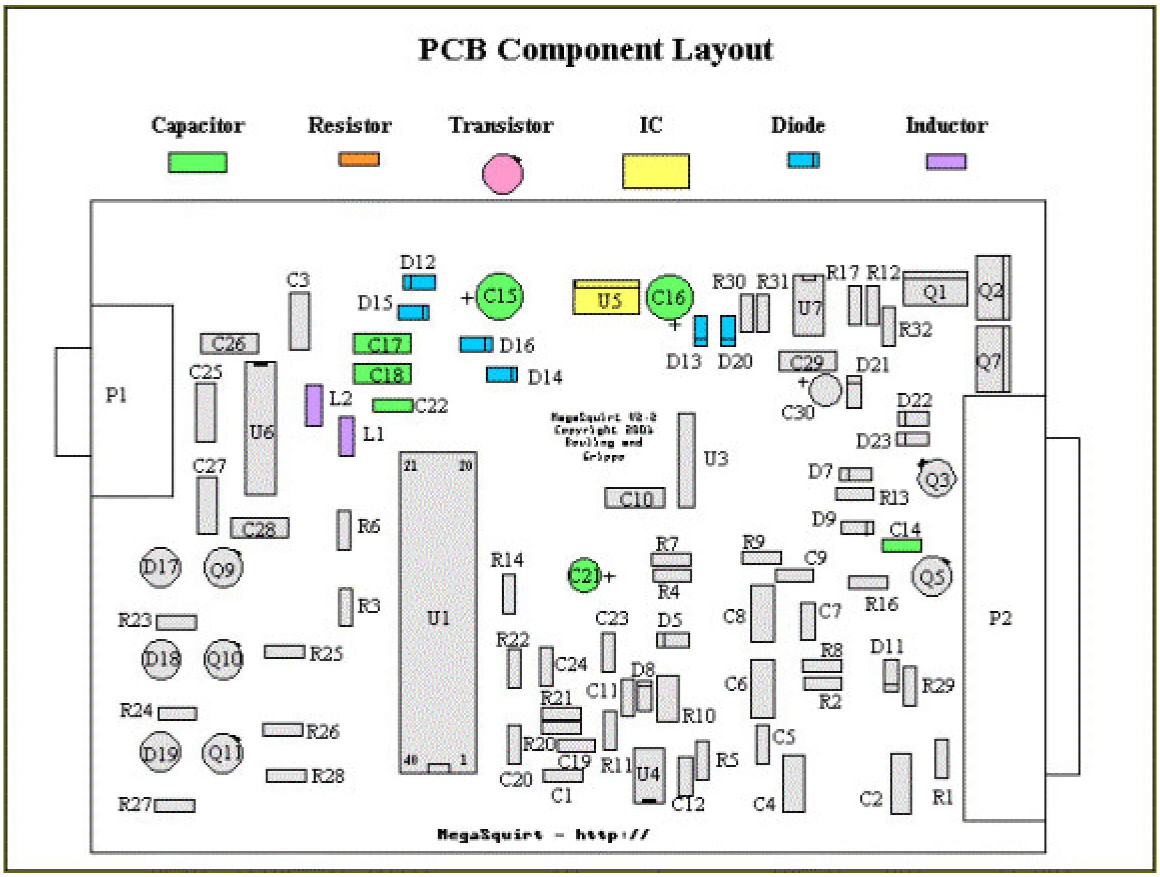
Power Supply Construction and Testing	(steps 1-19)
Serial Communications Construction and Testing	(steps 20-22)
Clock Circuit Construction and Testing	(steps 23-36)
Input Section Construction and Testing	(steps 37-56)
Output Section Construction and Testing	(steps 57-72)
Stimulator Assembly	(steps 73-80)

Each of these will be covered in turn.

Power Supply Construction & Testing

1. Get ready for assembling your MegaSquirt. Plan on 4 to 5 hours for the average person with average skills doing a first time assembly.

a. Familiarize yourself with the PCB, schematic, BOM, and this assembly guide - make sure you have everything available to assemble your MegaSquirt. The following colour coded diagram shows all of the components as they are laid out on the PCB. This can make it easier to find the proper locations, especially when the board is half done and some of the labels are hard to see. However, always verify the correct location on the PCB before assembling parts.



b. Trial fit your PCB in the enclosure before soldering anything to it. Your printed circuit board (PCB) might be slightly too wide and too long to fit into the case properly. It is designed to be 6.00" long by 4.00" wide (152.4mm x 101.6mm). The PCB manufactu rer allows some tolerance, so some boards might not quite fit without a little filing. Check the width first. Note that you have to slide the board in perfectly straight or it will bind, even if it is the correct size. If you still cannot slide the board in, deburring the box sometimes makes all the difference. The boards bind if the edges are sharp, but slip right in when cleaned up. If this still does not work, then before soldering anything to the boards file the sides down a bit. Use a 12" (30cm) finishing file. Slide the board back and forth on both long sides for about 30 seconds. (If you do not have your case yet, you can proceed and check the sizes later, it will just be a more delicate job).

Note: you should also check the length of the board in the case. Slide the board into the case. The 37 pin sub D connector mounting surface should be flush with the back of the case, look at the other side of the board (DB9 connector side) and see how much needs to be filed off so the cover can be mounted flush with the case. You may need to take as much as 0.025" (0.6mm) off the side, which may take up to 60 seconds of work with the file. When you are done the board should fit nice and snug.

2. Install and solder the DB-37 header (**P2**) {*A23289-ND*} on the PCB. Solder all of the pins to give the headers the maximum physical strength. Make sure you do not bridge adjacent pins with solder.

Then install and solder the DB-9 header (**P1**) {*A23305-ND*}.

3. Next, install the 40-pin DIP socket {*AE7240-ND* (or *A9440-ND*)} for the processor - notice that the notch installs near the bottom of the board, corresponding to the PCB silkscreen. Carefully solder the socket, and check each solder joint for shorts or cold joints.

4. Next, you are going to install the components that make up the power supply, and then verify operation. The first part to install is capacitor **C14** (*399-1818-1-ND*, 0.001µf, 102 marking).

Capacitor Identification

Capacitors may be marked directly with their capacitance. If not, they are frequently marked with numbers like:

104 K50 or 152 K100

The first two numbers are multiplied by ten to the power of the third number to getting the picofarad capacitance.

For example, since 10 to the fourth power is 10^4 = 10 x 10 x 10 x 10 = 10,000, the first capacitor would be 10*10,000 = 100,000pF = 0.1µF, since 1,000,000pF = 1µF.

The second capacitor would be 15 x 10^2 = 15 x 100 = 1500pF = .0015µF.

The upper case letter indicates the tolerance, M = 20%, K = 10%, J = 5%, H = 2.5% and F = ± 1pF. The last numbers are the rated voltage, 50 and 100 volts in these cases.

Note: Many of the component leads will have to be bent to go into the holes, use round-jawed pliers for this. The part ordering does not follow strict numerical increments, so there are gaps in the numbers - do not be concerned by this. If you follow this step-by-step assembly guide, then you will not even notice. As mentioned before, do not be concerned if you have extra resistors left after assembling your MegaSquirt. This is normal due to the Digi-Key minimum ordering quantities for some items.

5. Install and solder diode **D14** {*1N4001DICT-ND*} - make sure banded end is installed correctly as per board.

6. Install and solder diode **D16** (*1N4742AMSCT-ND*, 12 volt zener, 1N4742 marking) - make sure banded end is installed correctly as per board.

7. Install and solder **D13** {*1N4001DICT-ND*} - make sure banded end is installed correctly as per board.

8. Install and solder **D15** (*1N4749AMSCT-ND*, 24 volt zener) - make sure banded end is installed correctly as shown on the printed circuit board.

	Positive is:	
Capacitors:	**LEDs:**	**Diodes:**
the longer lead on polarized capacitors (not all are), sometimes marked with a small +	the longer lead on LEDs, and the lead opposite the 'flat" on the case.	the end FURTHEST from the band.

9. Install and solder **C15** (*P2051-ND*, a tantalum capacitor, 22 microfarads (µf)) - make sure polarity is observed. It has a small "+" near the positive lead. The longer lead is also always the positive lead.

10. Install and solder **D12** {*1N4001DICT-ND*} - make sure banded end is installed correctly as per board.

11. Install and solder **C16** (*P2051-ND*, tantalum, 22µf) - make sure polarity is observed. The longer lead is positive on all of the capacitors.

12. Install and solder **C17** (*399-1880-1-ND*, 0.1µf, 104 marking).

13. Install and solder **L1** (*M7010-ND*, inductor, 1uh, small coil of wire with leads). Space the inductor about 1/8" (3mm) off the PCB to avoid sorts on the traces underneath.

14. Install and solder **L2** (*M7010-ND*, inductor, 1uh). Space the inductor about 1/8" (3mm) off the PCB to avoid sorts on the traces underneath.

15. Install and solder **C18** (*399-1880-1-ND*, 0.1µf capacitor, 104 marking).

16. Install and solder **C22** (*399-1880-1-ND*, 0.1µf capacitor, 104 marking).

17. Install and solder **C21** (*P2047-ND*, 4.7µf electrolytic) - make sure polarity is observed.

18. Install the voltage regulator **U5** {*LM2937ET-5.0-ND*}. This part installs on the underside of the board, on the silver pad near the center of the board. Use heat-sink compound on the tab, and use the nylon screw and nut to fasten to the PCB. The leads go through the board and are soldered on the top side.

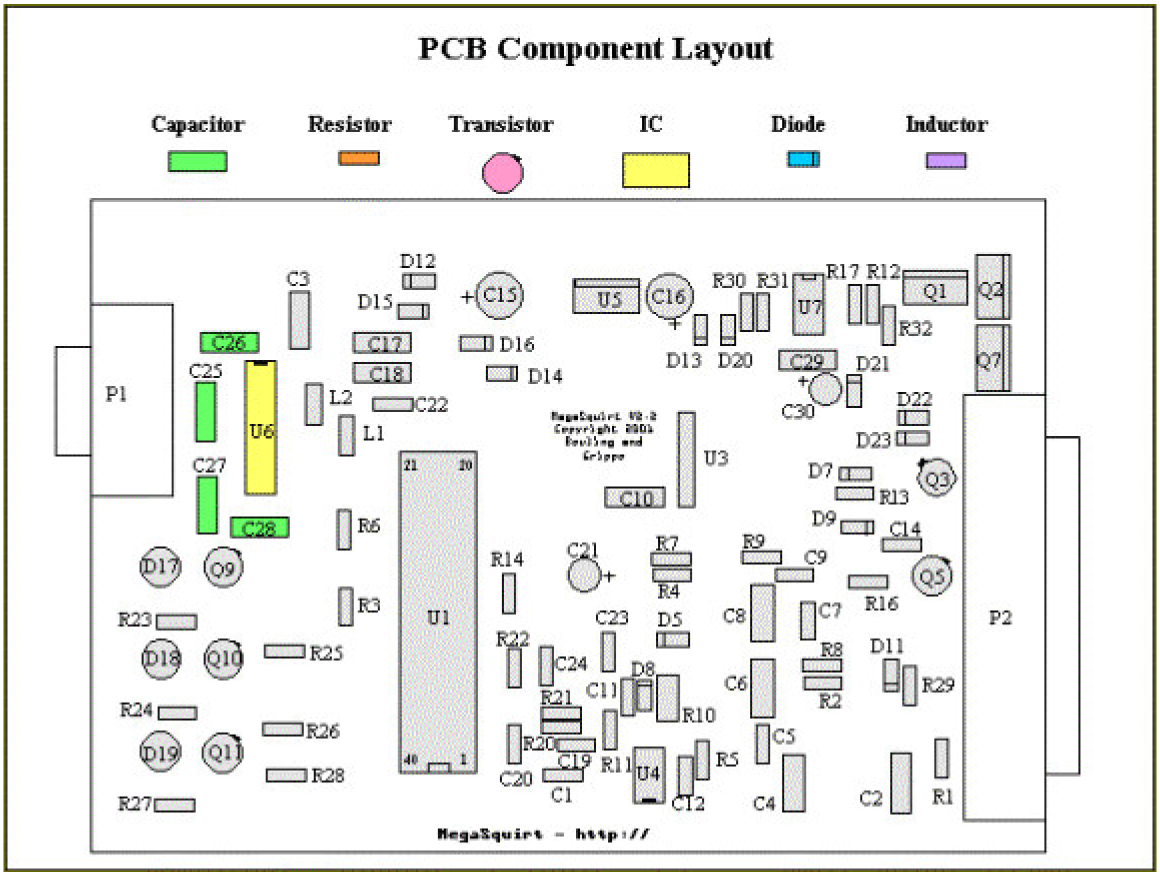
19. You now have the power supply assembled. Before you go any further, you are going to verify that the supply is operational. To test, install a battery in the stimulator, and plug it into the DB-37 connector on the ECU board. Next, using a DMM (digital multi-meter) on DC VOLTS setting, check for 5 volts on the 40-pin processor socket (which is empty). There should be 5 volts between pins 19 (ground) and 20 (+5). There should also be +5 on pin 1 and 31 (check against ground at pin 19), and ground potential on pins 2 and 32 (check against +5V on pin 20). An easy way to probe this is by using a component lead that you cut from one of the resistors and wrapping around the DMM probe tip, then plugging into the socket.

Remember that pin #1 on the 40-pin socket is on the lower right (at the same end with the notch), then goes up the 20 pins on that side, then over to the other side top, then down - it traces a counter-clockwise circle.

Check each box below as you measure the voltage between the ground pins across the top and the +5 pins down the left. You should get a voltage between 4.7 to 5.3 volts in each case (if your multimeter is accurate). Unplug the stimulator when finished.

Pin	**2**	**19**	**32**
1	____	____	____
20	____	____	____
31	____	____	____

Serial Communications Construction & Testing



20. Next, you are going to assemble the serial port link and verify operation. First step, install capacitors **C25, C26, C27,** and **C28**, (all *399-1880-1-ND*, 0.1µf, 104 marking) by soldering them in the appropriate locations.

21. Next, solder the **U6** {*MAX232CPE-ND*} - note the proper orientation on the silk-screening, be sure to install in the proper direction. Solder it in place.

22. You now have enough to test the serial link. Do the following steps to verify operation:

A. Using an ohmmeter, verify that your DB-9 serial cable is truly a pass-through and not a null modem. All DB connectors have the pin numbers moulded into the plastic insulation around the pin holes on both male and female ends. The numbers are quite small and you may need a flashlight and magnifier to see them, but they are there. Check that pin 2 on one end is connected to pin 2 on the other end, then do the same check for pins 3 and 5. If all these check out, you can proceed, otherwise you need to get a different cable.

If your laptop has a DB-25 serial port, rather than a DB-9, you can use a DB-9 to DB-25 adapter, available from most computer stores. For the rare DB-25 PC port, a "straight through" connection has pins 2, 3 and 7 (two, three and seven) on the DB-25 connected to pins 3, 2 and 5 (three, two and five) on the DB-9, respectively.

If you do not have a serial port (some newer computers do not), you may be able to use a USB port. The USB port on your computer cannot be wired to a DB-9 connector directly. You can buy an USB adapter, which may work with MegaSquirt. It is more expensive than the simple adapter solution. There have been some reports of problems when using a USB to RS232 adapter, though a few people have managed to make them work. One that some people have had success with is at: http://www.sewelldev.com/USBtoSerial.asp

Others have found that the Keyspan USB to Serial Adapter model number USA-19 QW works. You have to download the new driver and go to the Keyspan Serial Assistant. In it you have to change the baud rate to 9600 and the Com port to 1. The default is 6.

B. Connect the serial cable to your computer, but not to the MegaSquirt ECU yet. Use an alligator clip or something similar to jumper pins 2 and 3 on the loose end of the cable. This provides a loopback circuit to verify the operation of your computer and the cable without involving the MegaSquirt hardware yet.

C. On the PC, find and run HyperTerminal (HyperTerminal is usually under Start/Programs/Accessories/Communications, but if it is not there then search for a file called 'hyperterm.exe'). If you do not have HyperTerminal installed, you can get it from Hilgraeve (www.hilgraeve.com/htpe/htpe63.exe), who wrote the original for Microsoft Windows. HyperTerminal Private Edition (HTPE) is what you want, and it is free for personal use.

D. When Hyperterm appears, click on the red telephone icon, and enter a save file name (anything you want, say, "megasquirt").

E. When the "Connect To" dialog comes up, select under the "Connect Using" option the COM port to which the DB-9 cable is connected, i.e., COM1 or COM2. Do not worry about any of the other settings. Click OK.

F. Next, a dialog window opens with baud rate, stop bits, etc. Set the values according to the table below. Note: the last one, **Flow Control**, is very important – be sure to set it to **None**. Click OK.

Baud Rate	9600
Data Bits	8
Stop Bits	1
Flow Control	None

G. The HyperTerminal now is up and "connected."

H. Type any character - it should be echoed back to the screen, i.e. you will see it once if you do not have local echo enabled, twice if you do - if it appears on the screen then the link is working. If not, then check the cable connections and try different COM ports. You must see characters echoed correctly before you move on.

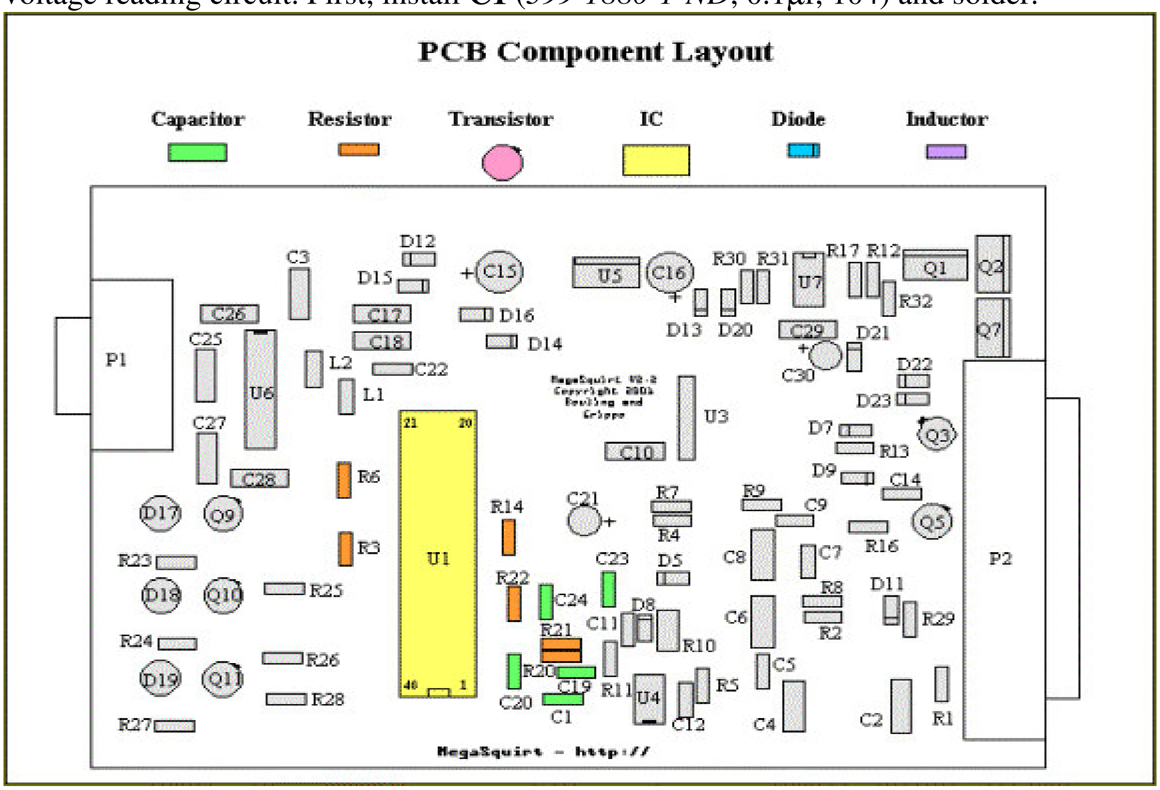
Once the connection is working with the cable loopback, it is time to connect the DB-9 cable to the MegaSquirt ECU. Remove the jumper on the loose end of the cable and plug it in to the MegaSquirt DB-9 connection.

J. Using a snipped-off component lead (the loose end from a resistor or capacitor, smaller is better to avoid damaging the socket), jumper pins 12 and 13 on the 40-pin processor socket so that a direct short is the result. This allows a full loopback test, all data sent to pin 13 is returned back on pin 12 through the MAX232 chip and all related communications circuits on the board.

K. Finally, plug in the stimulator to the MegaSquirt to power the board up. Again, type any character and again it should be echoed back to the screen. If characters appear on the screen then everything is fine, if not, then check solder joints on the sockets and components, verify voltages at the MAX232 chip connections and so on.

Clock Circuit Construction & Testing

23. Next, you are going to assemble clock circuit for the processor as well as the battery voltage reading circuit. First, install **C1** (*399-1880-1-ND*, 0.1µf, 104) and solder.



24. Install and solder **C19** (*399-1877-1-ND*, 0.033µf, 333 marking).

25. Install and solder **C20** (*399-1868-1-ND*, 0.01µf, 103 marking).

26. Install and solder **C23** (*338-1053-ND*, 47 pf, 47 marking).

27. Install and solder **C24** (*338-1051-ND*, 20 pf, 20 marking).

Resistor Band Color Reference					
Color	**Color**	**Band 1**	**Band 2**	**Multiplier**	**Tolerance**
Black		0	0	x 1	not used
Brown		1	1	x 10	not used
Red		2	2	x 100	not used
Orange		3	3	x 1000 = 1K	not used
Yellow		4	4	x 10000 = 10K	not used
Green		5	5	x 100000 = 100K	not used
Blue		6	6	x 1000000 = 1M	not used
Violet		7	7	not used	not used
Gray		8	8	not used	not used
White		9	9	not used	not used
Gold		not used	not used	divide by 10	= 5%
Silver		not used	Band 2	divide by 100	= 10%
None	X	not used	not used	not used	= 20%

28. Install and solder **R14** and **R20** (*10KQBK-ND*, 10K, brown-black-orange).

29. Install and solder **R21** (*100KQBK-ND*, 100K, brown-black-yellow).

30. Install and solder **R22** (*10MQBK-ND*, 10M, brown-black-blue).

31. Install and solder **R3** (*51KQBK-ND*, 51K, yellow-white-white-red-brown).

32. Install and solder **R6** (*10KQBK-ND*, 10K, brown-black-orange).

33. Install and solder **Y1** (*300-1002-ND*, 32768 Hz crystal, the very small silver can with the tiny wires). Bend the leads at a 90-degree angle so that the crystal lies flat on the

PCB. (Note that Y1 is not show in the diagram above for space reasons, it is located between C23 and C24.)

Note: You may want to "glue" the crystal to the printed circuit board with a cushion of silicone rubber adhesive (RTV). A small "blob" on the underside of the crystal will cushion the crystal and dampen any mechanical vibrations.

34. Insert the CPU **U1** into the socket - the notch faces downward (line up with silkscreen and socket notch). You may have to bend the leads inward a bit to get it into the socket - be careful not to break one off.

Note that bending the CPU leads can be tricky. Your objective is to have the width of the CPU leads exactly match the width of the socket pins, precisely 0.6 inches, before you attempt to firmly push the CPU into the socket. Ideally, you want to bend all pins at the same time. One technique is to hold the CPU with your thumb and index finger of each hand, so that one side of all the pins are against a rigid flat surface. Your thumbs are on the top of the CPU at each end and your index finger is underneath between the pins. By firmly tilting the CPU against the flat surface you will bend all the leads on one side of the CPU. Go slowly, a mini bend of a few degrees each time. Be careful not to bend the pins too far. Make several checks for fit in the socket as you go along. If you are having a difficult time visualizing this technique, place the CPU on a flat surface as if it were in the socket. Now turn the CPU up 90 degrees so that it is standing on the flat side of half its pins.

A second method to bend all the CPU pins at once is to use an extra long needle nose pliers and grab all the pins at once. A twisting motion applied to the pliers will bend all the pins simultaneously. With care, this will also work if the needle nose pliers are only long enough to grab half the pins. Just make the bends in two steps.

35. You are now ready to test the operation of the processor. Plug in the DB-9 serial cable into the board and to the PC. On the PC, run PC Configurator. Go into the "Communications" window and select the proper COM port (the "Verify ECU operation" does not operate, so do not be fooled). Exit this screen (back to the main window). Note: If your com port is on COM5, you will notice that the Configurator only offers COM1 through COM4. Modify the configuration file so that the first line says "COM5". (Use Wordpad, Notepad or something similar, be sure to save as a plain text file.) For PCC this file is "megasquirt.cfg", for MegaTune it is "megatune.cfg".

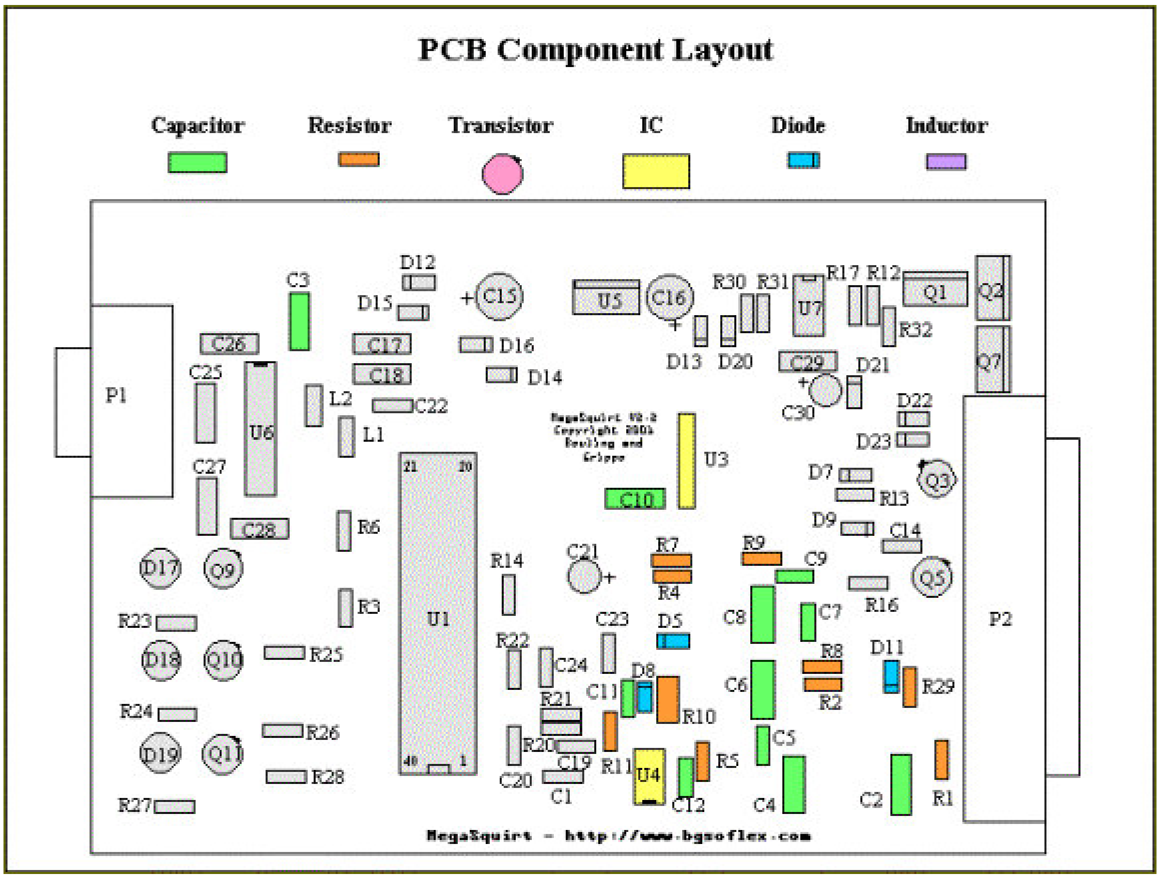
36. Plug in the stimulator into the ECU. On the PC, click the "Runtime Display" button, which brings up a new screen. Look at the "Seconds" box - it should be counting up, incrementing every second (it will roll over at the value of 255, back to zero). If the seconds count, you are running! If not, check the cable, make sure there is power, and check the COM port. The only other parameter that will read correctly is the "Batt V" box

- it should be displaying the battery voltage (from about 7.0 - 8.5 volts, depending on the 9-volt battery condition). All other boxes will have nonsense for numbers.

Input Section Construction & Testing

37. Remove the processor from the 40-pin socket - use a thin screwdriver and pry it from the socket, first one end, then the other - place back on foam pad.

38. Now, you are going to install all of the input sensor components. First, install and solder **C3** (*399-1880-1-ND*, 0.1µf, 104 marking).



39. Install and solder **C5, C7,** and **C9** (*399-1818-1-ND*, 0.001µf, 102 marking).

40. Install and solder **C11** (*399-1868-1-ND*, 0.01µf, 103 marking).

41. Install and solder **C2, C4** and **C10** (*399-1882-1-ND*, 0.22µf, 224 marking).

42. Install and solder **C6** and **C8** (*399-1887-1-ND*, 1.0µf, 105 marking).

43. Install and solder **R5** and **R8** (*2.2KQBK-ND*, 2.2K, red-red-red).

44. Install and solder **R1, R2,** and **R9** (*1.0KQBK-ND*, 1K, brown-black-red).

45. Install and solder **R11** (*4.7KQBK-ND*, 4.7k, yellow-violet-red).

46. Install and solder **R29** (*1.0MQBK-ND*, 1M, red-black-black-yellow-red).

47. Install and solder **R10** (*390H-ND*, 390 ohm, ½ watt, orange-white-brown). This resistor should be mounted roughly 1/8" (2mm) above the surface of the PCB. Also, the value of this resistor may have to be changed depending on application - start with this value, and if gets hot while the engine is running, then increase the value, in steps, up to 1K (like 470 ohms, 560 ohms, 680 ohms, 1K).

48. Install and solder **D5** {*1N4001DICT-ND*}. This is the infamous Wing Diode - you will want this (reduces tach signal false-triggering).

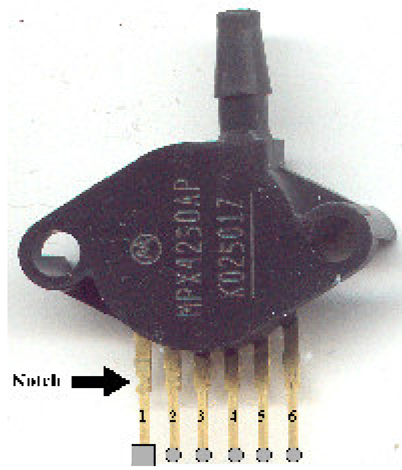
49. For most installations, diode **D8** (*1N4733AMSCT-ND*, John Zener, 5.1V, marked 1N4733) is not needed.

Note: this diode (D8) is needed if the ignition system has a large offset bias - most systems do not have such a bias. To start, you can either solder in a jumper wire in this location, or, you can install the diode D8, and then install a jumper around the two leads of the diode - in effect shorting it out. The latter will allow you to snip the jumper later on if needed, putting the diode back in circuit. Solder the diode in observing the banded end is per the board, then solder a wire jumper across the diode itself.

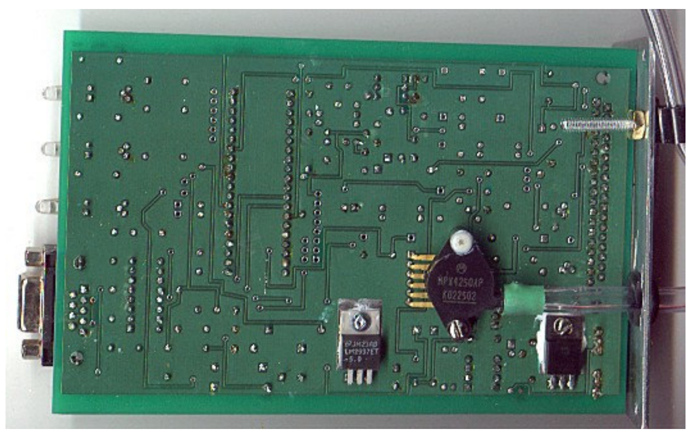
50. Install/solder opto-isolator **U4** (*160-1300-5-ND*, 4N25) - observe the proper orientation (**notch** matches PCB, or **dot** for pin #1 which is the square pad on PCB at the notched end of the silkscreen).

51. Install and solder **C12**, the Ed capacitor (*399-1818-1-ND*, 0.001µf, 102 marking). The value of this capacitor may need to be increased if there are noise problems with the tach signal - values up to 0.1uf will work. The 0.001uf value is a good starting point.

52. The MAP sensor, **U3** (MPX4250AP), is next. It mounts on the underside of the PCB, with the vacuum port facing the DB37 connector, and the markings on the sensor facing away from the PCB. The leads are bent toward the PCB, and soldered on the top side. The notch on the lead indicates pin #1 - this corresponds to the square pad on the PCB.



Here is how the MAP sensor should look in a fully assembled unit.



The MAP sensor is held to the PCB with two nylon screws - do not tighten the MAP sensor too tight, this will distort the case and introduce an offset in the readings by flexing the load cell inside the device. And, yes, solder the leads on the top side of the PCB. You will have to devise a scheme to run a tube from the barbed MAP fitting to your intake manifold.

Note: if you do not like the idea of mounting the MAP sensor on the PCB in the passenger compartment, and the long vacuum hose, because you feel it will cause a delay in engine response, you can remotely mount the MAP sensor. Bruce has tested this with about 30 feet of 1/8" tubing and almost no lag, certainly no more than 1 millisecond.

If you mount the MegaSquirt inside of the passenger compartment (inside firewall), then the length of tubing is only about 3 - 4 feet. Additionally, if one figures that many MAP sensor installs have the sensor mounted on the firewall on the passenger side near the heater core (many General Motors, Toyota, Nissan, etc. do this), then compare the extra length of tubing to go through the firewall to the MegaSquirt, it is not a large difference.

If you want to remotely mount the MAP sensor, use one of the unused connector pins for the MAP signal, there is Vref and ground coming out already for the TPS which you can share with the MAP sensor. The V2.2 boards have jumper "holes" to the output connector unused pins - you can use one to bring the MAP signal out quite easily. If you do remote-mount the sensor, be sure not to put any type of strain on the MAP sensor case - according to Motorola this can introduce DC offsets in the readings.

53. Install and solder **R4** and **R7** (*2.49KXBK-ND*, 2.49K, red-yellow-white-brown-brown).

Note: these are the two bias resistors that can be changed for use with different coolant (R7) and air temperature (R4) sensors. The 2.49K values are for the standard GM sensors (#12146312). If you want to use other sensors, you can either change the transfer-function files in the ECU processor (Use EasyTherm to change the controller code to match your temperature sensors), or switch these resistors, which may be easier in some cases. Changing resistors allows you to mix and match sensor types between air and coolant (e.g., use a Ford for air and a GM for coolant).

Sensor	Makes	Resistor (ohms)
AC Delco/GM	Daewoo, Buick, Cadillac, Chevrolet, Oldsmobile, Pontiac, GMC	**2.49K**
Ford	Ford, Lincoln, Mercury	**27K**
Bosch and Nippon Denso	Acura, Audi, BMW, Honda, Infiniti, Jaguar, Kia, Lexus, Mazda, Mitsubishi, Nissan, Suzuki, Toyota, Volkswagen, Volvo (96-up)	**2.2K**
Mopar	Chrysler, Dodge, Plymouth	**9.31K**

It is important to note that cross branding and cross licensing affect the sensor type. For example, the Mercury Villager is actually a Nissan Quest. The Ford Probe is actually a Mazda. The Chevy Sprint was actually a Suzuki Swift. There are many other examples. When in doubt, measure the resistance.

To avoid changing the tables in the controller code, the bias resistor should have a value equal to that of the thermistor sensor you will be using when it is at **81**° Fahrenheit, **27º** Celsius. However, the preferred method is to use EasyTherm whenever possible.

54. Now, it is choice time again, this time regarding the opto-isolator installed at U4. The LED inside of the opto-isolator is fired by a signal provided by the ignition system. The pulses existing on an ignition, especially when pulled directly off the coil primary, can spike to very high voltages. The return path of the LED is terminated to jumper pad XG1. This return path can either go directly to the board ground (by placing a jumper from XG1 to XG2), or, the return can be brought out of one of the jumper slots on the DB-37 connector (like X11), and then grounded with a separate wire on the DB-37 connector,

thus isolating the ground. Note: for the ECU to work on the stimulator, then the XG1 terminal needs to be hooked to XG2, and right now we are doing stimulator testing, so install a jumper from XG1 to XG2. Now, when you install the ECU, if you need isolation because the tach signal is resetting the ECU (for those installs tapping right off of the ignition coil (-) terminal), then you can remove this jumper and connect XG1 to X11, and ground this pin (#25 for X11) with a separate return wire. Note: if you are using a tach output from an aftermarket or many OEM setups, the tach signal is a nice +12V pulse - these will work fine with the XG1 terminal jumpered to XG2 in the install. Again: for testing right with the stimulator, hook XG1 to XG2. Later, after you install this on your vehicle, if you have reset problems, then remove this jumper and jumper XG1 to X11, and bring out a separate return ground wire.

Some installations have reported problems with low rpm "spikes". Typically this sees the reported rpm at 1100 rpm jump to 5000+ rpm for short periods. This can make idle and off-idle tuning difficult. To fix this, try the "Dave" capacitor. This is a 0.22µf cap across the junction of D5/R10 to XG1. (See the ignition triggering section of the Tuning section of this manual for details).

55. Install and solder **D11** (*1N4733AMSCT-ND*, 5.1 Zener diode, marked 1N4733).

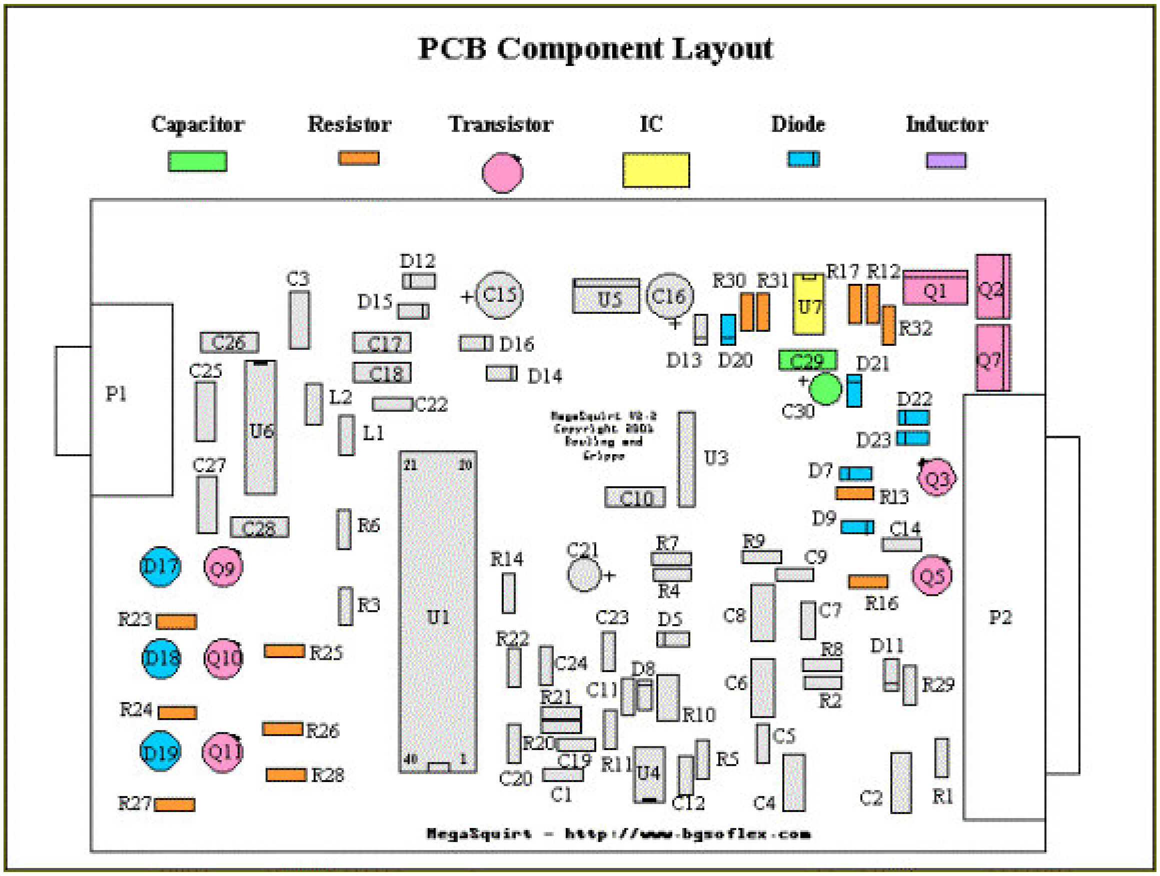
Note: diodes D1, D2, D3, & D4 are not installed - do not place jumpers in their place, just leave these locations open. The processor provides sufficient input protection, these diode are not needed. Motorola has confirmed that the MC68HC908GP32 has protection diodes on the inputs of the Analog-to-Digital Converter channels, and these are sufficient to prevent voltage spikes from damaging the processor or ADC channels.

56. Time for a little testing. Install the processor, hook up the stimulator, hook up the DB-9 to the board and PC, fire up PC Configurator, and bring up the "Runtime" screen. You should be able to see responses when you move the knobs on the stimulator. First, look at the RPM - it should change when you move the RPM pots on the stimulator. All sensors should react to the corresponding pots on the stimulator. When the O2 pot is moved, the O2 voltage moves irrespective of the other settings. The O2 voltage (top bar on the MegaTune Runtime dialog) is just the raw data coming in. On the other hand, the EGO correction bar (or equivalent gauge on the tuning screen) WILL NOT move away from 100% unless you have the EGO correction parameters set properly and MegaSquirt senses the proper inputs to activate EGO correction. Note that if you have not connected a TPS to your MegaSquirt, (testing in car, for example) the TPS value will slowly creep up to a maximum value, and O2 correction will be disabled.

You now have all of the inputs wired up. Next we are going to hook up the outputs and machine the case panels. Unhook the stimulator and DB-9 cable from the board, and remove the processor again.

Output Section Construction & Testing

57. Install and solder **R30** and **R31** (*10KQBK-ND*, 10K ohm, brown-black-orange).



58. Install and solder **R13, R16, R25, R26,** and **R28** (*1.0KQBK-ND*, 1K ohm, brown-black-red).

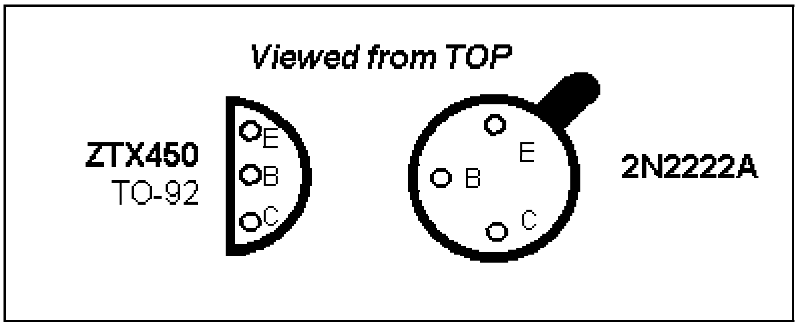
59. Install and solder **D7, D9, D20, D22,** and **D23** {*1N4001DICT-ND*} - observe the proper polarity.

60. Install and solder **R12** and **R17** (*22QBK-ND*, 22 ohm, red-red-black).

61. Install and solder **R23, R24,** and **R27** (*330QBK-ND*, 330 ohm, orange-orange-brown).

62. Install and solder the transistors **Q3, Q5, Q9, Q10,** and **Q11** {*PN2222AD26ZCT-ND* or *ZTX450-ND*}.

Note: Digi-Key parts kits use PN2222A or ZTX450 as a drop-in replacement for the 2N2222A used in the group buy #1 and #2. The package is different (TO-92) such that the leads are in-lined, but it is in the "E-B-C" order just like the 2N2222A. For the metal-can 2N2222A, if you hold the device, looking from the top, with the tab pointing towards the 2:00 position on the clock, the emitter is at 12:00, the base is at 9:00, and the collector is at 6:00. For the PN2222A/ZTX450, if you hold the flat side facing 9:00 on the clock, looking from the top again, the emitter is on the top or 12:00 position, the base is in the center, and the collector is down at 6:00. Simply bend out the center lead towards the flat side (towards the 9:00 position) and the part will drop right in the hole. It is very important to space the transistors 1/8" to ¼" off the surface of the PCB, to prevent shorting of the traces below.



If you use any other transistor other than PN2222AD26ZCT-ND or ZTX450-ND from the MegaSquirt/Digi-Key parts ordering page, you MUST check the pin orientation, as the order can be different for apparently identical parts!

63. Install **C29** (*399-1880-1-ND*, 0.1µf, 104) - and solder.

64. Install and solder **C30** (*P2047-ND*, 4.7µf), observe polarity. Recall that the longer lead on the capacitor is the positive lead.

65. Install and solder **D21** (*1N4753AMSCT-ND*, 36V Zener, 1N4753). Mount this one 1/8 - ¼ off of the surface of the board. This Zener diode sets the flyback breakdown voltage.

66. Install/solder **Q1** (*TIP32CFS-ND*, PNP power transistor, TO-220 package, TIP32C). This part installs on the bottom-side of the PCB, in the remaining "silver pad" area near the top corner of the PCB. Use heat-sink compound here on the tab, we want a good heat conduction path to the ground plane. Use the nylon screw/nut to mount. Solder on the top-side of the PCB.

67. Install and solder **R32** (*270H-ND*, 270 ohm, ½ watt). This resistor is mounted ¼" to ½" off of the PCB - you may have to do a little bending to get it to fit in the holes. When the ECU is installed in the vehicle, we will monitor this resistor (like the tach resistor) to make sure it does not get too hot for your application - if it does, then the value can be increased, or the zener D21 can be replaced with a lower breakdown value.

68. Install and solder **U7** (34151/IXDI404PI) FET driver.

We now have everything installed, other than the FETs and the LEDs - these mount on the case ends. We need to cut these out before we can proceed with the assembly.

If you do not want to cut your own endplates, you can get them CNC-made from Front Panel Express (http://www.frontpanelexpress.com/). Download their Frontpanel designer software at:

http://www.frontpanelexpress.com/download/index.htm

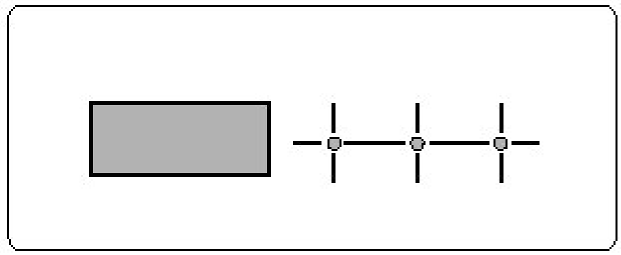
Then use the following files:

	Bowling and Grippo Panels
Front Panel:	http://www.bgsoflex.com/msfront.fpd
Rear Panel:	http://www.bgsoflex.com/msback.fpd
	Colin Gebhart - Revised Panels
Front Panel:	http://www.thegebharts.com/colinmsfront2.fpd
Rear Panel:	http://www.thegebharts.com/colinmsback2.fpd
	Bare Bones Panels
Front Panel:	http://www.megasquirt.info/msfront.fpd
Rear Panel:	http://www.megasquirt.info/msback.fpd

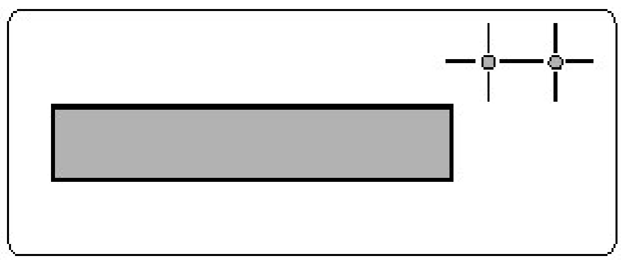
The Frontpanel Designer software lets you modify the files, get an exact quote, and send the order over the Internet. It is a very nice system.

To cut the end plates for the MegaSquirt yourself, do the following:

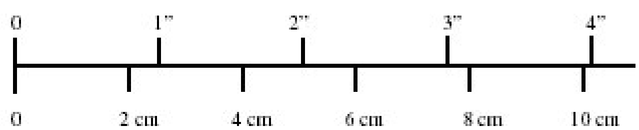
a. Print out the template below, and use it as a cutting guide (Please Note: *.PDF files do not maintain size integrity. Verify printed sizes before cutting!).



Front Panel Cut-out Template
LED Hole Size = 1/4 inch = *6mm*
DB-9 cut-out is 1.23" x 0.50" (~*31mm x ~13mm*)



Back Panel Cut-out Template
MOSFET Mounting Hole Size = 1/8" = *3mm*
DB-37 cut-out is 2.75" x 0.50" (~*70mm x ~13mm*)



Use a jigsaw to cut out the DB connector slots, or drill several smaller connected holes and file them out to a rectangle. Remove any burrs or rough edges with a file, especially around the FET mounting holes. Also, drill a hole for your MAP sensor vacuum line bulkhead fitting (You can get suitable 'fuel line" bulkhead fittings for R/C planes at your local hobby store. See http://www.mcnabs.com/ebay/bulkhead.jpg)

b. Stick the printout onto the case ends using double-sided tape (line them up in front of a bright light so you can get them exactly central).

c. Drill out the LED (¼") holes (make centre punch marks for the drill to start).

d. Drill a few holes in the DB connector squares to be cut.

e. Get hold of a piercing saw with a coarse blade (used in model making - looks like a G clamp with a blade where the screw thread goes)

f. Practice using piercing saw on something else if this is your first time!

g. Cut around the printout, leaving a small bit of extra material to file down later.

h. Remove tape and glue with white spirit

i. Clean up the connector openings with files. (Your cutting out probably was not good enough to leave it that way)

h. Drill whatever hole is required for the MAP sensor hose scheme you have devised.

(Steps a through d are a great start to the drill and file method, as you will have a layout to follow. You can also drill more holes and proceed directly to filing the openings, if you prefer. The aluminum is very soft, and files quickly and easily).

69. Now, take one of the case halves, and run the PCB in the second-down slot down from the top.

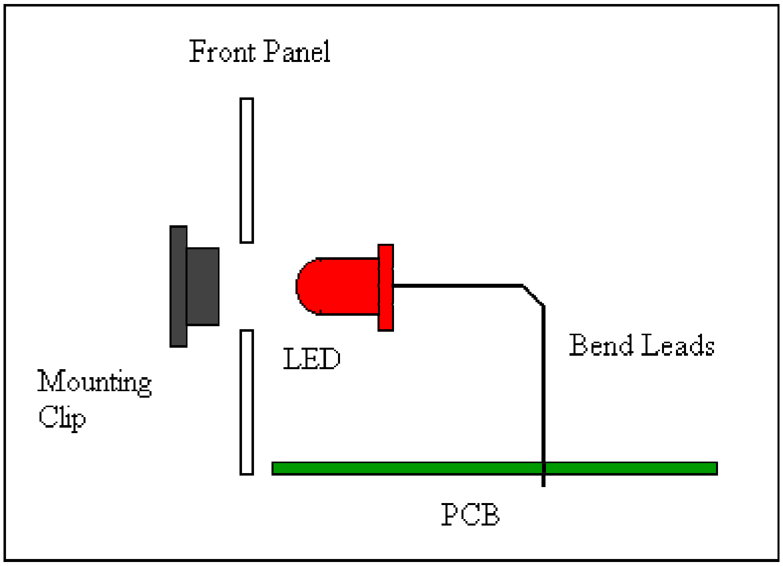
Note: you will want to orient the lip/slot on the top rail section of the case half such that the lip is on top and the slot is on the bottom (closer to the processor). In other words, the section halves of the case, where they join, have a lip on one side and a ridge on the other, to form the interlock. The other side has the opposite. The top side of the PCB (side with C15, the FET driver, etc) goes where the "lip" is.

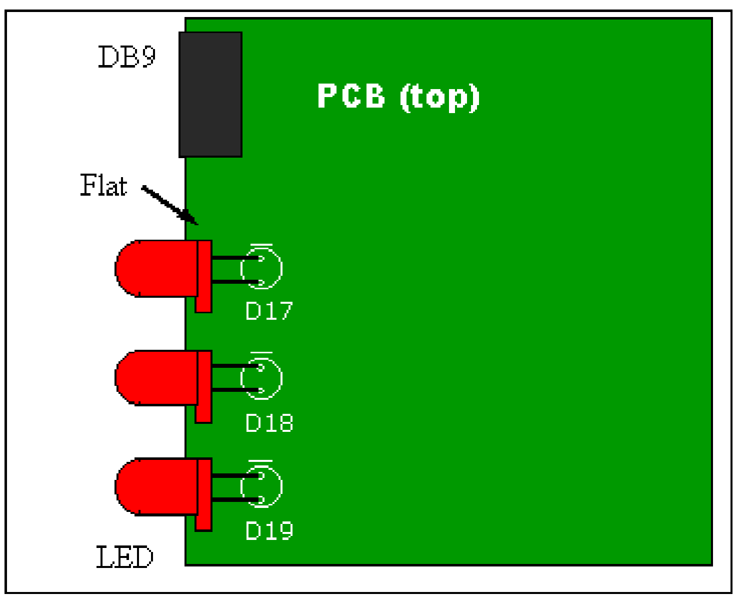
This gives more room for the FETs - if oriented the other way around, the groove may put stress on the side of the FET.

70. Next, mount the LEDs - **D17, D18,** and **D19** {*P301-ND*} to the case font, and bend the leads down to the board and solder. First, install the LED holders on the front panel, through the front.

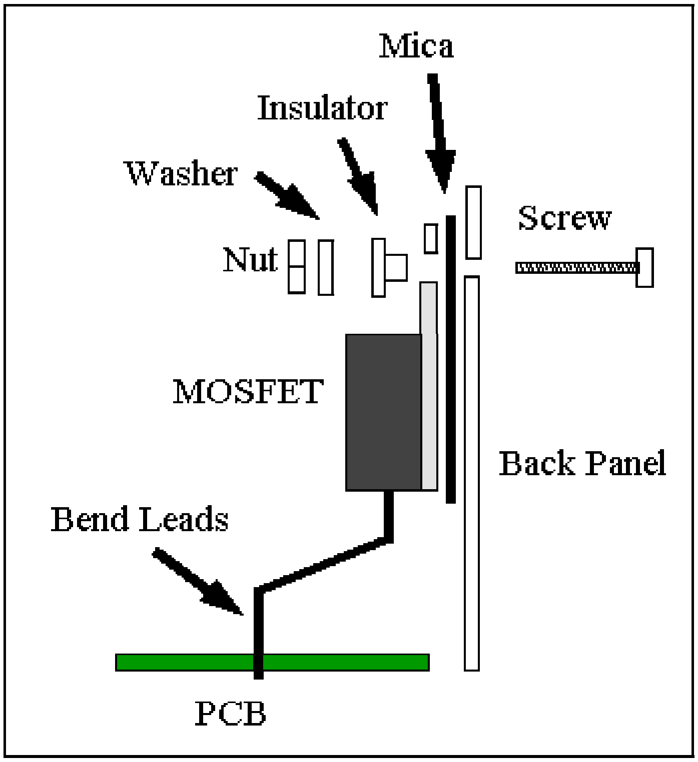
The LEDs press into the rear of the holder. Mount the case front panel to the case half (which has the PCB). Orient the FLAT on the side of the LED lip (the side with the shorter lead) towards the DB-9 socket (each LED). You will see that the PCB silkscreen also has a "dash" above the LED circle symbol indicating the side of the flat.

Bend the LED leads down to enter the PCB holes for them - you will have to do a trial fit, then trim the leads down a bit. See the illustrations below. Then solder the LEDs to the PCB from the top of the PCB. It is a little tricky - take your time.





71. Now, finally, its time to mount the two FETs - **Q2** and **Q7** {*IFRIZ34N-ND*}. If you received the plastic FET case variety (IRFIZ34N), then you can just screw them to the case. These are insulated case variety, so they just mount on the back panel. If you have substituted the metal-tab TO-220 type (IRFZ34N), then you need to use a mica insulator set-up to prevent the tab from touching the metal case back. Use the illustration below as a guide. (Insulating kits that include the mica, insulator, washer, nut, and screw are available from electronics shops for about $2).



72. In either case, the FETs mount on the back panel, held in with nylon screws/nuts. Be sure to apply heat-sink compound between the FET and the case. The leads are bent out from the FET at a 90-degree angle, and then bend the leads down to enter the holes in the PCB.

Assembling the Stimulator

Next, you need to assemble the stimulator to test your MegaSquirt.

Stimulator Parts Listing:

Part	Description
CLT	10k pot, black body
IAT	10k pot, black body
O2	10k pot, black body
TPS	10k pot, black body
RPMC	1M pot, green body
RPMF	50k pot, black body, marked 50k
C1	0.01 µF cap
C3	0.33 µF cap
C4	0.01 µF cap
R1	330 ohm res, 1/8 or 1/4W, orange orange brown
R2	33k ohm res, 1/4W, orange orange orange
R3	1.0k ohm res, 1/4W, brown black red
R4	1.3k ohm res, 1/4 W, brown orange red
R5	330 ohm res, 1/8 or 1/4W, orange orange brown
R6	330 ohm res, 1/8 or 1/4W, orange orange brown
R7	330 ohm res, 1/8 or 1/4W, orange orange brown
R8	1.0k ohm res, 1/4W, brown black red
R9	100 ohm res, 1/2W, brown black brown
IC1	LM555CN timer IC
T1	2N2222A NPN transistor
D1	red LED, fuel pump circuit indicator
D2	red LED, injector circuit 2 indicator
D3	red LED, injector circuit 1 indicator
D4	red LED, fast idle circuit indicator
F37	female DB37 connector
9V battery holder	
9V battery clip	
2 position terminal block	power input

73. Install and solder the **DB37 female connector** to the PCB.

74. Install and solder the **LED**s with flats facing the side of the board with the sensor stimulator pots. The LED leads may be tight in the PCB, this is okay - but use caution when inserting them. Needle nose pliers can help with this.

75. Install and solder the **potentiometers** (a.k.a. "pot"). The RPM circuit has both a coarse and fine control. The combination of the 1M (RPMC) and 50k (RPMF) pots allows precise setting of rpm.

Note that the PCB is marked "10K" on both the RPMF and RPMC pot locations, but this is an error. Do not use 10k pots in these locations. Use the 1M pot for RPMC, and the 50k pot for RPMF. The 10k and 50k pots look identical, however if you look closely on the bodies, you will find a **10k** or **50k** marking.

76. Install and solder all the **capacitors** in their respective locations as marked on the PCB.

77. Install and solder all the **resistors** in their respective locations as marked on the PCB.

78. Install and solder the battery **terminal block**, and attach the battery **clip** and **holder**. Pay attention to the polarity of the battery leads. Verify that the lead you connect to the positive terminal (+) is the positive leads from the battery using a voltmeter. Use the double sided tape to attach the battery clip to the PCB.

79. Install and solder the **transistor** (use the diagram in the MegaSquirt assembly manual [step 62]) to see how the leads should be arranged if you have the Digi-Key transistor - the flat side should face the TPS pot).

80. Install the **555 IC** in its locations as marked on the PCB. Pay careful attention to the orientation. The notch (and/or dot) on the chip goes at the end closest to C1.

The stimulator can be connected directly to MegaSquirt by removing the faceplate on the DB37 connector. *Not all connectors will need the faceplate removed, check first*. Otherwise, use an appropriate cable.

Note: Although there is a 9V battery clip and holder, this should only be used for quick checkout of the MegaSquirt. For extended use, an external 12V supply is recommended. Simply plug the power source into the terminal block taking care to get the polarity correct. The stimulator power supply goes directly to MegaSquirt, which returns 5V power the stimulators circuits. The stimulator will not operate independently, so there is no need to disconnect the battery after each session to avoid discharge.

Congratulations! You are ready to test it all! Plug in the MegaSquirt processor, DB-9 cable, and stimulator (with its battery attached).

On the stimulator, you should see the injector LEDs light up, tracking the RPM. Also, the fuel pump light should be glowing, and if you are above 500 RPM (check on the MegaTune Runtime display) and below 145 degree coolant temperature (adjust on the stimulator), the fast-idle LED should also glow.

On MegaSquirt:

- D17 will light each time an injector is fired.
- D18 is warm-up enrichment (WUE). It will light if you are in a warm-up situation (i.e. if the coolant pot on the stim is set to a value where the warm-up enrichment is greater than 100%).
- D19 is accel enrichment (AE). It will light briefly if you turn the TPS pot on the stim from idle to full throttle.

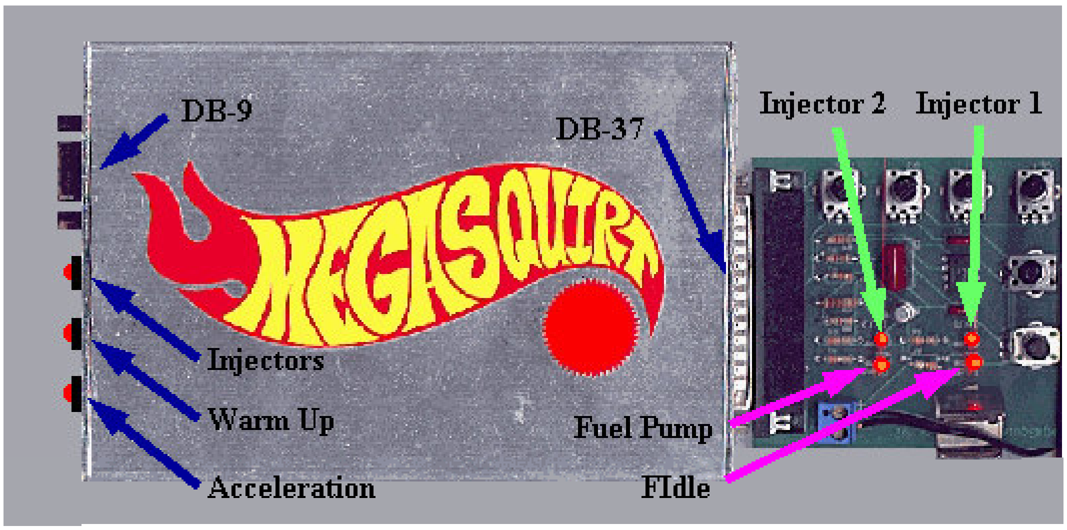
Note that stimulator resistor **R9** is heavily loaded in operation and will get very warm. If this becomes a concern for extended use, a change in value of one or more of C3, C4, R3, R4 can be made to lower the duty cycle of the tach circuit. See the LM555 datasheet for formulas to help determine these values.

Note: normal MAP readings in KPa for the MegaSquirt when the engine is not running (or is on the stimulator) should be somewhere around 95-103. If yours is around 47 kPa or 200 kPa, you have the wrong kpafactor.inc in the MegaTune directory. Grab the megatune.zip and extract the kpafactor.inc file that lives in the appropriate "turbo" directory (for all version 2.2 kits with the MPX4250 'turbo" MAP sensor). If the above checks out, you are finished. Mount the unit in the car, tune, and go.

If you want to seal the finished board, use a conformal coating. If you do not think you will be doing much repair work on the board, you cannot beat silicone conformal coating. It does require some digging to get off for repair, however. Avoid the urethane coatings, as they are considered permanent and are a pain to try to work through. You can also buy a spray can of acrylic lacquer conformal coating at most local electronics suppliers for around $10.00. If you are going to be working the board, "Krylon Krystal" clear spray works very well. Apply several coatings, preferably baked at 175-200 degrees in between. This should slow down or prevent "solder bloom" and other deterioration of the PCB. Condensation is inevitable for an outdoor component undergoing temperature changes. You can solder right through the stuff and the residue cleans well with pure grain alcohol.

The MegaSquirt enclosure is 6.25" x 4.25" x 1.75". You also need access on both ends, one for the harness to the motor and vehicle electric system (the DB37) for which the hood of the connector is about 2.25" long. On the other end you have the DB9 to go to your laptop (~2"). You cannot install the MegaSquirt box under the hood. Engine bay temperatures are just too high. The recommended place to install the MegaSquirt box is in the passenger compartment (like under the seat, kick panel, etc), this is where many OEM boxes are located. In addition, you will need access to the RS-232 serial line for tuning, which is hard to access under the engine hood. If you put the MegaSquirt box in the passenger compartment, you will not have heat-related problems (unless you mount it directly in the path of the air stream of the car heater). The limitation is the 68HC908GP32 processor itself (the part is rated to +70 degrees C), as well as other components like the MC33151P FET driver, MAX232 chip, etc. They are all limited to the commercial temperature range of +70 degrees C. maximum. MegaSquirt should be connected with a pass-through hole (and grommet) to the engine compartment for the wiring to the injectors, sensors, fuel pump, etc.

Understanding the MegaStimulator



There are 4 LEDs on the Stimulator, and 3 on the MegaSquirt. On the Stimulator, the 4 LEDs are:

Injector #1 - lights when the first injector bank is grounded [injectors firing].

Injector #2 - lights when the second injector bank is grounded [injectors firing].

Fuel Pump - lights when the fuel pump relay is grounded.

FIdle - lights when the Fast Idle solenoid is activated.

On the MegaSquirt, there are three LEDs, which are:

Injector - lights when either injector bank is to be grounded [firing].

Warm-Up - lights when Warm-up Enrichment (WE) is activated.

Acceleration - lights when Acceleration Enrichment (AE) is activated.

Note that these LEDs all do separate things.

The *Injector LED* on the MegaSquirt lights when either Injector bank is commanded to fire, while the injector LEDs on the Stimulator light when each injector bank actually is grounded. The MegaSquirt LED will flash synchronously with the Stimulator Injector

LEDs in simultaneous mode, and will flash twice as fast as either LED in alternating mode.

The *Warm-up Enrichment* values are separate entries in the software from the *Fast Idle Threshold* value, so these two LEDs will generally light at different, though similar, coolant temperatures.

The *Fuel Pump LED* is light whenever the fuel pump relay is grounded. Since the Stimulator puts out about 1 pulse per second minimum, and the MegaSquirt leaves the pump on for 2 seconds after the last ignition event, the fuel pump LED should be light whenever the Stimulator is plugged into the MegaSquirt.

By using these LEDs, and adjusting the RPM, coolant and air temperature, EGO, and throttle potentiometers on the MegaStimulator, while viewing the PC Configurator or MegaTune tuning software, you ought to be able to test every function of your MegaSquirt, except MAP function [for which you can suck and blow].

Putting it All Together

If you have not yet done so, go get the latest version of MegaTune from the Yahoo! files site:

http://autos.groups.yahoo.com/group/megasquirt/files/MegaTune/

You only need the installation zip file "megatuneNNN.zip" (NNN is the release number), not the source or support files for now. Unzip the contents of this file in a convenient directory, and create a shortcut to the megatune.exe on your desktop or task bar, whatever your preference. Note that the ".inc" files installed with MT are those for the standard GM temperature sensors and for the 250 kPa MAP sensor, if you have different sensors you will need to copy your customized include files over these.

Once you have MegaTune installed and talking to the MegaSquirt/MegaStim system, you have some homework to do. Start by going through the menus and familiarizing yourself with the various dialogs and their contents. Change things to see what happens. There is nothing you can screw up by doing this that you cannot easily fix. The stimulator provides a benign hardware environment, so you cannot accidentally fry anything. This cannot be said for an in-vehicle installation. Although you should set the agenda for your experimentation, here is a list of high points that you should hit.

1) Before you change anything, go to File -> Save (or just type Ctrl-S) and save the initial configuration. Later on you will want to do this a lot as you configure and tune your engine, just to be safe and to have a reference point when things go wrong. Right now, you are saving a known-good configuration to save yourself from a bunch of typing later.

2) Datalogs are your best friend, so go to Files -> Datalogging and create both some classic and full datalogs. Examine them with Excel if you can, or just edit them and view their contents otherwise. You can use either one for tuning purposes, since MSTweak3000 accepts both formats. Choose the one you like.

3) Go to Settings -> Constants and change various values (MegaTune has context sensitive help, so press F1 and you can see information about the settings; this same material will be covered in depth later in this manual, but knowing about the online help is useful). Make a preliminary set-up for your installation, set the number of cylinders, port/TBI injection, etc.

4) You have already done this part, but make sure to pop up Runtime -> Realtime Display. This is the best window to watch when you are debugging sensor problems. The top box on this dialog shows the sensor values that MS is using and is invaluable when you are first setting up the system to confirm correct operation.

5) Become familiar with all of the capabilities of Runtime -> Tuning, this is where you will spend the bulk of your time once the engine starts. Type "F1" and read through the list of keystrokes; type "Z" a couple times to zoom the tuning map; change the RPMs with the stim and then type "F" to see that the cursor follows the spot. You will be using the arrows and shifted-up and -down arrows a lot, so get used to that.

6) Try out Tools -> Generate Throttle Pos Inc. Set the TPS pot on your stim to some low value and hit the "Get Current" button next to the "Closed Throttle" field; move the pot up and do the same with "Full Throttle" button/field. You will be doing this again in the car, expect the actual values in the car to be about 25 for idle and 225 for WOT.

7) Do a Tools -> Dump, then look in your Megatune directory for "MegaTune.dmp". Open it up with your favourite text editor, such as NotePad or WordPad. This file is appended every time you perform the dump, and the contents can be invaluable when you ask for help on the Yahoo! e-mail list.

8) While you are looking in your MegaTune directory, edit the megatune.ini file. Read the various sections of that file and change things that you think might make life easier for you (most notably those in metric locations will probably want to change temperature units to "C"). In addition to the above you can change values on the Enrichments dialog, change VE values, set the RPM and MAP bins for the VE table and anything else you think is interesting. Once you are familiar with the overall operation of MegaTune and configurations, go install some hardware on your engine!

Troubleshooting

If you have put your MegaSquirt together, but it does not work, follow the instructions below:

1) The stimulator does not have the voltage to overpower the John zener (**D8**) diode, so it must be jumpered to test MegaSquirt on the stimulator. This diode (D8) is needed if your ignition system has a large offset bias - most systems do not have such a bias. So, to start, you can either solder in a jumper wire in this location, or, you can install the diode D8, and then install a jumper around the two leads of the diode - in effect shorting it out. The latter will allow you to snip the jumper later on if needed, putting the diode back in circuit.

2) If your oxygen sensor feedback does not seem to work, recall that the O2 voltage (top bar on the MegaTune Runtime dialog) is the raw data coming in (and it should respond to stimulator input). On the other hand, the EGO correction bar (or equivalent gauge on the tuning screen) WILL NOT move away from 100% unless you have the EGO correction parameters set properly and MegaSquirt senses the proper inputs to activate EGO correction. Do not confuse EGO and O2 voltage. EGO is a kind of integrator function that acts on the O2 voltage. O2 should respond, EGO will only respond if MegaSquirt has:

- been on for more than 30 sec,
- the current rpm (adjusted on the stimulator) above the EGO *active above* rpm threshold,
- EGO step and limit do not equal 0, and
- the coolant temperature above the *coolant temp. activation*.

These are set on the enrichments window of MegaTune.

3) Start troubleshooting the electronics by reviewing the assembly guide. Check each step to make sure that you have not missed any components. Also check all solder joints visually for solder bridging and excess flux. Verify that each component is the correct item for each location.

- Pay particular attention to make sure the correct diodes are in the correct locations. Their markings are very small and they are easily mistaken.
- Be sure you have not swapped some of the 0.1µf capacitors at C1, C3, C17, C18, C22, and C25 to C29 (marked 104) with the 0.01µf capacitors at C11 and C20 (marked 103). They are very similar looking and the markings are very small.

4) Verify that all components that have a particular orientation (polarized) are installed correctly - this includes all ICs, all polarized capacitors, all diodes and LEDs, the MAP sensor, the voltage regulator, and the transistors.

In particular, check:

Capacitors:

- **C15**: The positive lead (it will be marked with a small "**+**" on the right side of the label) is closest the DB9 connector.
- **C16**: The positive lead is nearest the U3 MAP sensor.
- **C21**: The positive lead is closer to the DB37 connector.
- **C30**: The positive lead is furthest away from the DB37 connector.

Diodes:

- **D9, D14, D15, D16**: have their banded end closer to the DB37 connector.
- **D5, D7, D12, D22, D23**: have their banded end closer to the DB9 connector.
- **D8** (if installed - should be jumpered for testing), **D21**: have their banded end closer to the top of the PCB (when the DB37 is on the right and your can read the copyright notice on the board).
- **D11, D13, D20**: have their banded end towards the bottom.

LEDs:

- **D17, D18, D19**: There is a small flat spot on the plastic base of the LED. In all cases, this flat is nearest the DB9 connector.

Transistors:

- **Q3**: The flat side should face away from D23.
- **Q5**: The flat side should face away from the DB37.
- **Q9, Q10, Q11**: The flat side should face the corresponding LED.

ICs:

- **U1**: The notch in the chip should be closest to the "**Megasquirt – http:www.bgsoflex.com**" label.
- **U3**: The notch in the pin #1 should be in the square pad nearest the empty space for D4.
- **U4**: The notch should be towards the bottom of the board. If you have a "dot" instead of a notch, the dot should be on the lower left (in the square pad closest to the "**www**" in the website address).
- **U5**: Should be on the underside of the board, with the flat side on the metal pad.
- **U7**: The notch should face away from C29.

If you find some that are incorrectly installed, de-solder them and turn them the right way around - it is likely that they are not damaged - EXCEPT for the tantalum capacitors (C15 & C16) that should be replaced if installed incorrectly.

5) You can use an LED in series with a 330 ohm (or 270 ohm) resistor and probe the input and output of various circuits, like the injector driver, to make sure that these are working. Solder the resistor to either leg of the diode, then solder a lead (20-22 gauge wire) to other end of the resistor, and another to the other end of the diode. Use heat shrink tubing or electrical tape to ensure that the leads cannot contact each other. Strip a bit off each end of the wires to use as probes, or solder on a bit of the leads you have cut off other components while assembling MegaSquirt, etc.

Test the probe by connecting it across your power supply. It should light when connected one way, but not light when connected the other way around.

Now you can use the ends of the wires to probe the circuits for signals - the led will light (or flash) if it gets a signal (positive voltage). The longer lead of the diode goes to the circuit you want to probe (for a positive signal) the other lead (from the side of the LED case with the flat on it) goes to a good ground (such as the through holes at the non-banded end of D1 to D4 - the diodes you did not install).

6) Check to see what (if any) functions work. Try the loopback test, the serial communications test, the clock count-up of the processor, and check for power and ground to the pins of the MC68HC908GP32 processor (see the assembly guide steps for details)

7) Note which (if any) of the LEDs light on the Stimulator, and under what conditions. If your are able to isolate the problem to a particular area of the MegaSquirt, check the schematics for that function, and double check all the related components for correct value, orientation, and proper soldering,

8) If you discover odd behaviour from your MegaSquirt (especially random or fluctuating sensor values) after you have installed the vacuum hose to the MAP sensor, it may be that the rubber hose used to connect your MAP sensor has an low surface resistance (about 2K per inch). If it touches any pins on the bottom of the board, it will short a lot of stuff out.

To fix this, pick up a length of 3/32" (~2.5mm); hollow brass tubing at the hobby shop - used in model R/C work. Cut off a piece enough to run out of the back. Then use a flare tool to make a small lip on both ends to act as a barb. You can then hook it up with a short piece of vacuum tube, and ran the brass tube out the back panel.

Or you can insert the rubber (or vinyl) MAP-Bulkhead tubing in a short length of heat shrink tubing before installing it, and shrink it carefully once it is in place. This insulates the tubing, and holds the tubing tighter on the barbs. You can also use it to hold it on the barbs on both sides of your bulkhead fitting. Heat shrink tubing is non-conductive [by design] and relatively resistant to puncture and abrasion. Choose an appropriate size so you do not collapse the tube.

9) If you suspect problems with the stimulator (for example, everything seems to work, but there is no RPM indication in MegaTune) follow these steps:

a. Do you have RPMC installed? Some people have had trouble sourcing one, and assumed the stim would work without it. It does not.
b. Are you are sure you have the battery wired in correctly? Use your LED tester (see step 5 to make one) to verify.
c. Plug the battery into the stimulator, and connect the stimulator to MegaSquirt.
d. Using the LED tester, you should be able to get a signal to one side of R10, though possibly not the other (depending on the LED and resistor you used).
e. However, you should definitely have a flashing LED at both sides of D5. If not, no signal is getting to the 4N25.
f. Assuming D5 is the correct item and installed the right way around, the next place to check is a small **via** hole, just to the right of R29. Put you tester + lead into this hole, and the - lead into the non-banded hole for D1 (ground). The LED should flash. If it does not then you need to check you soldering of the DB37 very, very carefully to make sure there are no bridges and no solder flux left in the pins. If it does flash, check the soldering, PCB traces, etc. between the via and D5. Use the schematics and PCB layout to help you.
g. If that checks out, connect the + lead of the tester to the very small via hole near the backside of the stim connector (- lead in non-banded end of D1 again), in line with the "Pump" label, adjacent the resistor R1. The LED should flash. If it does not, you need to check that the 555 timer on the stim is operating. If it does flash, check the soldering of the pins on the stimulator DB37 connector.
h. Now the stim is not actually powered by the battery. Instead, it powers the MegaSquirt, which then powers the stim via the +5Vref lead. So check that you have 5 volts at the MS regulator. This is installed on the underside of the MegaSquirt PCB. The outer pins are +12 Volts (actually 9V) from the stim and +5 Volts to the stim. The middle one is ground. So check the out two ones against the center (or the non-banded end of D1), with the LED, or preferably with a meter. You should get ~9 volts and 5 volts.
i. If you do not get 5 volts on the regulator pin closest C16, the stim (and most of MegaSquirt) is not getting any power. Check the DB37 soldering of the regulator, as well as the soldering, flux, etc. of pins 26 and 28. I you do have 5 volts, then check that it makes it to the 555 on the stim.
j. Pin 8 on the 555 chip on the stim is its power supply. Pin 8 is closest the RPMC pot. Check there (light the LED or 5 volts). If you do not have 5 volts (after checking all the previous items), check for inadequate soldering and excess flux around pins 26 and 28 of the stimulator DB37.
k. Okay, if there is 5 volts at the 555, then it is likely that the 555 is fried. You can get these at low cost at any electronics shop, like Radio Shack, etc. (5 for ~$3) Cut the legs off the old one while it is still on the board using wire snips, and de-solder the pins (a wick or a 'sucker"), also available at Radio Shack, etc. Then put a new 555 in and you ought to be functional!

10) Finally, if none of this helps to discover and solve your problem, send a message (including any information you found from doing any of the above) to the MegaSquirt Yahoo! list. Feel free to ask for help, that is why the MegaSquirt Yahoo! list is there - just realize that you may be sent back for more information. You will solve your problem much faster if you provide as much detail as possible when asking questions the first time around. By following the assembly steps, you will discover problems and correct them as you go along.

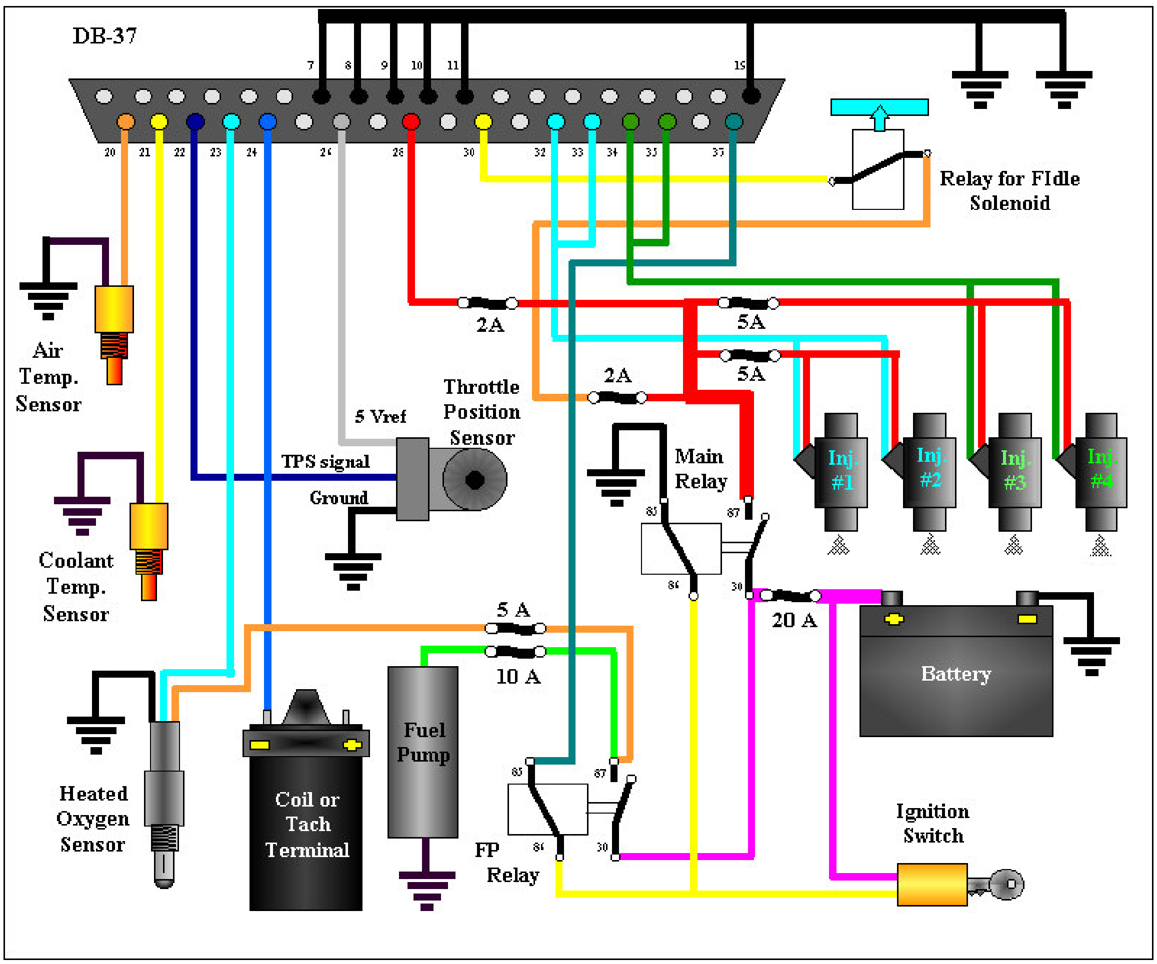
Wiring and Sensors

In order for your MegaSquirt to determine the amount of fuel to inject, you will need several functioning sensors:

- Coolant (CTS) and intake air temperature sensors (IAT),
- Oxygen sensor (EGO) is highly recommended, either narrow-band or wide-band, and threaded bung,
- And wiring and various connectors for the sensors, injectors, etc.,

In this section we will cover the requirements for these components. Note that injector wiring specifics are in the Injectors & Fuel Supply section.

External Wiring Schematic



(This diagram is for those creating their own harness.
If you are using the Relay Board, see the MegaSquirt site.)

You need to pay particular attention to your 12 volt power source and your ground location.

The 12 volt supply for MegaSquirt MUST supply power in both the RUN and CRANK positions. Verify this before attempting to start your engine. Many people have assumed they have a suitable source and spent many frustrating hours trying to figure out why their engine will not start, all because the power source they chose was not supplying 12 volts in the CRANK position. So before hooking your power wires up, put a voltmeter (or test light) between the source and ground, and verify that you have 9-12 volts while cranking.

Noise in the charging system (from the alternator and/or regulator) can cause processor resets or component damage in MegaSquirt. Try to connect the +12 volt switched lead (pin 28) as close to the battery as possible. The battery acts to smooth out the noise from the alternator. If you experience resets in your installation (i.e. the seconds do not count up to 255 and roll-over, they start over before getting to 255), go to your local RadioShack or automotive stereo shop and purchase an "isolation module". These EMI/RFI filters are used on radios to filter out alternator noise. The current MegaSquirt draws from the 12 Volt source is not a lot, but you should get the biggest isolator you can find.

Try to ground MegaSquirt as close as possible to the battery ground, sensor grounds, and other grounds on the engine. Often grounding MegaSquirt to the engine block (or intake manifold), with additional ground wires from the block to the frame and to the battery, is sufficient. If necessary, run additional wires to any other part of the vehicle that may be marginally grounded.

Note:

- *The sensor wires, etc. are not labelled at the sensors themselves, as there are many possible sensors. Each person has to figure the connections out for their particular configuration.*
- *To start, both the temperature sensors (IAT, CLT) have one or two connections. The recommended sensors have two connections. With these, one goes to ground, the other to MegaSquirt (the pins on the sensor are not oriented, you can connect the wires either way). With a one-wire sensor, the connection goes to MegaSquirt, and the sensor is grounded through its body to the engine.*
- *There are instructions in the below for finding out how to wire your TPS.*
- *The coil or tach lead connections depend on each particular set-up, check your maintenance manual, or ask on the list if someone has a vehicle similar to yours (give the make, model, year and engine).*
- *The injector pins do NOT have a polarity. Pick one on each injector to go to +12V, the other goes to MegaSquirt.*

- *For the O2 sensor, the wiring depends on the type (1, 3, & 4 wire) and make. There are some guidelines in this manual, and a lot of information in the archives. You can also check the manufacturer website.*

You will need connectors for wiring the MegaSquirt sensors, injectors, etc. Where you get these will depend somewhat on the sensors you are using. Before you head off to the local parts store, check with Mike Lough (http://www.locustom.com/ms_ordering.htm) and see if he has anything you need in his inventory.

Waytek (http://www.waytekwire.com/) is a site that has many different connectors that you can use in building your MegaSquirt. Their prices are about as cheap as you can find. The injector connectors are AMP part number 827551-3, but sometimes you have to buy a large quantity. Try also DelCity (http://www.delcity.net/). They are not quite as inexpensive, but they may have items that you cannot get from Waytek.

General Guidelines for Automotive Wiring

1) **Always read, understand, and obey all applicable safety precautions for your tools, equipment, vehicle, and electrical, mechanical, and fuel system components. Some precautions come in your owner manuals for your vehicle, tools, equipment, and components. You MUST find and read all of these precautions and follow them exactly. Failure to do so could result in injury, death, or property damage.**

2) Load on a wire in amps is:

Wattage of the device divided by 12 = Amps (volts x amps = watts),

3) Keep wire runs reasonably short, but leave yourself enough to replace the end if the terminal ever gets damaged.

4) DO NOT use solid core wire - it is not designed to flex or vibration - and it WILL fail. Whenever possible, use fine-stranded copper core wire.

5) Bundle wires and use convoluted tubing (available in many sizes) or spiral wrap (Spi-wrap) to protect your wires from abrasion. Clamp the bundled wires to appropriate (not hot, not moving) locations wherever possible using Adel clamps or nylon tie-wraps.

6) Use DIFFERENT color wires for different circuits - you have not lived until you have tried to troubleshoot a car done in all black wires five years after the fact.

7) Keep records of what you do - you will appreciate having a schematic two years from now when something stops working.

8) Use a load reduction relay from the ignition switch to switched hot. This is the Main Relay in the MegaSquirt schematics. If you try to route all the MegaSquirt current

through the ignition switch, it may not last very long. This is required for conversions on previously carburetted cars, as they usually have marginal electrical systems (carb-conversion installations can take good advantage of the relay board offered by Bruce & Al). On vehicles that previously had fuel injection, there is usually a relay system in place, at least for the high-current fuel pump.

9) Work in a well-lighted area - this is hard enough to do correctly even when you CAN see what you are doing.

10) Crimped vs. soldered connections - with a decent crimper used properly, crimped connections are good. With a decent soldering gun and with proper technique, soldered connections are good. Make sure that you have some kind of stress-relief for each kind. Many people prefer soldered connections, but crimped connections are faster and there is no fire hazard (and no solder blobs on the carpets).

11) Make room to work - partially gut the interior so you have room to move around and run your wires. Remember you may need access later, so try not to put wires where you can never reach them again.

12) If at all possible, try not to use "exotic" parts - stick with commonly available terminal strips, relays, connectors, etc - if the part you need five years from now is no longer available, you will have to do that part of the job over to use what you CAN get at the time.

Wire Sizes

For the wires from the DB37 connector to the sensors, injectors, etc., use 18 to 20 gauge for all the connections, then bring them to a common 14-12 gauge where appropriate. The only big wires are the ground and the two injector driver pairs, 32-33 and 34-35. All the rest can be 18 gauge all the way out.

Wire Size for Runs up to 15 Feet

Gauge	Metric	Amps
8	8.0	32-40
10	5.0	28-35
12	3.0	18-30
14	2.0	12-20
16	1.0	8-13
18	0.8	6-10
20	0.5	4-6
22	0.22	2-3

(Capacity depends on wire quality & length of run)

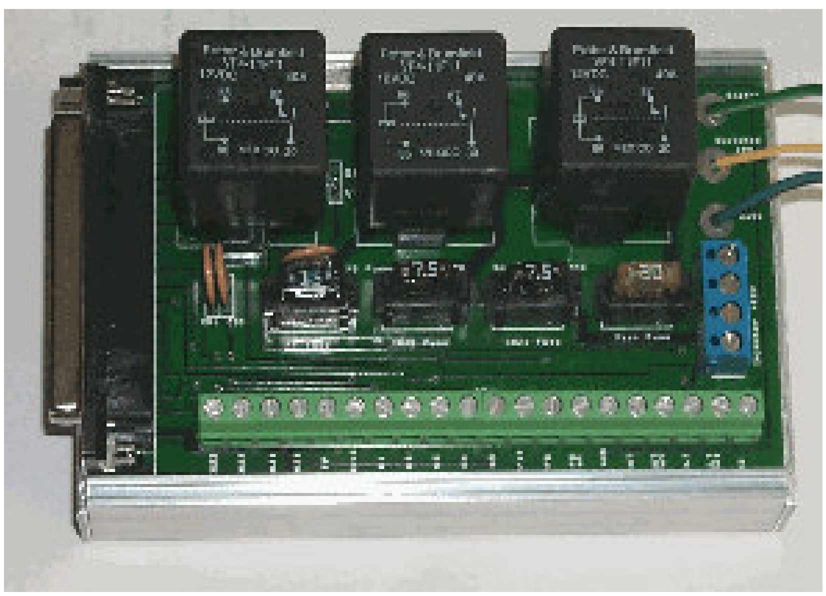
With LEDs flashing, etc., MegaSquirt has an average current draw of about 120 milliamperes. Of course, this is without any load. The injectors and fuel pump require additional power, but power for these are drawn externally, rather than from MegaSquirt, as MegaSquirt just grounds these circuits.

The box is 6.25" x 4.25" x 1.75". You need access on both ends. One end has the harness to the motor and vehicle electrical system, the hood on the DB37 is about 2.25 long. If you leave the hood off and just bend the wires from the connector, you can get it down to less than 1". On the other end you have the DB9 to go to your laptop. This can be stubby, too.

The Relay Board

The Relay/Power board does not come with the MegaSquirt kit, but you do not have to buy it to install MegaSquirt, it is just a convenience and reduces the chance of miswiring during the installation. The relay board provides a central place for all of the required relays, fuse protection, and external wiring for MegaSquirt. It was developed in a response to a few burned boards due to miswiring.

Here is a picture of the completed board:



Whether you need the relay board depends on your ability and what you are comfortable with. MegaSquirt gets its power from the car 12 Volt battery via pin 28 on the DB37 connector. The relay board, which is not required, makes it easier to hook up the wiring to MegaSquirt. It also makes it less likely that you will fry something in MegaSquirt through incorrect wiring.

With the relay kit, you still have to run a cable from the relay box under the hood to the MegaSquirt unit (which cannot be located under the hood), but then you have a nice terminal block for all of the engine wiring.

You order a PCB for the relay board kit at:

http://www.bgsoflex.com/mspo1.html

Then you can order a parts kit at:

http://www.megasquirt.info/rkbom.htm

Note that the external wiring diagram in this sensors and wiring section is entirely separate from, though similar to, the Relay Board. There is an separate internal wiring diagram for the Relay Board.

The relay board takes 12V from the vehicle and passes it to MegaSquirt, but it also handles fuel pump relay and other wiring needed from the engine side. However, you can just pass the wires through a hole in the firewall without using the relay kit.

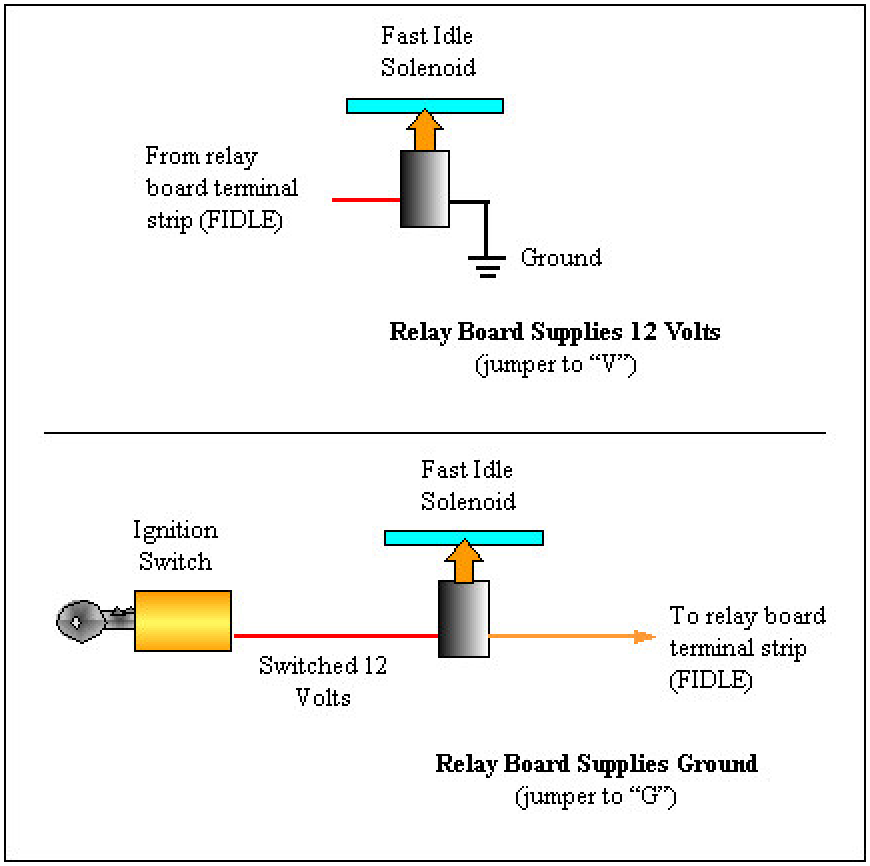
Assembling the relay board kit is straightforward. All the components are marked on the PCB. Only the relay sockets have a unique orientation. To orient the relay sockets, look at the bottom of the socket. You will see that there are three pins which are equidistant, but the fourth is a bit longer from the imagined center - look and you will see this. The "longer" pin points toward the +12V/Grnd/Switch+12V pads on the PCB, away from the DB-37 connector. This is the same for all three relays.

The FIdle should always be wired through a relay, since MegaSquirt is only capable of handling ~500mA in the "Fidle" circuit". The relay board has all of the circuitry, fuses and relays up to do this. Pin 37 on the MegaSquirt DB37 provides ground to the FIdle relay on the Relay Board (which is supplied with 12 volts from the main relay) that activates a solenoid.

You must select the voltage polarity for your fast idle air solenoid (a.k.a FIdle). On the relay board PCB, there is a spot for a three legged component between the two relays - it is marked **J1** and has two holes marked **G** and **V**.

However, in general FIdle valves can be wired into the Relay Board in two ways. They can take 12 volts from the relay board, and be grounded at the solenoid or at any common ground, OR they can be fed 12 volts from a switched supply (separate from the relay board) and then be grounded by the relay on the Relay Board when the DB37 connection causes the relay to close by providing a ground.

The first instance supplies 12 volts when MegaSquirt wants FIdle activated. The second instance supplies a ground when FIdle is activated (mimicking the DB37 pin). If you are designing you own wiring system and using an "off -the-shelf" vacuum solenoid with two wires for FIdle control, you can do it either way, so long as the solenoid is not grounded through the case.



One type of solenoid has only one wire, and is grounded through the case, so it must have the relay board supply 12 volts. You would set the jumper to "V". This is the most common option, unless you are converting a previously injected engine which is wired for "active ground" and you wish to use the existing fast idle valve and wiring (though most EFI engines do not have a FIdle valve, they have a stepper motor, which will not work with MegaSquirt in any case).

Note that you cannot install the upper part of the relay board case with the relays in place. The relay board is designed to be open-top, which is not a problem under the hood or inside the passenger compartment. The top is included in the relay board kit because it was easier to ship (not having to take apart all of the cases). Now, if you want, you could potentially cut out the top lid for the relays.

There is one DB37 hood supplied with each MegaSquirt kit but none with the relay board kit. Only one hood is included, because the ones the plastic hoods would not survive under hood temperatures. Many people are soldering the wiring directly on the relay board, which means that they do not need the connector at all.

You may want to spray on conformal coating after the PCB is soldered up - be sure to cover up the sockets with tape before spraying. You should drill a very tiny hole inside of the top and bottom flange of the case to allow moisture to escape if mounted under hood.

If you are using a relay board, but in the car, the runtime display shows that both your air and coolant temperatures are 170°F and the TPS is at 100%, you need to run a sensor ground. Until you do so, the engine will not start because it thinks it should be in "clear flood" mode due to the TPS signal.

On the relay board, the grounds for the coolant temperature sensor, air temperature sensor, and TPS are all brought in separately in to pins 14, 17, and 19 (on **JP1**), and feed to pin 19 of the **DB37**. Pin 19 of the DB37 MUST be grounded if your sensor grounds are brought back to the relay board as designed. The relay board cable has a return wire that goes from DB37-pin 19 to a common ground on the MegaSquirt PCB.

If you do not have this wire, you need to connect the sensors to ground. You can do this by:

- Adding an extra wire to pin 19 of the **JP1** terminal block and running it to the same spot the main MegaSquirt ground is located, OR
- Moving your sensor grounds directly to the same place that MegaSquirt grounds itself on the engine, OR
- Connecting a wire between pins 19 of the two ends of your **relay board/MegaSquirt DB37 connection cable**, as shown in the schematic.

All of these are electrically equivalent, however the last option (the way the relay board was designed) lowers the possibility of signal noise on the sensor inputs by giving them a separate ground path.

Making a "Pigtail" to Connect to MegaSquirt

You will need to connect your MegaSquirt to power, ground, sensors, fuel pump, fast idle valve, and injectors. You can do this using 18 or 20 gauge wires. The ground and injector wires carry more current, however they are "doubled-up" on the board.

Wherever possible, use coloured wires to make hook-up and troubleshooting easier. You may wish to build up the connector from multi-conductor cable, instead of individual wire runs, though it can be difficult to find multi-conductor cable with enough wires.

You will need wires for the following:

Function	Number of Wires to MegaSquirt	Pins on DB37
Injector #1	2	32, 33
Injector #2	2	34, 35
Fuel Pump	1	37
Coolant temperature (CLT)	1	21
Intake Air Temperature (IAT)	1	20
Oxygen Sensor	1	23
Throttle Position Sensor (TPS)	2 (5Vref, signal)	22 (signal), 26 (5Vref)
Ignition	1	24
Power (+12V)	1	28
Fast Idle Valve (FIdle) (thru relay)	1	30
Ground	5	7, 8, 9, 10, 11
Sensor Ground	1	19

If you are triggering MegaSquirt from the negative-terminal of the coil (-), you may want to use a shielded wire for this (there have been reports from the field indicating that shielded cable helps reduce false triggering).

Normally, you want to ground the opto-isolator by connecting **XG1** to **XG2** with a jumper. However, if you are triggering off the coil primary, you may want to run the opto-isolator circuit return through the shield. Connect the shield to one of the unused jumper locations, like X11 (pin 25). *Note that XG1 MUST be connected to XG2 for testing with the stimulator.* Be sure that there is a jumper on MegaSquirt PCB from terminal XG1 to the terminal you choose for the return, like X11. Note that the X jumpers are brought out on the relay board terminal strip as "S" terminals, i.e. X11 is brought out to "S1", X12 goes to "S2", etc.

Assembling your wiring harness is not difficult, though it can be tedious. The specific procedure will depend on whether you are using a relay board. Below are some general directions. For some installations, it may be desired to run the cable through the firewall, and assemble the connectors on each end (one inside of the passenger compartment, the other inside of the engine compartment). If you do this, be sure to connect one wire at a time, on both ends, to make sure the wiring order is maintained correctly.

If you are **NOT** using a relay board, you only need to wire one DB37 connector. However, be very careful to position and label every wire so that you can connect it correctly. Use the above external wiring schematic.

If you are using a relay board, you will need to run wires from the various sensors and actuators to the relay board through the **JP1 terminal block**, where the external wires can be clamped into the relay board terminal strip using the small set-screws.

Relay Board JP1 Terminal Block Pin-Out

Pin	Function	Pin	Function
1	Injector 2 (ground by MS)	11	S5 (not used)
2	Injector 2 (ground by MS)	12	Vref (+5 Volts)
3	Injector 1 (ground by MS)	13	TPS Signal
4	Injector 1 (ground by MS)	14	TPS Return (Ground)
5	Fuel Pump	15	Tach/Ignition
6	Fast Idle	16	Air Temperature Sensor Signal
7	S1 (not used)	17	Air Temperature Sensor Return (Ground)
8	S2 (not used)	18	Coolant Temperature Sensor Signal
9	S3 (not used)	19	Coolant Temperature Sensor Return (Ground)
10	S4 (not used)	20	O2 Sensor Signal

The following instructions are for creating a MegaSquirt to Relay Board cable.

Do not use the external schematic from the FAQ/manual. It is for those who are creating their own harness. The relay board schematic from the Bowling & Grippo site is the ones you should use for wiring your MegaSquirt to your relay board, and wiring your relay board to the engine.

1) First, find locations to mount MegaSquirt and the relay board. MegaSquirt should be mounted away from excess heat, like in the passenger compartment. The Relay Board can be mounted in the engine compartment, or in the passenger compartment next to MegaSquirt. With both boxes mounted, measure the distance between them from DB-37 connector to DB-37 connector - this will be the length that you will cut the individual wires. If you are not using a Relay Board, allow enough length in each of your wires to reach the target component. It is often better to be too long and trim afterwards, than to be too short and have to splice additional lengths on.

2) Purchase some $^1/_8$" (3mm) heat-shrink tubing which you can slip over the soldered connection and shrink. It is sometimes easier of you cut and strip each wire ahead of time, and cut ½ inch (12mm) lengths of heat shrink tubing and run two each on each wire, one for each end. For a Relay Board cable, you can move both heat shrink pieces to the center of the wire length, and then twisting the center of the wire with a few twists to hold the heat shrink in place, so that it does not fall off the wire or run down while soldering the connection. For a pigtail, you can slip the heat shrink tubing on later.

3) Find a vise and place the two DB-37 connectors, solder-cups up, in its jaws. Orient them so that both are facing the same way, with pins 1 - 19 closest to you. If you do not have a vise, you can clamp the connector(s) between two small pieces of wood (~1" x ~1" by ~1 foot long) with 2" (50mm) woodscrews. You will definitely want something to hold the connector, since as you attach more wires it wants to move around more, while at the same time you have less room to solder. Having it held stable helps a lot.

4) Now, you are going to affix one wire at a time (18 - 20 gauge), starting with the ground wires. Run one wire from pin #1 to pin #1 (there are numbers on the connectors) and solder both ends. Repeat with pins 2, 3, and 19 (this one is important - it is the return wire for the coolant temperature sensor, air temperature sensor, and TPS). If you want to run more ground wires from pins 4 - 18, you may do so - three is enough, but run more if you like (it cannot hurt). Note that each connector looks the same as the other - one pin to one pin.

5) Now, turn both connectors around, and start wiring away. You are gong to run the 18 - 20 gauge wires from the "active" pins from 20 to 37. Note that t here is no wire for pin 36. Run each of these one at a time, starting with pin 20 to pin 20, then another wire from 21 to 21, etc. And, if you are using shielded wire for the coil (like RG-174 or audio cable), the center lead connects to pin 24 and the ground to pin 25 - make sure you run a wire from the terminal strip "S1" terminal to engine ground.

6) Next, unwrap all of those loops on the wires holding the heat shrink in place, and work each piece to each end of the connector, and shrink the tubing down with a heat gun, or even a lighter. At first, the wires will be a tangled mess, but when you start working the shrink tubing to each end, the kinks will work themselves out.

7) Finally, wrap the wires in electrical tape from connector to connector. The wiring will be slipped inside of a wire loom after being installed in the vehicle. An alternate way of bundling the cables is by using a large-diameter heat shrink tube, and run each wire inside of this large tubing when making up the connectors, then finally shrinking the entire piece down.

To test a MegaSquirt/Relay Board cable,

1. Connect the cable to both MegaSquirt and the relay board.
2. Apply **+12 volts** to the **12 Batt** pad lead, and return battery to **Engine Ground**. If you jumper the **Switched 12V** to the **12V Batt** pad, you will hear the main relay kick in, and MegaSquirt will power up. Keep this jumper connected.
3. Next, fasten down a wire to the **Tach** terminal on the relay terminal strip, and touch this to the +12V source (or use the **Injector +12V** terminal strip) - each time you touch it, the tach trigger LED (nearest the DB9) on MegaSquirt should flash. The first time you do this, the fuel pump relay should click-in, and it will stay in as long as you keep on touching/releasing the tach wire (i.e. pulsing the

circuit). After two seconds from when you stop pulsing the tach circuit, the fuel pump relay will de-energize.

4. Next, hook up the sensors, e.g. hook the coolant sensor between the **CLT** and the **CLT Ret** terminals, which are the coolant temperature sensor signal terminal and coolant temperature sensor ground. Do the same for the **MAT** and **TPS** (the TPS connectors to the **Vref**, **TPS** and **TPS Ret** terminals). For each of these, run the PC Configurator and verify that these are working.
5. For the O2 sensor, touch a jumper wire from the **O2** to the **Vref** terminal (*NOT* 12 volts or injector +12V) - check on the PC Configurator for O2 sensor voltage.
6. To check the injector drives, you can use the injector themselves, or use a taillight bulb and pigtail for this - connect from the **Inj1** to the **Injector +12V** terminals, and repeat for the **Inj2** side as well. For the fuel pump, hook a taillight between the **FP** terminal and ground - it should light when you trigger the tach wire.

MAP Sensor

The most fundamental measurement MegaSquirt uses to determine the amount of fuel to inject is the manifold absolute pressure. MegaSquirt uses the MPX4250AP as a MAP sensor, and it is supplied with ALL the units from the current group buy. It will correctly measure from a near vacuum to ~21 psi of boost. It is suitable for all naturally aspirated and most turbocharged engines. If you are going to run more than 20 lbs of boost, you need a MAP rated at a higher pressure. Ask the MegaSquirt Yahoo! list for advice on this topic.

MegaSquirt normally mounts the MAP sensor in the MegaSquirt enclosure, where it is protected from mechanical and electrical stresses. As noted in the assembly guide, it can be mounted remotely, if desired. This was discussed in detail in the assembly guide.

You need to run vacuum tubing from the sensor to the engine intake manifold. You can use a port on the throttle body that has full-time engine vacuum (i.e. NOT ported vacuum). The source you choose should have a high vacuum at idle, if it does not, it is a ported source, and you need to hook your vacuum line somewhere else. Make sure the tubing you use is appropriate for automotive environments, so that it will not melt, dissolve from oil, etc.

Oxygen Sensors

An exhaust gas oxygen sensor (EGO) is very useful for setting up the MegaSquirt volumetric efficiency table, and while it is highly recommended, it is not essential.

MegaSquirt can read from just one oxygen sensor. People who have engines with separate cylinder banks (V6, V8, etc.) will have to make a choice:

They can use one sensor in the crossover pipe between the exhaust pipes (which they may have to add), however the sensor will be a long way from the heat of combustion and you may require a heated sensor (see below),

They can put a sensor in just one bank, as close as possible to the point where the exhaust gases from that cylinder merge, and assume the other bank is the same. Many manufacturers did this in the early days of electronic fuel injection,

They can put in two oxygen sensors, one in each bank, with a switch on the lead to MegaSquirt for the driver to choose which cylinder to read.

It is very important that there be no exhaust gas leaks upstream of the oxygen sensor. Certain conditions can draw ambient air into the exhaust, causing MegaSquirt to compensate for an apparently lean condition. This will falsely create a rich mixture in your system that can be difficult to diagnose. Those who have converted late-model "emission" engines, should be careful to understand and modify the operation of any air injection systems they have to be sure air is not being pumped into the exhaust ahead of the oxygen sensor(s) during "closed -loop" operation.

Closed loop refers to those times when an EFI computer is using the feedback on the mixture provided by the oxygen sensor to effectively control the injected amounts. For MegaSquirt, this is when the engine has been run for 30 seconds, the engine RPM is above the 'EGO Active Above RPM", the coolant temperature is above the 'Coolant Temp Activation", and the TPS is below 70%. See the Settings/Enrichments section of MegaTune. "**Open Loop**" refers to those times when MegaSquirt ignores the feedback from the oxygen sensor. Note that MegaSquirt also allows you to set limits on how much (**EGO ± Limit (%)**) and how fast (**EGO Step (%)** and **Ignition Events per Step**) the oxygen sensor feedback can influence the injected amount.

One, three and four wire narrow band O2 sensors [NB], and two wide band sensors [WB] are currently available on the market. MegaSquirt was originally designed with an interface to a basic narrow band 02 just for cruise. Bruce, Al and others are working on options for wide band [WB] EGO sensing and tuning, and the current tuning software accommodates both the narrow band and wide band stoichiometric and voltage slope characteristics.

Narrow band O2 sensors are designed to measure stoichiometric [chemically correct] air/fuel mixtures [A/F] of 14.7:1 to allow catalytic converters to work efficiently. Narrow band sensors always have one wire for the sensing function. Additional wires are for the heater and its ground (3 wire sensor), and possibly an additional wire to ground the sensor itself (4 wire). The sensor needs to be quite hot to operate. The heater keeps the sensor at operating temperature under more conditions.

Examples are:

- **Standard Motor Products SG5** (~$18) is a one-wire sensor for a mid-eighties Chevrolet; the mating connector is **S554**
- **AC DELCO AFS75** is a four-wire sensor; **PT368** is the matching "pigtail" connector for splicing into your harness (from a 95 Corvette 5.7l V8). You can also get this as a Walker 4-wire OEM replacement pn# **250-24012**, priced ~$50USD (black connector end), or the Walker 4-wire UNIVERSAL replacement is pn# **250-24000**, priced ~$49USD (solder/crimp wire ends)

The difference between the heated (3 or 4 wire) O2 sensor and a non-heated (one wire) sensor is the A/F ratio sensing of warm up and low load conditions. The heated sensor uses an internal coil to heat the ceramic element to the desired 400 degrees Celsius in 30 or 40 seconds. This temperature is also maintained when the car is at idle for extended periods of time or is under low load conditions where the exhaust gas temperatures fall below 400 degrees C.

Under other operating conditions the exhaust gas temperature will be much greater than 400 degrees C. and heating is not necessary. The non-heated sensor relies on the exhaust gas heat to keep it at its operating temperature. This works most of the time but there is still times that it might drop below its desired operating temperature and show a leaner than actual mixture as its output drops to zero.

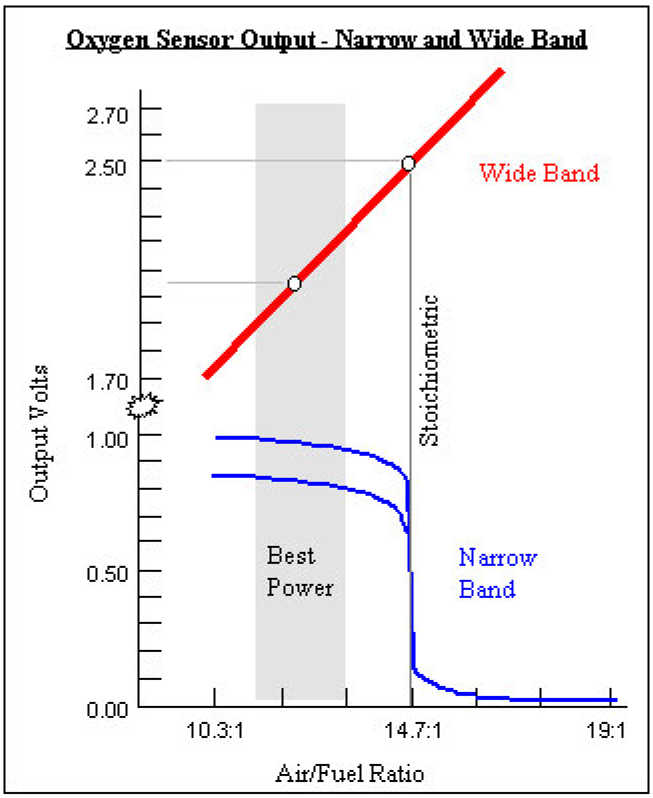
A 1-wire sensor is as good as a 3-wire provided that it is always at operating temperature. If you cruise around for a bit with the engine at low load, the O2 sensor COULD cool down. If you do not have exhaust gas temperature [EGT] monitoring then you cannot be sure.

Once warm, a 3-wire O2 sensor will stay warm. For most of us the one wire will prove to be adequate. A 4-wire has a shielded cable. You only need to ground the shield at one end. In many installations there is not enough voltage drop from the manifold to ground to make shielding worth the bother, but every little helps.

So the more wires the O2 sensor has, the more situations in which the sensor will be active and accurate, but you are still stuck with knowing whether you are rich or lean, but not by how much.

MegaSquirt software has some support for Wide Band (WB) EGO sensors made by NTK (**L1H1**), also sold as Bosch P/N **13246**. These sensors have a different trigger point for stoichiometric, and the opposite "slope" to the voltage curve. See below for details. They require a separate driver board to interface between the WB sensor and MegaSquirt (or any other ECU). The DIY-WB PCB and parts kits can be found at the DIY-WB site (http://www.diy-wb.com/info.htm).

If you are using a wide band sensor with MegaSquirt, select **WB** on the PC Configurator or MegaTune Enrichments screen to take the WB characteristics into account. The MegaSquirt EGO correction algorithm treats a WB O2 sensor as if it were a narrow band sensor with a different voltage and slope (see diagram), but does not take advantage of the fact that it can accurately report AFR away from stoichiometric. In this sense it takes limited advantage of the sensor, but datalogs derived using a WB sensor are still very valuable because MSTweak3000 can use the sensor readings to their fullest.



Sensor Type	Stoichiometric	Best Power
Narrow Band	**0.45 Volts**	???
Wide Band	**2.5 Volts**	**~2.08 Volts**

The Wide Band Advantage

With a narrow band sensor, we can really only tell for certain whether we are rich or lean, but not by how much. If you look at the graph, you can see that for a narrow band sensor, the 12.5:1 AFR required for maximum power can give O2 voltage from 0.8 to 0.95 (depending on exhaust gas temperature), yet this same range of O2 voltages can indicate mixtures from 10:1 to 14.5:1. So we cannot use it reliably to set mixtures for full power. With a wide-band sensor, 12.5:1 corresponds to 2.08 volts, and 2.08 volts means 12.5:1. Thus there is no ambiguity over AFR and voltages. We can measure any mixture in the range we are likely to use, from full power through to maximum economy. MegaSquirt does not currently have the capability to fully exploit a wide-band sensor by incorporating full time, all conditions closed loop feedback for fuelling. MSTweak3000 is planned to soon have wide-band mixture target settings with real-time updating of the VE table.

If your car did not come with an oxygen sensor, you can add one. The thread for all oxygen sensors [including wide-band] is: 18mm x1.5mm, the same as 18mm sparkplugs.

You can go to your local automotive parts store and in the section with all the HELP products, pick up a package of "18mm Sparkplug Anti-foulers". Cut off the externally threaded part, and weld the rest onto your manifold or down pipe. Works wonderfully and you can do 2 cars for 4 bucks! Or you can go to muffler shop and ask for an O2 bung. If you know the guy he will cut you a deal on a nice machined 02 sensor bung. They can weld them in for you too!

The MegaSquirt version 2.2 hardware does not support two or more O2 sensors, only one. However, on version 2.2 boards the spare A/D channels are brought out on jumper pads, as are the extra connector pins, so you could wire up the filter network and put this in-line with the pads. There are no plans currently to modify the software to handle multiple-O2 sensors, but everything is there for you to do the modifications.

If you have installed a heated sensor, you will need to wire the heater in the sensor. Connect one heater wire into ignition-switched 12 volts, the other heater wire goes to ground. The heater wires are the often thicker than the signal and ground wires, and are sometimes white. O2 sensor heaters typically are about 18 Watts (1.5 Amps), so use an appropriate wire gauge and fuse.

The heating element is Positive Temperature Coefficient PTC (non-linear) resistor. When it is cold it has low resistance and draws about 2.4 Amps at 12 volts. As it heats up its resistance increases and current reduces down to much lower values (below 0.5 Amps). Thus it is self-regulated and when warm the current draw can be neglected. Most new cars have it connected in parallel with the fuel pump (which draws 8 Amps and more).

<u>Temperature Sensors</u>

MegaSquirt uses coolant and air temperature sensors to determine the warm-up characteristics of the engine and the density of the intake air. They are essential to proper functioning of MegaSquirt. Both sensors are Negative Temperature Coefficient (NTC) thermistors. This means that they are resistors whose resistance decreases as their temperature goes up.

Naturally aspirated engines using MegaSquirt can use the same sensors for coolant and air temperature. These sensors are inexpensive (roughly US$9.00) GM units readily available from any parts store (GM part number **12146312,** may have been replaced by #15326386). However, you will save some money if you can source these from a salvage yard, with the mating connectors. If you are unable to get them this way, consider using a "spade-type" connector or reusing your existing sensors (with EasyTherm and/or resistor calibration adjustments).

Turbocharged or supercharged engines should use an open-element air temperature sensor for a faster response time. Here are some reported part number equivalents for both the coolant and air temperature sensors (verify before ordering):

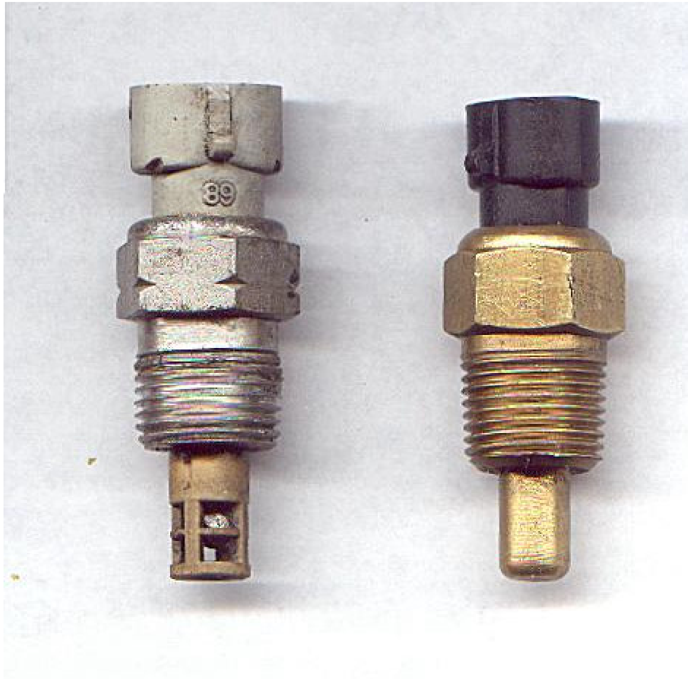
Coolant temperature sensor (CLT)	Air temperature sensor (IAT)
GM #**12146312** (may have been replaced by #**15326386**) Wells **SU109** Standard **TX3** GP SORENSEN **TSU81** AC DELCO **213-928** NIEHOFF **DR134AK**	GM #**25036751** Wells **SU107** Standard **AX1** GP SORENSEN **779-19001** AC DELCO **213-190** NIEHOFF IGNITION **DR-136W**
Connector Pigtail (CLT) (mushroom keyway)	Connector Pigtail (IAT) (square keyway)
Wells PN **254** NAPA PN **ECHTSC200** Conductite/Dorman **85100** (~$9 @ Autozone (PN 047131))	Wells PN **235** NAPA PN **ECHTSC300** Niehoff PN **PS77421** (~$15) Conductite/Dorman PN **85110** (~$12 @ Kragen partsamerica.com)

The coolant temperature sensors were apparently found in the following applications:

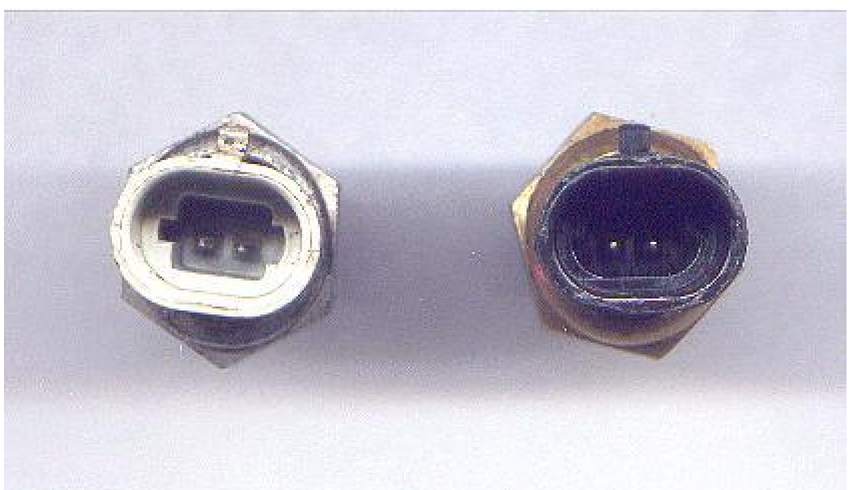
- ALL GENERAL MOTORS (Chevrolet, Pontiac, Buick, Oldsmobile, Cadillac, GMC) 81-96
- HONDA TRUCK 94-96
- ISUZU TRUCK 92-96
- JEEP 82-87

Note: A few early installations using the open-cage MAT sensor experienced vibration induced failure of the sensor. The thermistor bulb is supported only by two thin wire legs. These can apparently fatigue and break when installed in high vibration environments, such as occurs when you screw it directly into an intake manifold.

Several people have solved the breakage problem by "potting" the legs of the thermistor with O2-sensor-safe silicone (most silicones destroy O2 sensors, so pay attention!), squeezing it down inside the sensor body but leaving the bulb exposed.



Note that these sensors have different connectors. The coolant temperature sensor uses a "mushroom" shaped keyway where it inserts into the sensors, while the open element intake air temperature sensor uses a "rectangular" connector ke yway.



The wiring schematic for DB37 shows only one input for all of the sensors (except for the two for the TPS). The recommended GM sensors all have two wire connectors. The missing connection is a ground wire for the sensor. Sensor grounds should be brought to the same grounding point on the engine block as the MegaSquirt ground, unless they are grounded through the body of the sensor.

If you are looking for sensors with a standard "spade" type connector and a ground through the body of the sensor, GM part number **25036135** is what you need - see the illustration below:

You can also use the "button" type sensor (below) AC Delco **G1852**, which accepts a spade type terminal. These were used on 1973 Chevrolet Camaros with 350 cid V8 engine, and sell for about $8.00. Either of these will eliminate the need for expensive, specialized connectors.

The resistance curves for the MegaSquirt/General Motors coolant and air temperature sensors, as well as various part number cross-references, are listed in this section.

GM Temperature Sensor Resistance

Degrees F	Degrees C	Ohms
-40º	-40	100,700
0º	-18	25,000
20º	-7	13,500
40º	4	7,500
70º	21	3,400
100º	38	1,800
160º	71	450
210º	99	185

The thread for the recommended General Motors (and equivalent replacement) coolant and air temperature sensors for MegaSquirt is 3/8 inch National Pipe Thread [NPT]. A

9/16 inch pilot hole is required for the tap. (Recall that pipe sizes are based on nominal inside diameters, not outside diameters as for standard National Coarse [NC] and National Fine [NF] threads...)

Approximate sizes

Nominal Pipe Size - actual ID is slightly bigger	Approx. Outside Thread Diameter	Drill Size
1/8"	3/8"	5/16"
1/4"	1/2"	7/16"
3/8"	5/8"	9/16"

These sensors were been used on practically all GM cars in the 1980s and are easy to find - the same is true for the correct connectors. However, other sensors can be used if the EasyTherm software is used to recalibrate your MegaSquirt.

EasyTherm

If you are using non-standard coolant and/or air temp sensors, you must create ".inc" files that are essentially look-up tables for MegaSquirt to relate resistance to temperature. These files must then be compiled into one .s19 file, and then downloaded to the MegaSquirt controller. EasyTherm makes it very easy to use "non -standard" temperature sensors with MegaSquirt. It does three things that otherwise can be a bit of a pain:

1) It automatically creates the .inc files from 3 temperature/resistance pairs. Entry in degrees Fahrenheit or degrees Celsius is allowed. Non-standard bias resistor values can be entered.

2) It creates the .s19 file using the above data - you do not need a compiler!

3) It downloads this .s19 file to the MegaSquirt controller via the serial link (once R6 is shorted to enter bootloader mode), and reboots the MegaSquirt - so you do not need to mess with Hyperterminal.

Do not forget that you need to copy the applicable .inc files that EasyTherm creates to your MegaTune directory after a successful download.

The EasyTherm file can be downloaded from the MegaSquirt Yahoo! file section.

To use MegaSquirt with an air-cooled engine, you will have to decide where the best place is for the coolant sensor: in the oil, or on the cylinder head. There are various arguments for and against using either CHT or oil temperature as the CTS input on air-cooled motors. A lot depends on whether the motor is substantially oil cooled or not.

Since the CTS input is used for warm-up enrichment, you want something that responds rapidly, so this is highly engine-dependent.

One side of the argument says to use the CHT over the oil, as the oil takes over twice as long to get to operating temperature than water in a water-cooled car does. The engine does not need to run rich for long periods, only enough to keep the car driveable while it is warming up. Once the cylinder head is up to operating temperature, the car is usually quite driveable. For an air cooled engine you can drill and tap into a fin in the head for the CHT sensor.

The other side says that it does not matter if the oil warms more slowly, you can just set the warm-up enrichment to come off at a lower temperature. In that case, the GM coolant sensor fitted in the oil (sump) will work nicely. Search the archives for extensive discussions on these points. It is your decision.

Throttle Position Sensor

MegaSquirt uses the throttle position sensor (TPS) to determine when the engine is at or near full throttle (to shut off feedback from the O2 sensor), when the engine throttle is opening or closing rapidly (and needing an accel/decel enrichment), and when the engine is flooded and needs to be cleared. While very helpful, some people have managed to make their engines function reasonably well without one. This is not recommended, however.

You will need a "TPS" that is really a potentiometer and not a switch. Many older cars had idle or WOT position switches instead of a real TPS. A real TPS gives a continuously varying signal with changing throttle. There are two wires on the external wiring schematic that go from MegaSquirt into the TPS sensor. These two MegaSquirt wires are +5 Vref signal and a sense line. There is a third wire going to ground. Assuming that you have a proper potentiometer TPS, then +5 Vref goes to one side of the pot, the other side goes to ground and the sensor line is hooked to the wiper.

To hook up your throttle position sensor (TPS), disconnect the TPS, and use a digital multi-meter. Switch it to measure resistance. The resistance between two of the connections will stay the same when the throttle is moved. Find those two - one will be the +5 Vref and the other a ground. The third is the sense wire to MegaSquirt. To figure out which wire is the +5 Vref and which is the ground, connect your meter to one of those two connections and the other to the TPS sense connection.

If you read a high resistance which gets lower as you open the throttle, then disconnected wire is the one which goes to ground, the other one which had the continuous resistance goes to the +5 Vref from the MegaSquirt, and the remaining wire is the TPS sense wire.

TPS voltage should increase when throttle is opened - verify this on your set-up.

To calibrate the TPS, use the MegaTune utility "Generate Throttle Pos Inc" under Tools, to turning the raw ADC values into percentages. You should do this each time you change the idle position or reassemble the throttle linkage.

If the acceleration enrichment (AE) on your MegaSquirt comes on for no apparent reason, it will make the car run rich. It will also run jerky while cruising. If this happens, check your TPS accel activation threshold setting - if this is low, then you will get erroneous triggers due to small noise spikes or bit error.

Also, check to see that the TPS wires are not near spark plug wires that could introduce noise. Finally, check to make sure that the TPS ground wire has a good connection - this could also cause random accel triggers. Watch the runtime screen at idle to see if the TPS number bounces around.

Fast Idle Solenoid

The fast idle solenoid is an open/close solenoid vacuum control valve to admit more air when cold. Unlike a cold start injector, it does not handle fuel at all, only additional air. The fast idle solenoid is not the same as an IAC motor, or anything that is controlled like a stepper motor. It is either open or closed. The fast idle solenoid is an off/on electrically controlled vacuum "leak" that speeds the engine RPM for cold starts. Such solenoids have been used often in modern cars, frequently to control EGR valves.

The fast idle solenoid takes clean air from the air cleaner and allows it to bypass the throttle and go directly into the intake manifold. This does not cause a lean condition [as it would with a carburetor] since the MAP sensor adjusts for the "extra" air.

The fast idle is simple, just like the MegaSquirt system is simple. There are simply too many different stepper motor types out there (General Motors uses bi-polar, some Chryslers use unipolar, others use PWM proportional control, etc., etc.) to manage with a simple solution. The control of all of the different types of IAC motors out there would also be a support nightmare.

The philosophy of MegaSquirt is simple, and the fast idle solenoid control is a simple as it gets. If your application requires fine control of idle, then you will need to pay more and purchase a commercial unit.

Note: MegaJolt Light is expected to have some form of IAC stepper control when it arrives in early 2003.

SDS sells a air bypass valve which you could use for a fast idle solenoid. The price is ~$70.00 - look for "fast idle solenoid" on their specifications page. However, the "Fast Idle Solenoid" that SDS sells appears to be the same thing as the "Solenoid-actuated 3-Port Fuel Tank Selector Valve" that J.C. Whitney sells for half that price under P/N 81ZX2686W.

Other possibilities can be found at McMaster-Carr under Process Control and Instrumentation/Solenoid Valve/Aluminum and Thermoplastic Solenoid Valves.

There are some possibilities for the fast idle solenoid from the NAPA catalog:

2-2307	EGR Solenoid	(91-93 Buick, 88-93 Chevy)	$28.19
2-2109	Bowl Vent Solenoid	(78-86 Ford 2bbl)	$47.89 (Ford CX-239)

These all have separate inlet/outlet that looked useable for rubber hose connection. You may be able to get one at a wrecking yard.

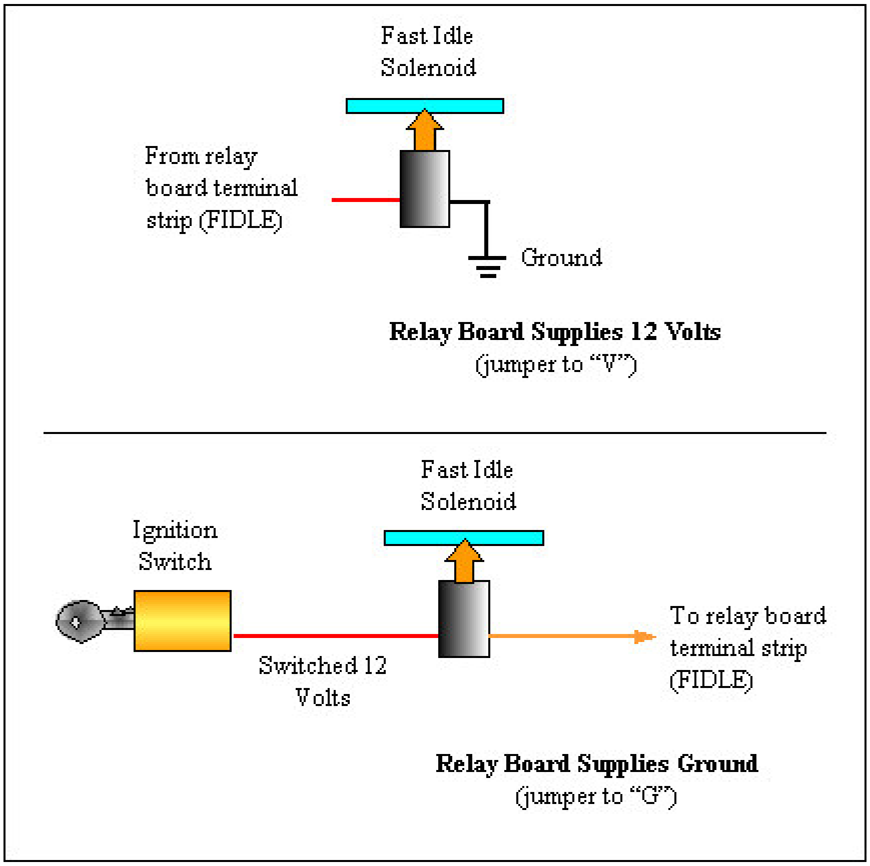
If your throttle body has the OEM IAC [idle air control] stepper motor installed, you will need to plug/disable/adjust it so that you can leave it in place. If you search for your throttle body servicing information you may discover that you can indeed manually adjust your IAC.

For example, with a General Motors IAC, you remove the IAC from the throttle body. Then simply hold the spring back and turned the tip of the IAC until it unthreads. Then turn it back in until it tightly seals the port. Now you can simply set your warm minimum idle speed by manually adjusting the IAC tip in this manner.

There also may be an idle speed screw in the throttle body, however it may be blocked by a small metal plug. Remove that plug and you will see a conventional idle speed screw. It is easier to make fine adjustments in the field with this screw than it is with the IAC.

If you are using a Relay Board, note that your FIdle valve can be wired into the Relay Board in two ways. It can take 12 volts from the relay board, and be grounded at the solenoid or at any common ground, OR it can be fed 12 volts from a switched supply (separate from the relay board) and then be grounded by the relay on the Relay Board when the DB37 connection causes the relay to close by providing a ground.

The first instance supplies 12 volts when MegaSquirt wants FIdle activated. The second instance supplies a ground when FIdle is activated (mimicking the DB37 pin).

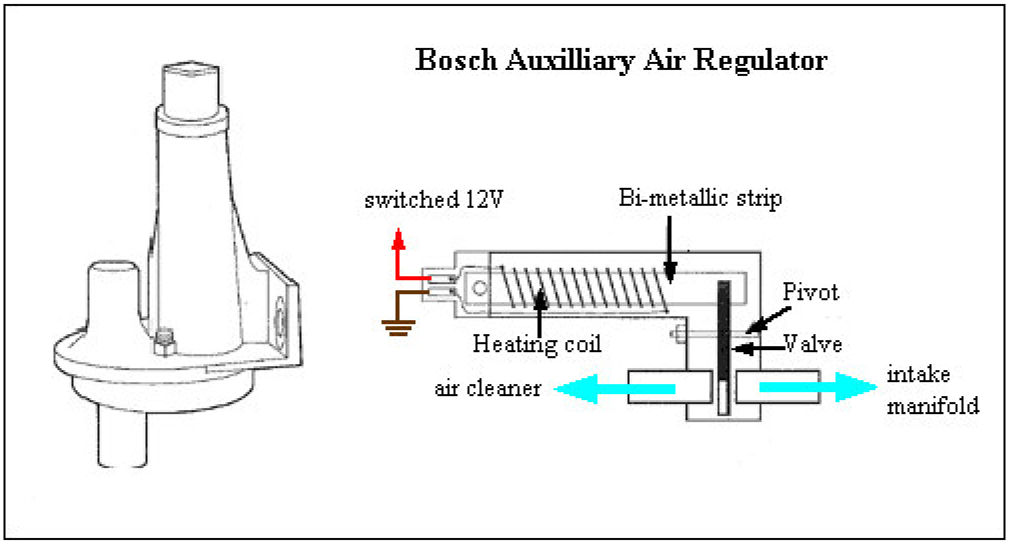


If you are designing you own wiring system and using an "off-the-shelf" vacuum solenoid with two wires, you can do it either way, so long as the solenoid is not grounded through the case.

For example, some solenoids have only one wire, and are grounded through the case, so they must have the relay board supply 12 volts. In this case set the jumper to "V". This is the most common option, unless you are converting a previously injected engine which is wired for "active ground" and you wish to use the existing fast idle valve and wiring (though most EFI engines do not have a FIdle valve, they have a stepper motor, which will not work with MegaSquirt in any case).

Some people have been using an auxiliary air regulator for fast idle control. SAAB, VW, and many other European vehicles used this system on their early EFI systems (D-jetronic) and on their mechanical injection system (CIS).

The great thing about this system is that it does not need to connect to MegaSquirt at all. You just hook up 12 volt, ignition switched, and you are ready to run. Use 12 volts from the fuel pump relay. If the engine is not actually running you do not want it powered up, as it will move to the "warm" position even though the engine is not running.



Mount the regulator to the engine such that engine heat can keep the valve closed when you do not need any additional air for warm-up. During cold starts, the auxiliary air valve opens to allow additional air into the inlet duct. As engine heats up, a bi-metallic element expands and closes valve. At approximately 140°F (80°C) the auxiliary air orifice is completely closed by the valve.

This valve is especially useful to those that have adopted one of the ignition variants of MegaSquirt (MegaSquirt*n*Spark, MegaSquirt*n*EDIS, etc.), as the FIdle control function is typically lost in these implementations.

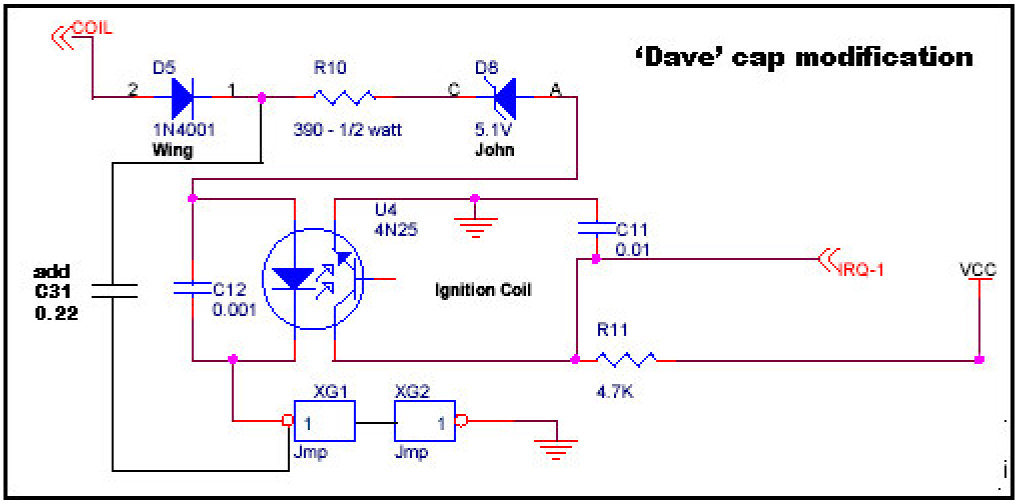
Ignition Triggering

In most cases, you can just hook the MegaSquirt tach signal wire to the tach pin on your ignition and it will work fine. For some installations, however, getting a decent tach signal may require some trial and error.

Here are some things to try if you experience tach noise:

1) Before anything, make sure that the ignition system is up to snuff - good plugs/wires/coil/etc.

2) Some installations have reported problems with low rpm spikes. Typically this sees the reported rpm at 1100 rpm jump to 5000+ rpm for short periods. This can make idle and off-idle tuning difficult. To fix this, add the ‘Dave” capacitor. This is a 0.22µf cap across the junction of D5/R10 to XG1.

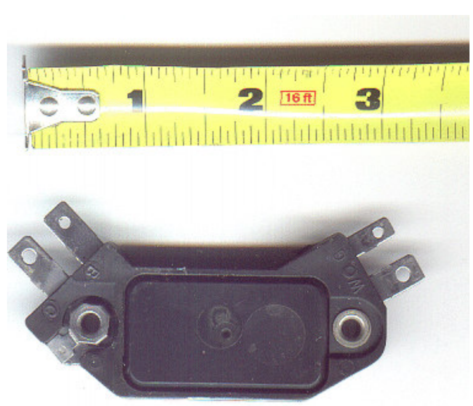


Suitable capacitors include:

Digi-Key Part Numbers for the "Dave" Cap C31			
EF2224-ND	0.22µF, 250V	METAL POLY CAP, ±10%, Radial	$0.54 each
BC1828-ND	0.22µF, 250V	CAP FILM MMKP, ±5%, Radial	$0.59
BC1779-ND	0.22µF, 250V	CAP FILM MKT, ±10%, Radial	$0.269
P11118-ND	0.22µF, 250/300VAC	CAP INTER SUPP, ±20%	$0.61

Many other capacitors can be used, including 0.33µf. People have used capacitors rated as low as 50 volts, however higher rated caps with better withstand the voltage spikes of up to 120 Volts that can appear in the tach signal. See the Dave Hayne web site (www.ep90.com/archives/00000002.htm) for more details.

3) If you are running a VR (variable reluctor) sensor, one method that works nicely is to use a 4-pin HEI module as a trigger. You use this in parallel with the existing HEI module, in that the VR sensor wires hook up to both modules. The new module is used to generate tach signals to MegaSquirt only.



NAPA OnLine sells the 4-pin HEI ignition module, **ECHTP45**, for ~$39 + shipping. These are also widely available as Wells **DR100**, Niehoff **DR400**, Standard part number **LX-301** (~$28); or AC DELCO **D1906** (~$33), and were used on many non-computer GM V-8s, V-6s and I-6s from 1975 to the mid 1980s.

Here is how to wire it up. The four HEI module terminals are labelled **W, G, B** and **C**.

- **W** = positive lead (+) from the pickup
- **G** = negative lead (-) from the pickup
- **C** = negative side (-) of the coil
- **B** = positive side (+) of the coil

"**W**" and "**G**" hook up to the VR sensor (parallel with the existing module). Hook a 470 ohm, 1/2 watt resistor between terminal "**B**" and "**C**". Hook terminal "**B**" to a switched +12V supply. Hook "**C**" to the tach lead on the MegaSquirt box. Be sure to mount the HEI module such that the metal bottom is connected to ground (either engine or chassis). The module will not get hot, since there is not much load (the resistor), but the metal still needs to be grounded. In the MegaSquirt box, be sure there is the Wing diode (no John zener) and Ed capacitor (try 0.001mf).

This trick works for virtually any VR ignition system - it does not have to be a GM, pretty much any VR sensor will drive the HEI module. The HEI module presents a high-impedance to the VR sensor circuit, so you can parallel with an existing ignition set-up without harm. It is possible to trigger off the (-) terminal of the coil, and in many cases it is successful - Bruce has been running this way for a year, so have others. But, there are some applications that the trigger will be noisy - and, unfortunately, it is impossible to "predict" ahead of time which vehicles will be the noisy ones -what works on one car will not work on another car, even the same make/year.

4) Change the value of the Ed capacitor - from 0.001mf to 0.1mf. The higher value capacitors will reduce more of the noise through "averaging", but may inhibit higher RPM trigger due to too much averaging.

5) For a few ignitions, varying the 390 ohm resistor up to higher values, up to 1K, may also reduce the noise in some cases. It is not possible to predict in advance what value will work with which ignition.

6) If there are processor resets, then running the optoisolator LED return back to the engine ground via a dedicated wire will solve this. The assembly guide has details on this.

7) It has been reported that running shielded cable back to the ECU for the tach signal will help a great deal for some installs.

Now, if the above does not work, then an alternative-form of trigger is required. If one is using a VR sensor, then using an external VR amp, like a General Motors HEI module, paralleled off the VR sensor itself, will work. See step #3 above. The HEI module is used as a nice trigger source for the MegaSquirt box.

For Hall sensors, taking the signal right off of the hall sensor works nicely. The value of the pull-up resistor, as well as the 390 ohm series resistor, may need to be adjusted. There are plenty of people on the Yahoo! list with experience on how to do this.

There is a big difference between these two types of sensors.

The **VR sensor** is an induction type sensor, it is "passive", i.e. it does not require a power source, and has a small magnet built in. It works like a dynamo. The output of this sensor varies with the speed of the engine. At idle the output is approximately .6 volts, at mid RPM it is closer to 3 volts, and at high revs it goes to almost 50 volts. You have to keep in mind that this type of sensor produces an AC output. The pulse is positive when the "pole" is approaching, and negative when the pole is leaving (provided you have the right polarity). The simplest way to see this is by hooking it up to a cheap analog voltmeter and using a wrench or other "non magnetic - soft iron" piece of metal. When you put the metal piece on the sensor the needle on the voltmeter will swing one way. When you quickly remove it the needle will swing the other way.

A **Hall sensor** is an "active" magnetic field presence sensor. It is based on the Hall effect, in which a semiconductor changes its resistance in a presence of a magnetic field. These types of sensors require a "flying magnet" wheel. Instead of teeth on the wheel you must have small magnets. This type of sensor has an electronic circuitry built inside and thus provides a constant voltage pulse regardless of the speed. The sensor is also sensitive to the polarity of the magnet. N pole will turn it on, S will not, or vice versa dependent on the orientation of the sensor. The pulse produced is as long as there is a magnetic field of some strength present, and is always of the same polarity (positive with respect to ground).

VR sensors are cheap and very rugged, Hall effect sensors are much smaller, more expensive, and nearly as rugged.

If you cannot get any of the above suggestions to work, then another trigger source, like an external VR sensor with a crank wheel, will work. This will require more work on the user end, but if the situation leads you to this, then this is all that can be done.

MegaSquirt cannot handle a capacitive discharge ignition (CDI) output directly. The CDI primary voltage is around 400V. Either uses a tach signal or the VR/points input.

Injectors and Fuel System

In order to make your MegaSquirt work on a vehicle, you will need the following additional fuel system items to suit your installation:

- Injectors and bungs/manifold,
- Throttle body,
- High pressure fuel pump, supply/return lines, and rails,
- And a fuel pressure regulator.

Note that if you start by installing MegaSquirt with a throttle body injection (TBI) unit from a late model vehicle, it will likely come with the injectors, pressure regulator, and throttle position sensor; this will greatly simplify the installation of MegaSquirt on a vehicle that was previously carburetted. If you choose a TBI unit, you will not need as much wiring, fuel rails, manifold modifications for injector bungs, etc. Once you get the TBI set-up working, you can later switch to port injection and use the TBI as an air door only.

Injector Selection

In order to properly install your MegaSquirt, you need to select and install fuel system components appropriate for your engine. Most important is that you have fuel injectors that are the correct size. Injectors that are too large will make it difficult to tune the engine at idle and cruise. Injectors that are too small can starve the engine of fuel at full power, and seriously damage your engine. To determine how big should your injectors should be, multiply estimated horsepower (HP) of your engine by the brake specific fuel consumption (BSFC)* and divide by the number of cylinders and the desired duty cycle and you will get a rough estimate of injector size:

InjectorSize = (HorsePower * BSFC) / (#Cylinders * DutyCycle)

For example, a 135 horsepower gasoline fuelled 4 cylinder engine with 2 throttle body injectors and 0.55 brake specific fuel consumption gives:

(135 HP * 0.55 lb/hr/HP) / (2*.85) = ~ 43.7 lb/hr

Injectors rated between 42 and 45 lb/hr would be okay in this case.

**BSFC is the amount of fuel your engine uses to make 1 horsepower for one hour. It is usually between 0.42 and 0.58 at wide open throttle. Normally aspirated engines with efficient combustion processes are at the lower end of the BSFC scale [~0.45], supercharged engines tend to be towards the higher end [~0.55].*

You can use the following chart to select injectors based on the total horsepower of your engine and the total number of injectors:

Injectors Rating Required for Specified Horsepower in lbs/hr and (cc/min)						
	Number of Injectors					
Horsepower	1	2	4	5	6	8
100	59 (620)	29 (305)	15 (158)	12 (126)	10 (105)	-
150	88 (924)	44 (462)	22 (231)	18 (189)	15 (158)	11 (116)
200	-	59 (620)	29 (305)	24 (252)	20 (210)	15 (158)
250	-	74 (777)	37 (389)	29 (305)	25 (263)	18 (189)
300	-	88 (924)	44 (462)	35 (368)	29 (305)	22 (231)
350	-	-	51 (534)	41 (431)	34 (357)	26 (273)
400	-	-	59 (620)	47 (494)	39 (410)	29 (305)
450	-	-	66 (693)	53 (557)	44 (462)	33 (347)
500	-	-	74 (777)	59 (620)	49 (515)	37 (389)
550	-	-	81 (851)	65 (683)	54 (567)	40 (420)
600	-	-	88 (924)	71 (746)	59 (620)	44 (462)
based on 0.50 BSFC and 85% duty cycle Turbo/supercharged engines should add 10% to listed minimum injector size						

Injectors are usually rated in either **lbs/hour** or **cc/min**. The accepted conversion factor between these depends somewhat on fuel density, which changes with formulation (i.e., by season), but the generally used conversion for gasoline is:

1 lb/hr ≃ 10.5 cc/min

Another way to select injectors is to take them from an engine that makes nearly the same power as your engine will [assuming the same number of injectors].

However, do not install injectors with a much larger flow capacity than you need. Very large injectors will create idle pulsewidth issues that will make tuning very difficult. You can estimate your idle pulse width beforehand. For proper tuning, you will need an idle pulsewidth of at least 1.7 milliseconds. To calculate the idle pulsewidth, recall that the fuelling equation for MegaSquirt is:

PW = REQ_FUEL * VE * MAP * E + accel + Injector_open_time

So, find the REQ_FUEL that corresponds to your injector flow rate and engine size. There is a REQ_FUEL calculator in MegaTune. If you have the engine running, you can check the MAP at idle (or you can guess - pick about ~25 kPa for a stock cam, ~35 for a performance cam, ~45 for a race cam). Then you only need the idle VE (and injector open time) to predict the idle pulsewidth, since this is minimum when there are no enrichments (E=0, accel=0). *Note that you need to use the "downloaded" REQ_FUEL, which is adjusted for the number of injectors and their staging.*

A good "rule of thumb" for idle VE is 30%. You may actually be 20% or 40% depending on things like compression, overlap, ignition timing, etc., but 30% will be close enough to give you a good idea about idle pulsewidth. Use 1.0 msec for the injector opening time, unless you have a very good reason to do otherwise.

For example, on one engine:

PW = 6.3 msec * 30% * (33 kPa / 100 kPa) + 1.0 msec = 1.62 msec

The measured idle PW was 1.7 msec. These injectors are okay on this engine, but just barely. If it had been 1.2 or 1.3 milliseconds, these injectors would have presented very significant tuning problems on this engine.

Injectors frequently have identifying numbers stamped on them. You may be able to identify your injectors by looking on:

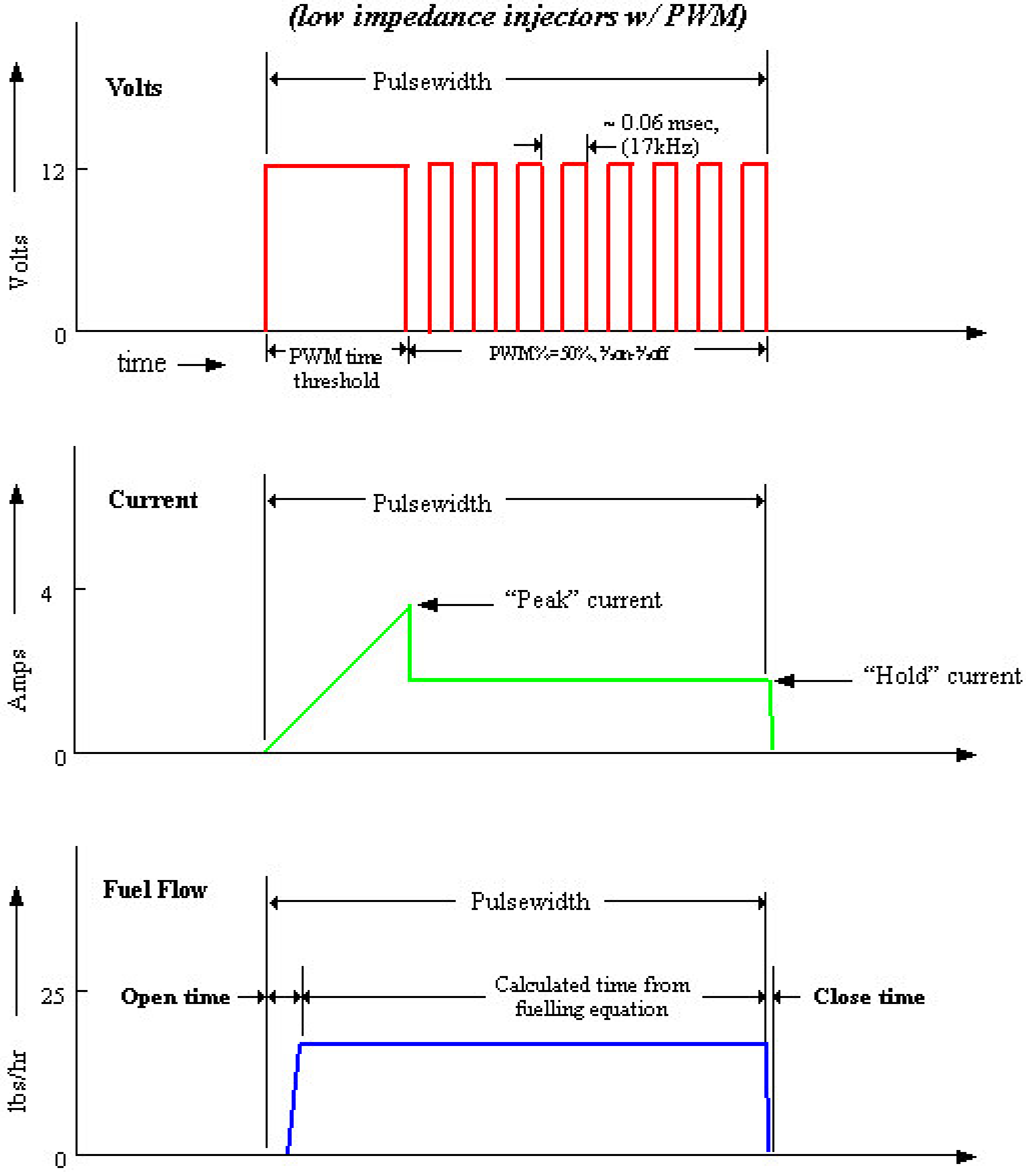
http://www.geocities.com/MotorCity/Pit/9975/dataBySubject/Injectors.html
or
http://www.telusplanet.net/%7Echichm/tech/injectors.pdf

Injectors should not be used at more than 80-85% duty cycle. However, injector rates are always specified at 100% duty cycle and some nominal pressure (usually 43.5 psi = 3 atmospheres). The manufacturer leaves it up to you to determine a system pressure and maximum duty cycle in order to compute the resulting flow.

Injectors are driven by an electrical signal from MegaSquirt that grounds the +12 volt supply through the injectors to open them. Once they are open, they flow at a constant rate until closing. The amount of time required to open and close the injectors is specified in MegaSquirt as the "Injector Opening Time" (usually about 1.0 msec). Here is an example of a low impedance injector pulse voltage, current, and fuel flow:

Injector Electrical and Flow Characteristics

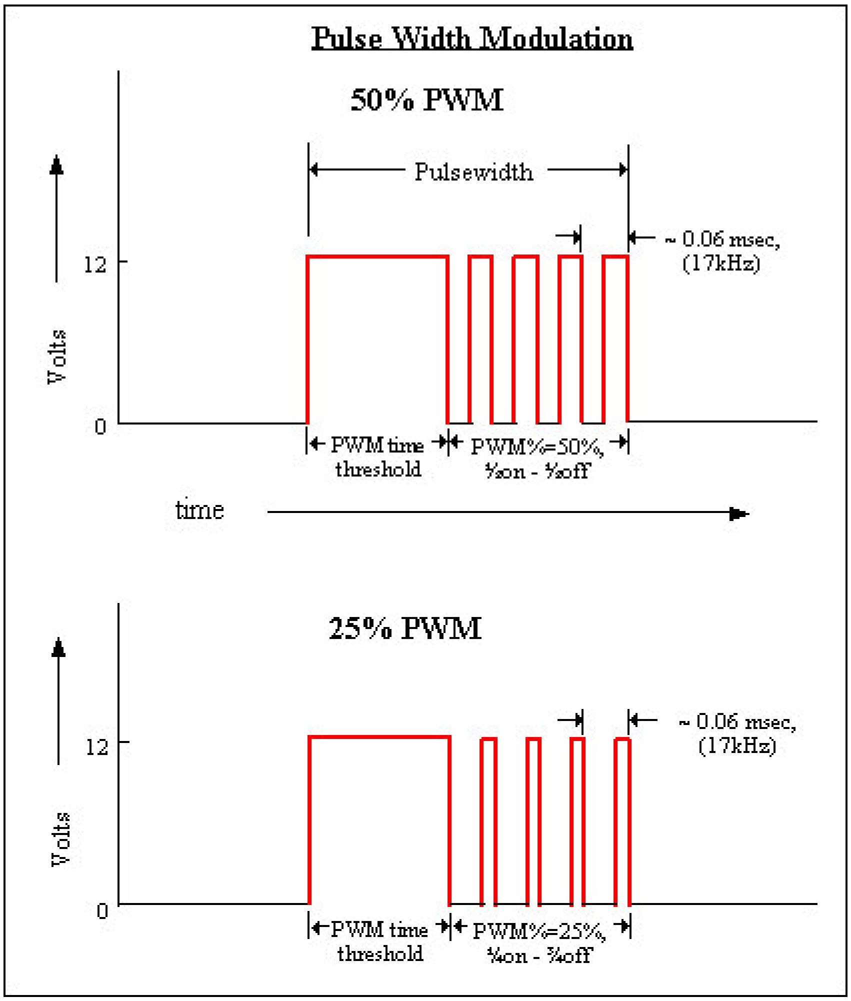
(low impedance injectors w/ PWM)



The fuel flow is basically square wave in nature, as the pintle motion in the injector is very fast. The physical valve opening and closing happens less than 0.1 ms. What we call "injector opening" is really the time needed to get the coil charged to the point where the field strength exceeds the internal spring load and then the pintle slams open.

Pulse Width Modulation

Injectors are either high impedance or low impedance. High impedance injectors (usually about 12-16 ohms) can take a 12 supply directly, without a form of current control. Low impedance injectors (generally below 3 ohms) require some form of current limiting. With MegaSquirt, you can use resistors to limit current, or you can use **Pulse Width Modulation** (PWM), which is a software solution built in to MegaSquirt.



PWM works by switching the 12 volt ground to the injector on and off very rapidly (in about 0.000059 seconds!). The ratio of the "on" time to the "off" time determines the current through the injectors. However, the easiest way to think of the PWM% is as a percentage of the supply voltage, so 50% PWM on a 14 volt supply becomes effectively 7 volts on average, 28% would be 4 volts, etc.

Remember that pulsewidth and PWM% are two different things. Pulsewidth is the total duration of the signal whereas PWM% is the ratio of 'on -time' to 'off -time' within the pulse. So in the above illustration, the pulsewidth for both is the same, but the PWM% for the first is 50%, while for the second it is 25%.

The PWM% you will be able to use depends on the flyback circuit you have. Version 2.2 hardware generally requires about 55% to 75% PWM. Often the engine will run with lower values, but will not have enough voltage to re-start. *Note that using embedded code version 2.986 or higher will disable PWM during cranking, allowing somewhat lower PWM% values.* The Flyback Board allows you to lower the PWM% dramatically, generally to 30% or less. It also helps close the injectors faster.

With better flyback control, you can reduced injector opening times (recall that the injector opening time is really the sum of the opening and closing times), and increase the duration of the "controllable" part of the pulsewidth (i.e. after the opening time),

The important thing about the injector open time is that it sets a lower bound for the pulsewidth (regardless of whether PWM is on, etc.). If you have injector opening at 1.7ms, you cannot set it to 1.6 or anything lower, even with VE=0. MegaSquirt assumes no fuel is injected during this time, but some is, though it is hard to calculate how much. The longer it takes to open, the more fuel is likely injected during opening. With lower opening times (by allowing full voltage (i.e. no PWM), you can get the injectors open quicker.

Your engine will need a certain amount of fuel to run correctly at idle when fully warmed up. If this amount is below that injected during the injector opening time, you will always be rich and have no way to lean it out, short of reducing the fuel pressure.

Note that PWM is disabled (in v2.986 code) during cranking so the injectors get full battery voltage. This makes "severe" starting condition s (lower cranking voltages, etc.) less likely to result in the injectors not opening. This is not possible with resistors, unless you devise a way to bypass them during starting (like the older cars did for the ignition coil).

When using low-impedance injectors, which are also called peak and hold injectors (P&H), you wire them in parallel. The wiring the same for P&H or saturated [high-impedance].

To **exceed the recommended number of injectors (see below)** either requires resistors in series with each injector or a modified flyback setup.

The following is a guide as to whether you need to use resistors or the flyback board:

Injector Impedance	Number of Injectors (total)	MegaSquirt Hardware	PWM Mode
High (12 - 16 ohm)	up to 12	V2.2	no PWM current limit
Low (2.4 ohm)	up to 4	V2.2	use PWM current limit
Low (2.4 ohm)	more than 4	V2.2	Use injector resistors or flyback board
Low (1.2 ohm)	up to 2	V2.2	use PWM current limit
Low (1.2 ohm)	more than 2	V2.2	Use injector resistors or flyback board

The Flyback Board

People running a number of very low impedance injectors have reported problems with the flyback circuit failing. Typically, this will happen with 4 (or more) low-impedance injectors, such as the Holley 85 lb/hr TBI injectors. This can be avoided by using resistors in series with the injectors, and disabling the pulse width modulation (PWM). However, a more elegant solution that continues to use PWM is the Flyback Board.

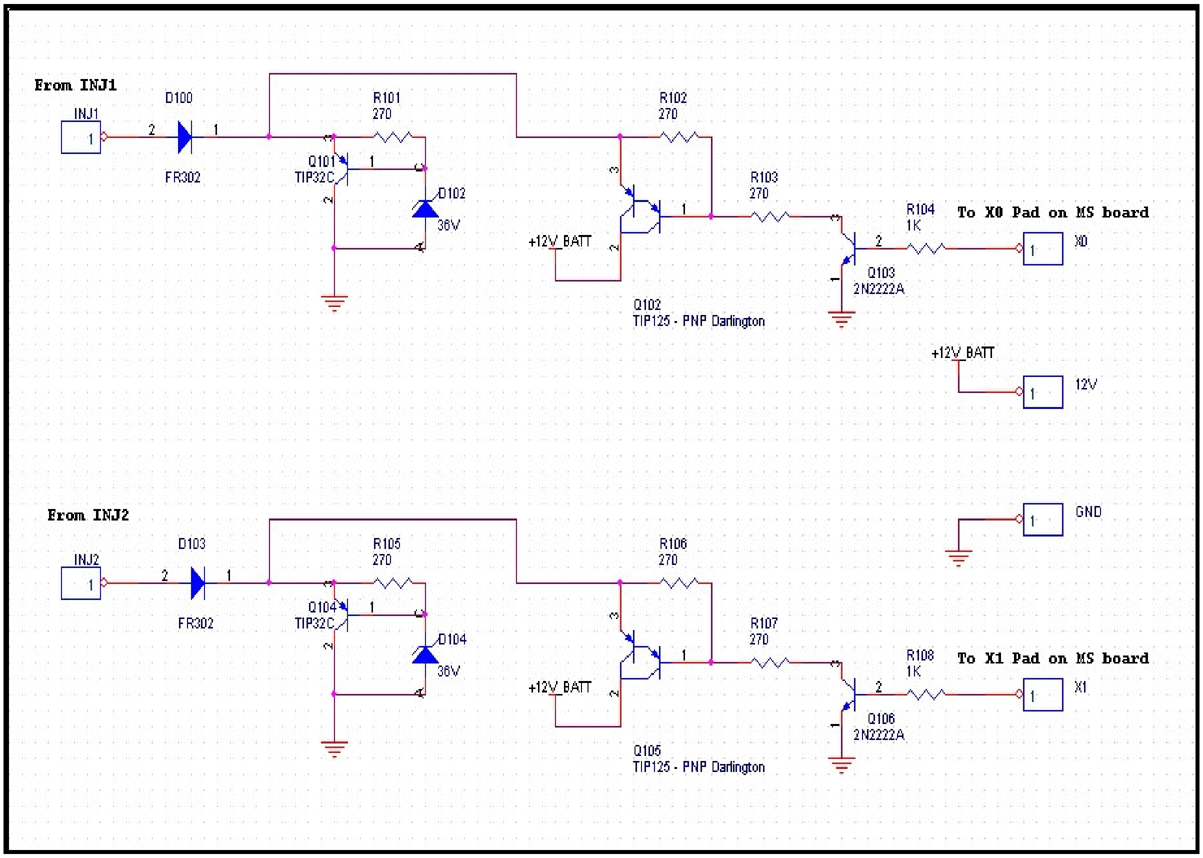
The Flyback board is an additional "daughtercard" for MegaSquirt that does a n umber of things:

- It provides each injector bank with a separate flyback circuit,
- It uses "heavy -duty" components capable of handling higher currents and transients,
- It has a very substantial aluminum heat-sink,
- It invokes the flyback circuits only after the PWM has ended, eliminating the load on the flyback components during PWM.

The Flyback Board installs in the up half of the MegaSquirt case. It slides into the lowest slot, and is attached to a substantial heat sink (that you make yourself from ½"x¾" aluminum angle). Six wires (two injector banks, two CPU [X0, X1], +12 volts, and ground) connect the Flyback Board to MegaSquirt.

The Flyback board must be used in conjunction with embedded code version 2.986 or higher. This code has the proper switching code to turn the Flyback circuits on after PWM ends.

This is the schematic for the Flyback board:



Like all other MegaSquirt kits, you order the PCB at:

http://www.bgsoflex.com/mspo1.html

Then place an order for most of the remaining parts with Digi-Key through the BOM at:

http://www.megasquirt.info/fbbom.htm

To assemble the flyback board, follow these instructions:

1) Disable the existing flyback circuit. You can do this by cutting the leads to **D22** and **D23**. You can remove the remaining flyback components if you wish. They are: **R32** (270 ohms, ½ watt resistor), **Q1** (TIP42 transistor), and **D21** (36 volt zener diode). Removing components is easiest if you cut the leads, then remove each lead separately. This puts less heat into the board and other components.

2) If you are upgrading your flyback components because of a flyback failure, replace the 34151 FET driver IC, and the two **FET**s (IFRIZ34) as well.

3) Install and solder **R101, R102, R103, R105, R106,** and **R107**. All of these are 270 ohm, ½ watt resistors {270H-ND}.

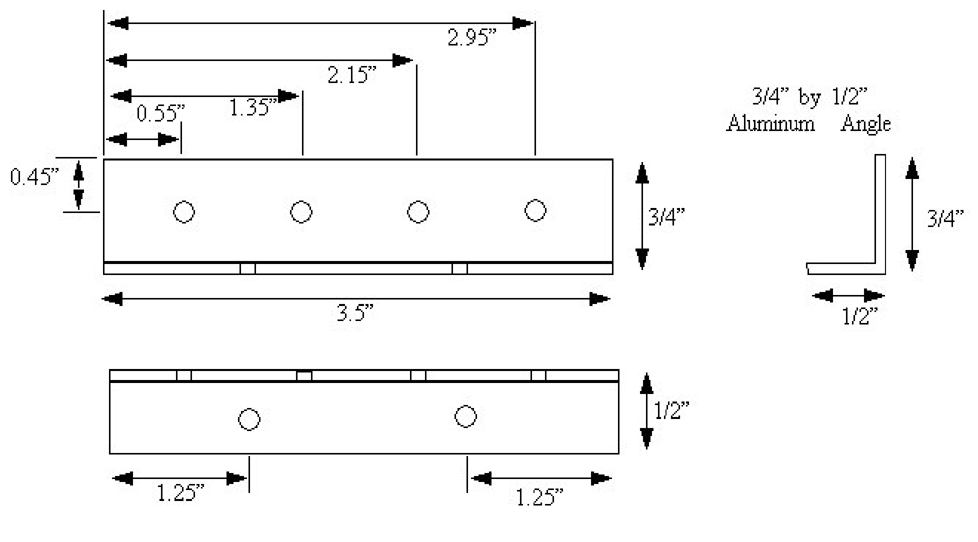
4) Install and solder **R104** and **R108** {1.0 Kohm, ¼ watt}.

5) Install and solder **D100** and **D103** {fast recovery diodes, FR302DICT-ND}. Be sure to orient them with the banded end as shown on the silkscreen.

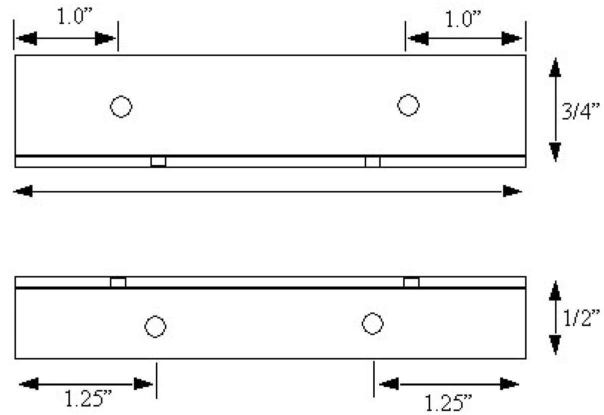
6) Install and solder **Q103** and **Q106** {transistors, ZTX450-ND}. Note that the flat side faces to the left when the silkscreen printing is oriented so that you can read it. You have to bend the middle leg slightly towards the flat side to fit it in the holes.

7) Install and solder **D102** and **D104** {36 volt zener diodes, 1N4753AMSCT-ND}. Be sure to orient them with the banded end as shown on the silkscreen.

8) Before installing the four T0-220 transistors, you need to fabricate the **heat-sink**. You need two 3½" (89mm) long pieces of aluminum angle that are ½" by ¾" (13mm x 19mm), about .040" to .080" thick (1.0mm to 2.0mm). Drill (1/8" - 3mm) these as indicated below:



Alumunum Angle Section #1 Drilling Guide

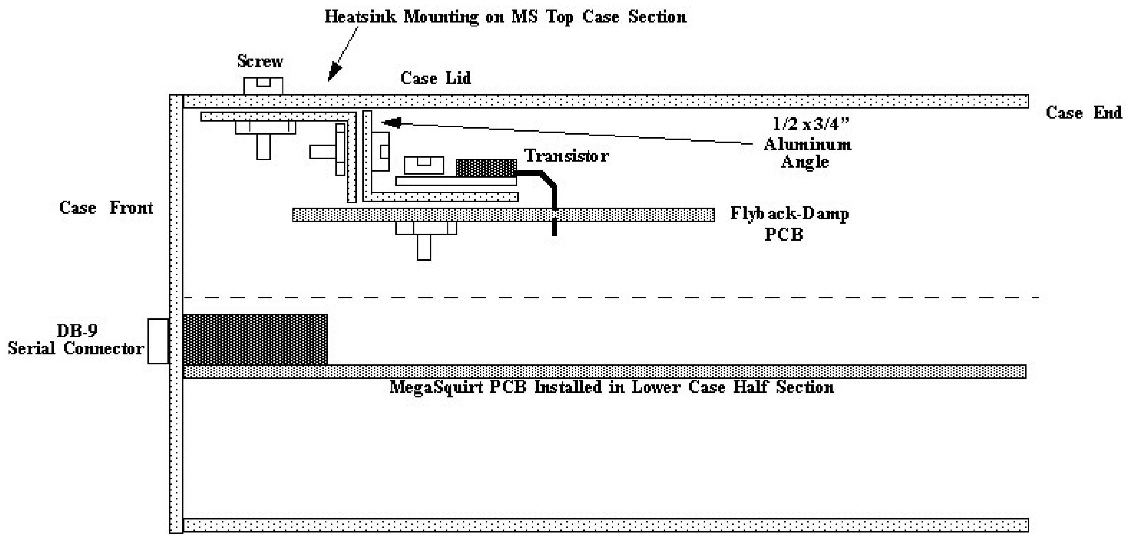


Aluminum Angle Section #2 Drilling Guide

Make sure your heat sink is no longer than 3½" (89mm), so that it can sit flat against the case. The edge of the heat sink is flush with the end of the case. Drill corresponding holes in the case. Be sure to drill the correct end of the case (the DB9/LED end). Verify that the heat sink will sit flat when bolted to the case.

The heat sink is design to attach to the Flyback board by the four transistor mounting holes. The heat sink should just be tall enough to allow the Flyback board to slide underneath it when it is installed in the lowest slot of the upper case. **Make sure to get the heat sink dimensions correct** - otherwise you could stress the Flyback board and/or impair the heat conduction abilities of the Flyback board. Either could lead to failure.

9) Assemble the heat sink (but do not fasten it to the case) as shown below using ½" (13mm) #4-40 machine screws and nuts:



Note: Apply heatsink compound on transistor, aluminum angle, and case lid at all adjoining sections

Note: Transistors Q102 and Q105 require mica insulating washer between transistor and aluminum angle. Q101 and Q104 do not require mica insulator and mount directly on aluminum heatsink.

10) Bends the leads of the TIP125 Darlington transistors **Q102** and **Q105** so that the mounting holes and leads line up with both the PCB and heat-sink. **Make sure the leads of the transistor will not touch the heat sink!** The heat sink is sandwiched between the transistor body and the PCB.

Apply heat sink compound between the two angles, and between the transistors, mica, and heat sink. Bolt the transistors in place using #4-40 machine screws and nuts using a mica insulator kit between each transistor and heat sink. Be sure to place the bolts for the transistors/heat sink through the bottom, and the nuts on the top, as clearance is limited.

You might have to trim the mica with a sharp pair of scissors to make it fit properly. Solder the transistor leads in place.

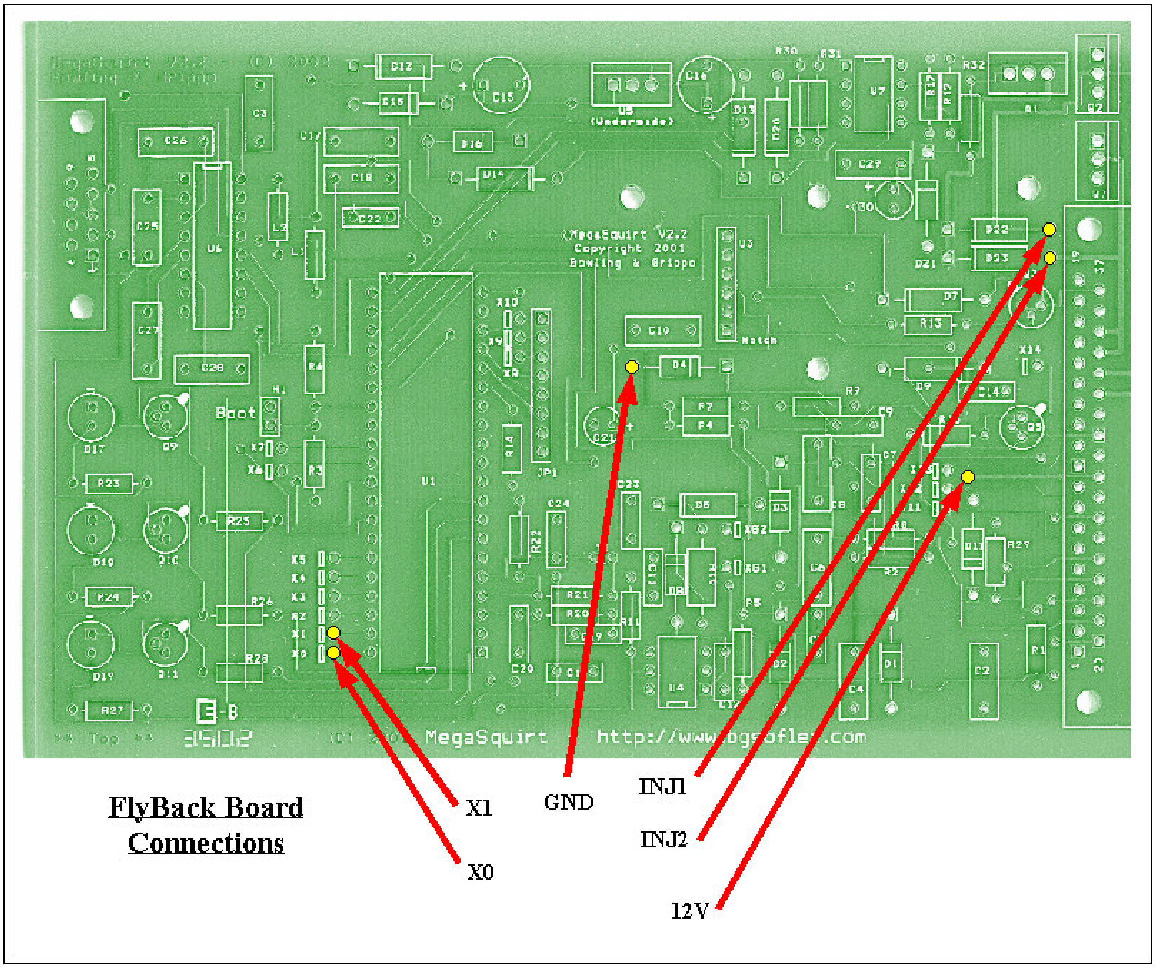
Use a multi-meter on its highest resistance setting to check that you have "infinite" resistance between the metal mounting tab of the transistor body and the heat sink. If this is not the case, your insulator is not insulating. Find out why. You may have to de-burr the transistor mounting holes in the heat sink (you can counter sink them with a quick touch of a ¼" drill). You can also sand the surface of the heat sink lightly where the transistors bolt on. Be sure to thoroughly clean the heat sink afterwards.

Do not proceed until you have electrically isolated the TIP125 transistor mounting tab from the heat sink.

11) Bends the leads of the TIP32C {TIP32CFS-ND} transistors **Q101** and **Q104** so that the mounting holes and leads line up with both the PCB and heat-sink. **Make sure the leads of the transistor will not touch the heat sink!**

Apply heat sink compound between the two angles, and between the transistors and heat sink. Bolt the transistors in place using #4-40 machine screws and nuts. These transistors do not need a mica insulator. Be sure to place the bolts for the transistors/heat sink through the bottom, and the nuts on the top, as clearance is limited. Solder the leads in place.

12) Run a jumper wire from **X0** on the MegaSquirt PCB (near the CPU) to **X0** on the Flyback PCB.



13) Run a jumper wire from **X1** on the MegaSquirt PCB (near the CPU) to **X1** on the Flyback PCB.

14) Run a jumper 12 volt power wire from the unmarked through hole just to the right of **X13** (and slightly below) on the MegaSquirt PCB to the hole marked **12V** on the right side of the Flyback PCB.

15) Run a jumper ground wire from the unmarked through any of the holes for the "non-banded" end of the unused diodes (at D1, D2, D3, or D4) on the MegaSquirt PCB to the hole marked GND on the right side of the Flyback PCB. For example, if you use D4, install the ground wire from the end of D4 closest the CPU to the hole marked **GND** on the Flyback PCB.

16) Connect a wire from the hole at the non-banded end of D22 (the one you removed) on the MegaSquirt PCB to the hole on the Flyback PCB marked **INJ1**.

16) Connect a wire from the hole at the non-banded end of D23 (the one you removed) on the MegaSquirt PCB to the hole on the Flyback PCB marked **INJ2**.

17) Install the heat sink and Flyback board into the case. The board slides in the first slot in the case. Apply heat sink compound between the case and heat sink. Use #4-40 screws to fasten the heat sink. You may need to bend any of C12, C15, C17, C18, C19, C22, C23, and/or C24 over a bit to get enough clearance, depending on how much lead length you left when they were originally soldered in.

18) Make sure to load version 2.98 embedded code or higher into your MegaSquirt.

19) Reset your PWM parameters. Try **30%** and **1.0ms** to start, then "tune" them as described in the manual.

20) Reassemble your case, and you are ready to go! Be careful not to "pinch" any of the connecting wires between the two halves of the case when you reassemble.

However instead of the flyback board, you may choose to use resistors in series with your injectors.

Several people reported that resistors do NOT result in significantly longer opening times, or any other troublesome effects, so this is a good solution for many installs. To eliminate PWM altogether, use a 5 to 8 ohm resistor (with a 20 to 25 watt rating) in series with each injector.

<u>Injector Resistors</u>

If you want to avoid using PWM with your low-impedance injectors, you can use ballast resistors in series with the injectors. You should use one resistor (20-25 Watts) in series with each injector, otherwise the injectors may not all draw the same current, and the failure modes become complicated and difficult to diagnose. As well, you would need a very large resistor to handle more injectors. For example, if you allowed 2 Amps through four 1.2 Ohm injectors wired in parallel (0.3 Ohms total) to one 7 Ohm resistor, the power dissipated would be:

P = V * I = 12.5 Volts * 2 amps x 4 injectors = 100 Watts!

If you use resistors that limit injector current to less than 2 amps, you can disable the PWM mode (by setting PWM% to 100%, and time threshold to 25.4msec) and treat the system as high-impedance. To limit the current to less than 2 amps, you need:

resistor ohms = (alternator voltage / 2.0 amps) - injector resistance

For example:

resistor ohms = (14.0 volts / 2.0 amps) - 1.2 ohms

=> resistor ohms = 7.0 - 1.2 = 5.8 ohms

The 25-watt resistors aluminum case Ohmite resistors (with 1% tolerance) from www.digi-key work well. Below is a picture of a 7.5 ohm resistor, Digi-Key part number **825F7R5-ND**.

Ohmite has several suitable resistors, with part numbers that start 825F (25 Watt, aluminum case with mounting ears) and end in XRY, where X and Y indicate X.Y ohms. Depending on injector, pick 2-8 ohms or so.

You may be able to use less resistance to protect the flyback components - just a few ohms combined with PWM may do the trick. Be sure to use one resistor in series with each injector, and then you can parallel these into the two banks. Do not share two or more injectors per resistor, use a resistor per injector.

There is a lower bound to the pulse width, below which a low impedance injector cannot be expected to reliably function. Two problems with running the very lower pulse widths that result from overly large injectors:

- There is a limit on the physical ability of the injector to opening and close as quickly as possible, and
- There is also a limit to the ability of the MegaSquirt controller to adjust the pulse width to an optimum value at very low pulse widths.

The absolute physical limit depends on your particular injectors and the hardware that controls them. Some are able to go as low as 1.1 to 1.5 milliseconds [ms]. Note that there are three components to the injection duration - the opening time, the commanded pulse, and the closing time.

Ideally you would want the opening and closing times to be a short as possible to have the controller determining as much of the amount of the time injected as possible. The opening time is difficult to adjust given a certain operating voltage. The closing time, however, is controlled to a degree by the flyback circuit in the MegaSquirt.

With very large injectors [for a given application], the idle pulse widths may be around 1.0 millisecond. This is a problem because in the standard code for MegaSquirt, the resolution of the steps is 0.1 ms. So a 1.1 millisecond "squirt" will only be able to be adjusted in ~9% increments (i.e. 1.0, 1.1, 1.2 etc.), which may be too coarse to get a good idle.

The high-resolution MegaSquirt code can help in this situation, but you lose the PWM current limiting mode so you have to run resistor packs with peak and hold low-impedance injectors.

An ideal idle duration is around 2.3 ms, and this is approximately where properly sized injectors should operate. This gives good resolution [~4%], and you should be able to get a real good idle.

You will need to acquire connectors for wiring the MegaSquirt to your injectors, etc. Niehoff has individual injector connectors under part number **28419** (connector) and **28418** (sealing boot). On the web, Waytek has many different connectors that you can use in building your MegaSquirt. Their prices are about as cheap as you can find. The injector connectors are AMP part number **827551-3**, but sometimes you have to buy a large quantity. Also try DelCity. They are not quite as cheap, but they may have stuff you cannot get from Waytek.

You can get information on injector bungs for port injectors by checking out www.sdsefi.com for injector/manifold installation information, along with lots of other great information. The bungs are 0.530"-0.535" inside diameter [about 17/32" or 13.5 mm]. The fuel supply lines for the top of the injectors are the same size.

VERY IMPORTANT! If you do not own at least two fire extinguishers, go buy some right now! Experimentation with EFI can be very dangerous because you are playing with high pressure gasoline. Install at least one fire extinguisher in your work area (away from where the fire is mostly likely to occur) and carry another one in your car. Do not ignore this advice. We do not want to be visiting you in the hospital or worse!

Injector Bungs and Fuel Rails

MSD and others have an **“Epoxy-In Pocket”** fuel injector bung as **PN 2120** (set of 8). This bung can be held in place with a strong epoxy or welded.

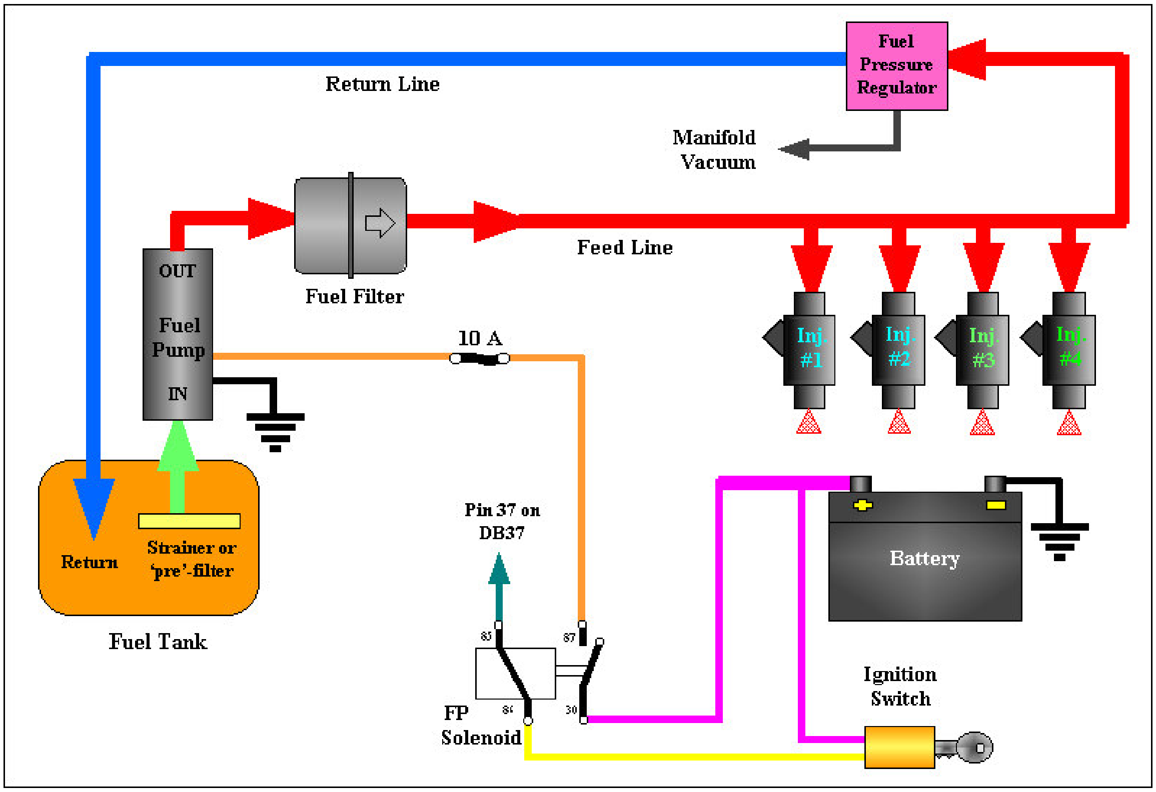
These Pockets are CNC-machined from aluminum for precise dimensions and have a ¾” OD. Internally, the pockets are contoured to accept the bottom sealing O-ring of a standard injector. MSD also has **“Thread-In Pockets”**. The aluminum pockets will screw into a ¾”–16 hole and are supplied with a #8 O-ring to seal the pocket to the manifold. **PN 2125** gets a set of 8.

For fabricating fuel rails, MSD has **“Fuel Delivery Top Mounts”, PN 2115,** set of 8**.** These fuel delivery mounts are CNC machined from #304 stainless steel for great durability and precise dimensions.

They slide over ½” steel tubing (MSD PN 2205) then are brazed or TIG welded in place to form a fuel rail. Fuel is routed through a 5/16” hole aligned to the mount and the injector. The PN 2105 Fuel Rail Clip is required for assembly. Their “**Stainless Steel Fuel Tubing”, PN 2205,** comes in 2 four feet lengths of 304 stainless steel tubing, and is perfect for making custom fixed rails. The seamless tubing has a ½” OD and .035” wall.

Fuel Supply System

In order to use MegaSquirt, you will have to implement a high-pressure fuel supply system. You MUST understand how to do this properly, and this manual DOES NOT include everything you need to know. If you are unsure about your installation, have a qualified mechanic look it over before attempting to start your vehicle.



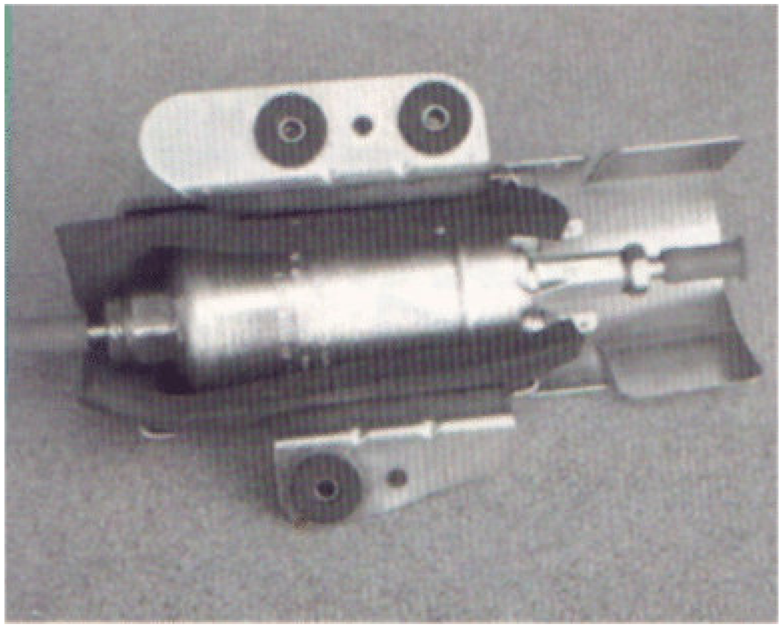
Fuel Pumps

You will need a high pressure pump with enough volume at your operating pressure to feed you engine under maximum load. Typical pressures needed in the neighbourhood of ~45 psi for port fuel injection, ~10-20 psi for TBI injection. A port injection pump will work with TBI, but not vice-versa.

OEMs usually place pump inside the fuel tank. In an EFI retrofit it is generally easier to use an external fuel pump. Ford used external fuel pumps on 1989 era F-150 trucks which may be a candidate for use. These are high pressure [port EFI] pumps that will work in most applications. Econoline vans have these as well.

The external pumps used in Ford F150 fuel injected trucks from the 89-93 model years are **Delco EP286**. At 12 volts, the operating pressure is 70-95 PSI with 36-40 gals per hour. The biggest Delco pump is the **EP424**, which is 75-90 PSI at 40 gals per hour. EP 268 is a GM# 25117086, EP 424 is a GM# 25176156."

Here is a picture of the Econoline pump:



The Carter pump **#P70199** (the outlet is 7/16 standard pipe thread and the inlet is 15/32 clamped hose type fitting or 3/4 standard thread. The specs are 95-PSI max, 68-93 G/Hr wide open). This is the highest flowing Carter external fuel pump in the book. It will produce up to 95 psi, and crosses over to **EP7107** at Kragen for about $80 (unfortunately one end does not come off like the Carter). You might want the Ford style pump **EP7109** ($80). You will need this if you want to be able to modify ends to be 3/8".

Others have had luck using the external pump from various fuel injected VolksWagen models (87 VW Fox, for example). Part number is: **Bosch 0 580 254 957** reportedly rated at 90 GPH@ 70PSI, you might find them for about $130 new from www.germanautoparts.com. This pump consists of a fuel pump, filter, and an "accumulator". You can leave the accumulator in place since it does not affect the running volume or pressure, and on used pumps they are often rusted so you might not want to mess with it.

Auto Performance Engineering has many high volume Walbro pumps (and their specifications) on their site.

Fuel Line

Steel tubing is recommended, but you MUST have short sections of rubber line in the feed and return lines between the engine and frame to allow for engine movement. The return line should have minimal restriction. For reference, GM systems typically have 3/8" feed lines and 5/16" return lines.

You may be able to use your original fuel line as a return line, plumbing a new 3/8" (10mm) line for fuel supply. You can run the return line into the tank, or reroute it to a fitting or nipple you install in the fuel tank filler neck/tube assembly (in which case you may be able to use the original pick-up for your supply line). If you run a new pick-up into the tank, it will need a filter. GM sells a sock-type filter that is a good fit for 3/8" lines. It is part number **5651702** and costs about $15.

If you need a simple way to get to a barbed fitting to connect the rubber EFI hose to the GM 2 bbl TBI, your local auto parts house probably stocks GM fuel line repair kits in the HELP section. These consist of 9" of steel fuel line in 3/8 and 5/16 diameter with an O-ring and Saginaw fittings 14/16 mm, respectively, on one end and a barbed end crimped on the other. The steel lines are about $4.00 each. This pieces thread into the steel adapters that should be there from the factory on the GM Rochester TBIs. For a complete listing of various fittings with part numbers, etc. go to:

http://www.ag.auburn.edu/users/gparmer/efi/fittings.txt

IMPORTANT: Keep the fuel lines out of passenger compartment and routed safely away from moving or hot parts to avoid damage/excessive heat. For flexible rubber hose use the SAE 30R9 EFI hose which is rated at 250 psi. EFI hose clamps are also recommended rather than gear clamps. Check with someone who knows if you are not sure about your installation. Nobody needs a 50 psi gasoline fed fire to ruin their day!

Fuel filter

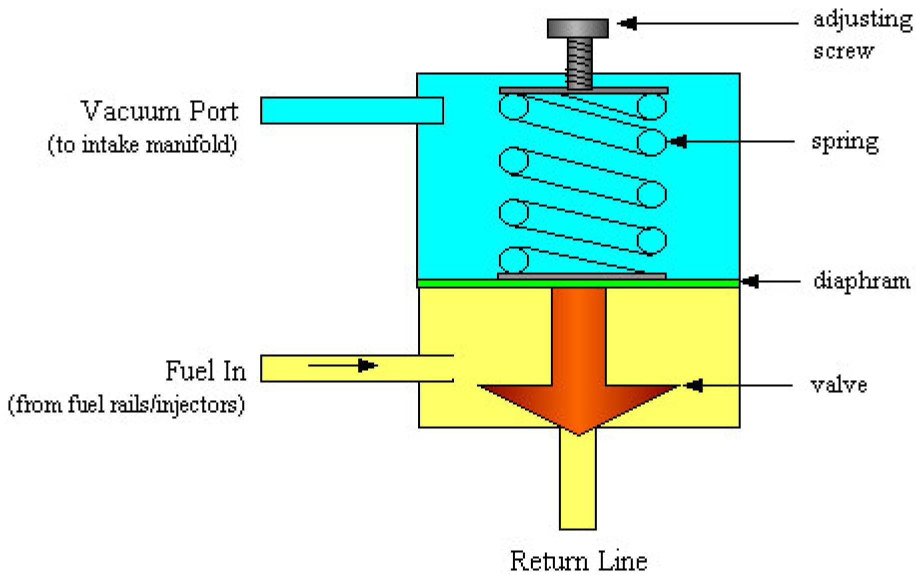
Use a fuel injection fuel filter rated for the pressure at which your system operates. DO NOT use a universal carburetor filter- the pressure may cause it to burst! Position the filter downstream of the pump so that a clogged fuel filter will not overheat the fuel-cooled pump.

Fuel Pressure Regulator

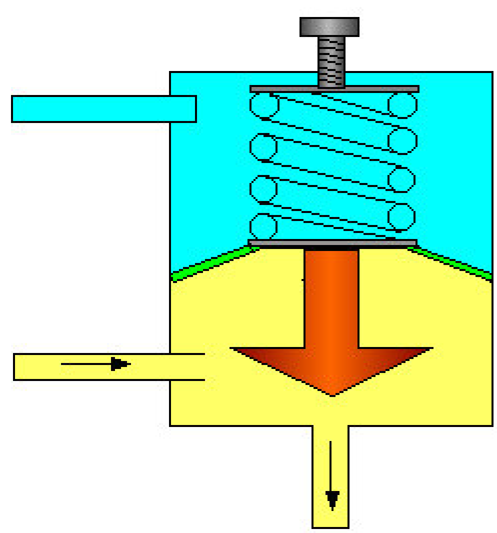
The vacuum referenced fuel pressure regulator is essential. It provides constant pressure differential between fuel at injector nozzle and manifold air pressure [port EFI] or atmospheric pressure [TBI]. This makes the injected fuel quantity solely a function of the injector open time.

The regulator is typically at the far end of the fuel rail, but performs its job anywhere, so long as it is after the fuel pump.

A Port Fuel Injection Regulator

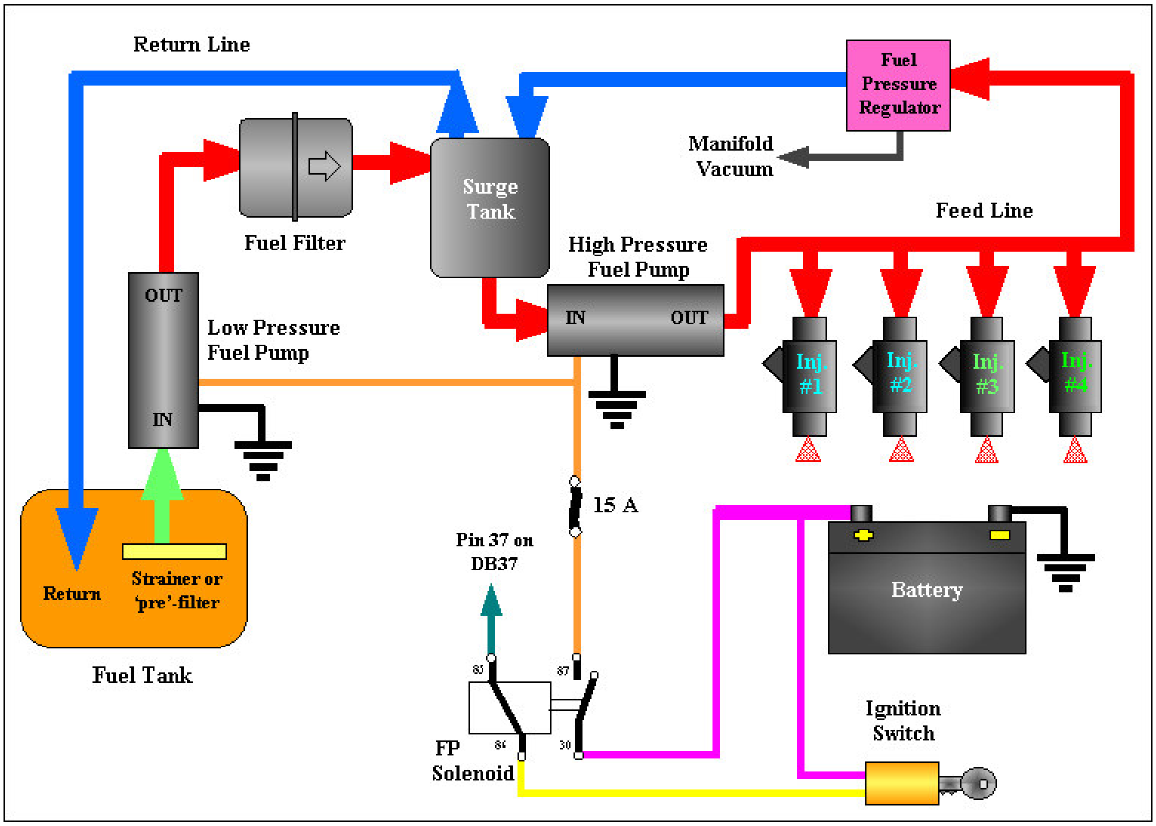


If the fuel pressure is below the specified level, the return valve is closed and the pressure builds (above). When the pressure in the fuel rail is able to overpower the spring pressure (minus the vacuum on the diaphram), the return valve opens and fuel is released until the pressure lowers (below). This keeps the fuel pressure at the pre-set value above the intake manifold pressure.



Surge Tank

You only need a surge tank if you are using a low pressure pump to supply an external high-pressure pump. Some pumps come with an accumulator after the pump, and these can be left in place.



Wiring the Fuel Pump

To activate the fuel pump, MegaSquirt provides a ground for the fuel pump relay circuit on pin 37. The relay is wired for 12 volts switched from the ignition switch, and the relay is grounded through MegaSquirt [pin 37 on the DB-37 connector].

MegaSquirt will disable the fuel pump when RPM = 0 and enable while non-zero (cranking/running), except for Version 2.00 (and up) embedded software which will perform a short priming pulse, then shut down the pump if the engine is not running after 2 seconds.

You might want to consider a safety switch in the fuel pump circuit when installing an electric fuel pump. Holley has one (**12-810**, ~$20) that will ensure the fuel pump will not run unless the engine has oil pressure. It stops the pump from running if the motor stalls with the ignition on. Wiring the switch through the starter solenoid circuit energizes the pump on engine start-up. Once the engine has started, the switch continues to provide power to the pump as long as there is oil pressure to keep the switch turned on.

Note: An inertial safety shut off switch should be installed and used to kill power to the pump upon significant impact to vehicle.

These switches are available in junkyards from EFI Fords. The switch is on the drivers side in the trunk, near the trunk hinge, mounted so that it is between the interior bracing and the rear quarter panel (protected from being knocked around if you stuff your trunk full of stuff). It is mounted with the reset switch straight up. Note switch mounting orientation probably matters.

It is Ford Part # **F2AB-9341-AA**. The wire going into it is about 14 gauge, so it should be capable of handling the full current of the fuel pump.

The markings on the switch show that it has NO/NC (normally open/normally closed) positions so that it should be able to accommodate any possible fuel pump configuration.

Tuning Your MegaSquirt

Now that you have assembled, tested, and installed your MegaSquirt, you need to get your engine started and tuned. This is not too difficult if you work methodically, and do not let your enthusiasm prod you into a premature full-throttle melt down. It does help if the engine was running before the conversion, and does not need a pile of tune-up/rebuild parts.

When you do your conversion, it helps if you can hook the fuel injection up (sitting on the fender) except for the actual injectors, while still running the engine on its original fuel system. This allows you to start the engine and verify that the temperature sensors, TPS sensor, the O2 sensor, fuel pump, etc., work as expected. It will ease your mind when you proceed to running on MegaSquirt. If you have a running engine, it is something you might consider.

Tuning Theory

Tuning involves setting all the parameters that MegaSquirt uses to be optimal for your engine, injection, and driving. These include things like cold start pulsewidths and acceleration enrichments. The most fundamental parameters are in the 8x8 volumetric efficiency table.

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

Remember that people tuned engines for maximum performance and efficiency for many years with carburetors without any quantitative feedback at all. They often got very good results The O2 sensor and MSTweak3000 make tuning much easier. By the time you have had a few sessions with MSTweak, you will have a better idea of how to tune the remaining areas.

When tuning:

- Do not change more than one thing at a time and always be able to get back to where you started,
- Do not try to drive the car if you cannot get it to idle properly, fix the idle first,
- Do not try to tune accel before you have tuned VE,
- If you report a problem to the list, please supply details, do not just say it does not work.

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

Air/Fuel Ratio Equivalents

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

Tuning Software

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

- **PC Configurator** - The original tuning software from Bowling and Grippo, it has fewer features than MegaTune. Having two independent tuning packages can be useful to determine if issues that arise are related to the tuning software or the MegaSquirt code.
- **MegaTune** - for tuning and datalogging MegaSquirt with a laptop computer running Windows 9x/ME/XP, it has more features than PC Configurator. In this manual we will assume you are using MegaTune, but PC Configurator is similar in most respects. (Eric Fahlgren),
- **MegaTweak3000** - for refining your volumetric efficiency table from datalogged data, (Darren Clark),
- **EasyTherm** - to simplify configuring your MegaSquirt to accept the substitution of non-standard temperature sensors and to upload software revisions. (Roger Enns)
- **MS Palm** - to tune and datalog with a Palm (Roger Enns)
- **MS Logfile Visual Viewer** - A very handy program that displays your datalog files in graphical form. You can see the 'big picture" this way. Note that your screen resolution must be set to 1024 x 768 for this software to work. (Mike Robert)

To tune all the parameters of MegaSquirt so that your engine runs the best it can, you will need to do the following:

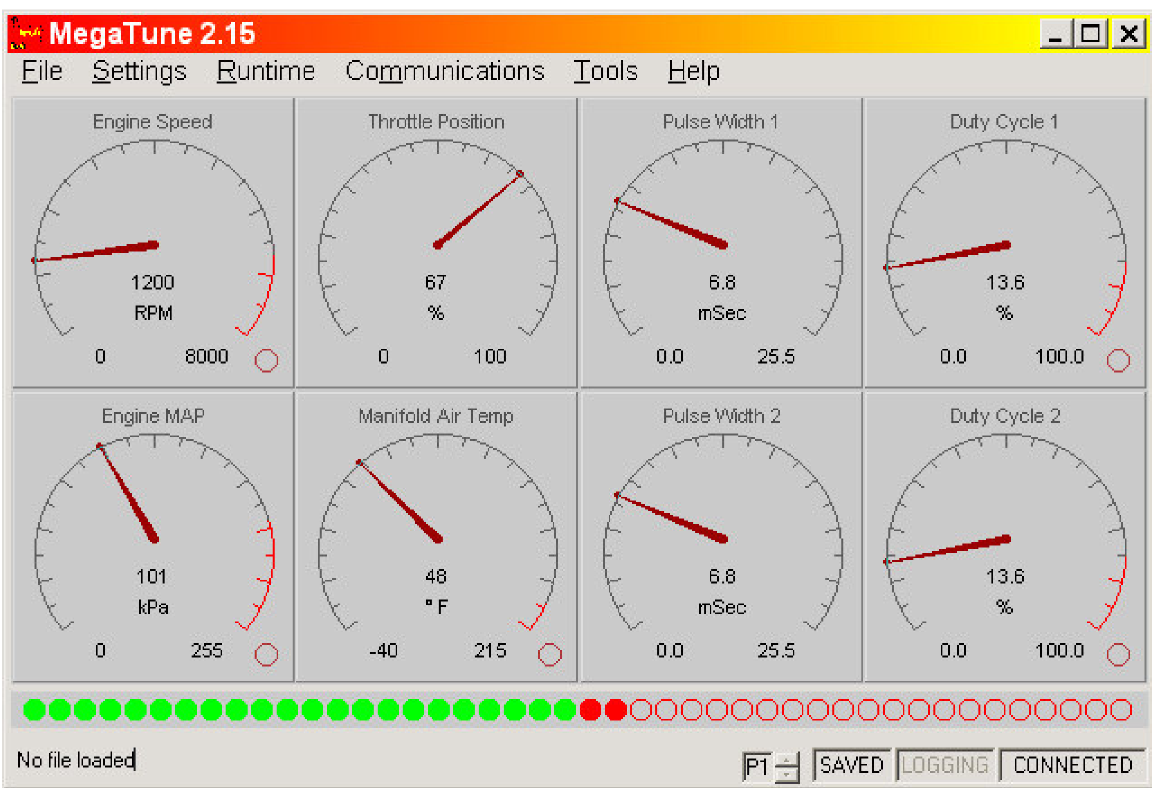
1. First, learn to use MegaTune,
2. Next, set the constants,
3. Get the engine started and idling,
4. Then set the PWM criteria,
5. Then set the cold start and warm-up enrichments,
6. Then set the VE table,
7. Set the acceleration enrichments,
8. Check that certain resistors are not getting too hot while driving.

We will go through each of these steps in turn.

Using MegaTune

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

The front page shows eight gauges, the left four of which are the major inputs to MegaSquirt and the last four are the output pulse width and resulting duty cycle for the two injector banks.

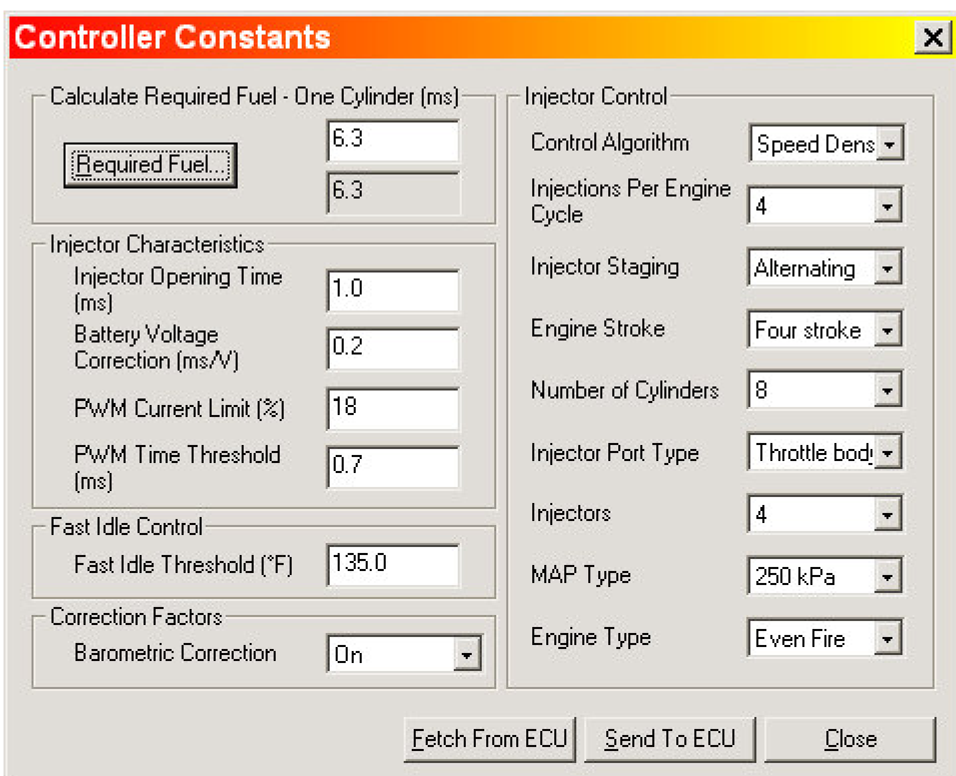


Pulse width is the measure in milliseconds of how long the injector is opened for each pulse, regardless of how many times it is opened in a cycle. Duty cycle gives the percentage of time the injector is open irrespective of individual pulse duration.

The bar gauge across the bottom of the window shows the oxygen sensor reading. The scale is determined by egoGauge value in the Tuning section of the megatune.ini file. This same setting controls the analog and bar gauges on the tuning page. The first value of this controls the lowest voltage displayed on the gauges, the second number controls the highest and the optional third value specifies the "alert" value, above which the LEDs are red. The bottom of the front page contains a status bar. The current file name (used for Save operations) is displayed in the left part of the status bar, followed by "saved" status. When the memory image has been modified since the last Open or Save operation, this entry shows "**SAVED**" in bold face.

Setting the Constants

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



On the Settings/Constants page:

If you have low impedance injectors,

- Set the PWM time threshold to 1.0 ms, and
- Set the PWM % to 75% (30% if you have installed the 'Flyback Board" daughtercard).

You will tune these after getting the engine running. See 'Setting the PWM Criteria" in this section. **Failure to perform these steps can result in damage to your injectors**. If you have high-impedance injectors, set these values to 25.4 ms and 100%, and you do not need to tune them further.

"**Control Algorithm**" lets you choose between Speed Density and Alpha-N. In all cases, you should choose speed density unless you have a good reason to do otherwise, and understand how this will change your tuning efforts. All tuning advice in this manual is based on the speed-density algorithm. Alpha-N uses the throttle position (alpha) and RPM (N) to calculate the amount of fuel to inject as opposed to using the manifold absolute pressure (MAP) and RPM to calculate the amount of fuel to inject. Alpha-N is useful for long duration cams where the resolution of manifold air pressure (map) would be small. It is also useful to get smoother idle on engines that have erratic map values. MegaSquirt be converted from its default **speed-density** calculations to **Alpha-N** which uses RPM, temperature and TPS only. You must have version 2.0 (or higher) of the embedded software installed. Start up the tuning software, go to the Constants dialog and change speed density to Alpha-N. Re-map your VE table. You will no longer use the MAP sensor for estimating the load on the engine -- the throttle position and rpm are used instead. This can help with cams with long duration and/or a lot of overlap, as they have low and variable vacuum at idle, making tuning very difficult.

Required Fuel – (Req_Fuel) this is top field of the Constants window. It has a calculation dialog to help you find an appropriate value. It should contain the injector pulse width, in milliseconds, required to supply the fuel for a single injection event at stoichiometric combustion and 100% volumetric efficiency. In order to come up with this value, MegaTune provides a calculator that will suffice for 99% of applications (those for which it will not work generally require changes to the MegaSquirt controller code itself, and that is beyond the scope of this manual).

For a 4-stroke, a complete stroke cycle is 720 degrees of crankshaft rotation (i.e. two revolutions); for a 2-stroke, it is 360 degrees (this is also factored in the REQ_FUEL value downloaded to MegaSquirt). In the tuning software, the upper REQ_FUEL box is the amount per cylinder, as noted above. The lower REQ_FUEL box is the downloaded value to the ECU - this is the REQ_FUEL number on top, but scaled by your injection mode (number of squirts and alternate/simultaneous). For example, if you inject simultaneous and one injection, and have the same number of injectors as cylinders [i.e. port injection], then REQ_FUEL on the bottom is the same as REQ_FUEL on top. The same reasoning applies with "alternate" and two squirts. If you put in simultaneo us and two squirts, then REQ_FUEL is divided in half - because you squirt twice, you need to inject 1/2 the fuel on each shot.

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

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

Injections per Engine Cycle is set the number of squirts you want per engine cycle. You want this to be set so that your idle pulsewidth is no less than 2.0 ms, if possible, and your Req_Fuel is less than 12-15 milliseconds, but more than 8 milliseconds. These values allow proper tuning of the idle mixture while maintaining the ability to apply enrichments (acceleration, warm-up, etc.) under full throttle. This is the total number of injector events that you wish to occur for every engine cycle (360 degrees for two stroke engines and 720 for four strokes).

Injector Staging values for injector staging are simultaneous or alternating. If you wish for all your injectors to fire at once, select simultaneous. More likely you will choose alternating, as this helps even out the pressure fluctuations in the fuel rail.

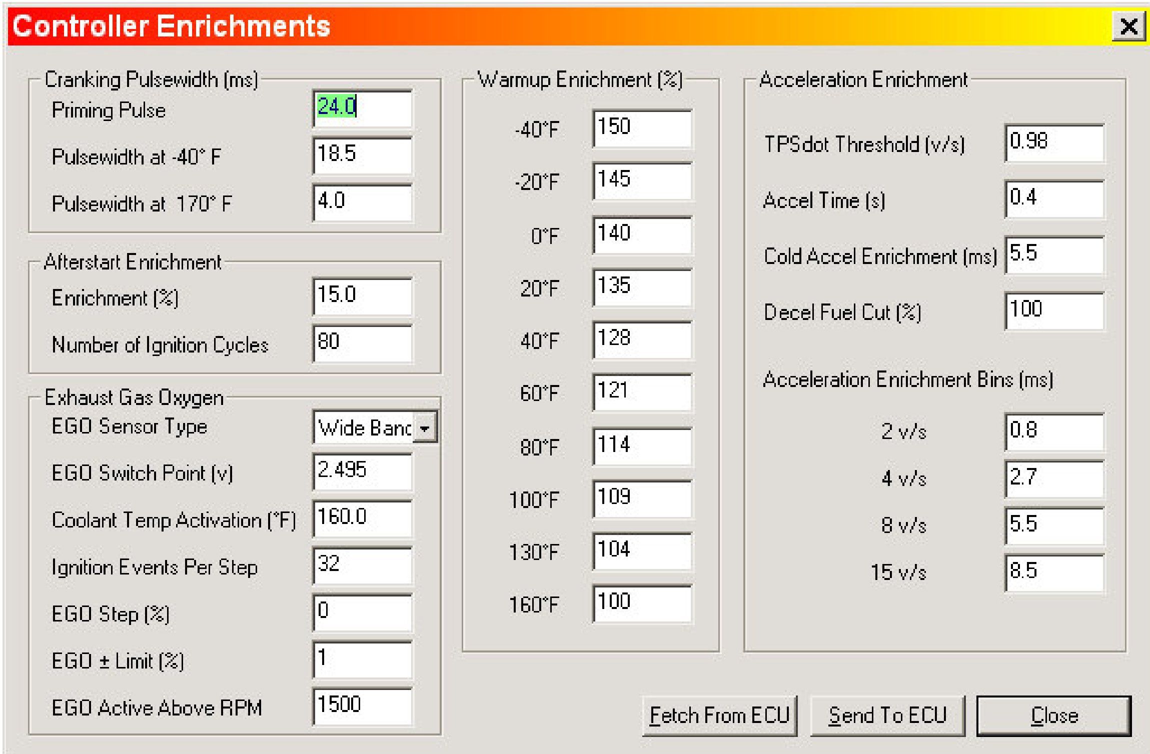
Engine Stroke values for engine stroke type are two-stroke or four-stroke. MegaSquirt uses engine stroke to determine how many degrees are in an engine cycle.

Number of Cylinders is the count of the cylinders on your engine. If you are unsure how many cylinders your engine has, you should not be installing MegaSquirt on it. This value is actually the number if ignition events per cycle sent to the ignition input on the controller.

Injector Port Type is used to select the type of injectors that you are using, throttle body or multi-port.

MAP Type values for this may be selected from the option menu, and are either 115 kPa or 250 kPa. All Version 2 MegaSquirt partial kits have the 250 kPa MAP sensor. This should be auto-detected from MegaSquirt, but if it is not, select the right one and hit "Send to ECU" right away.

On the Enrichments page:



Set the **EGO switch point** to a value between 0.45-0.50 volts with a narrow band O2 sensor. With a wide-band sensor, set it at 2.50 volts (DIY-WB, others may differ). These values will attempt to give stoichiometric mixtures under closed loop operation.

On the Communications/Settings page:

Port - The communications port number should correspond to the port to which the MegaSquirt controller is attached.

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

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

Before Starting Your Engine

If your engine is newly assembled, consider running it on a known good carburetor before attempting to run it on MegaSquirt. This way you wont have to worry about proper run-in for the camshaft, proper ignition timing, etc., while trying to get a reasonable initial tune into MegaSquirt. Before starting, make sure to:

- Have two fully charged fire extinguishers on hand,
- Check the entire fuel system, from the tank to the injectors and back, for leaks while running the fuel pump. DO NOT attempt to start the engine if there are ANY leaks whatsoever. **Fix any leaks before proceeding**.
- Check that the fuel pressure is appropriate for your system (usually about 42-45 psi for port injection when not running, usually around 12-15 psi for throttle body systems).
- Verify that you have powered your MegaSquirt form a +12V source that will supply current **while cranking**. Many reported problems with MegaSquirt have been traced to power sources that are connected in "run" but not while cranking. Check your vehicle wiring diagrams if you are not sure.
- If you have a throttle body injection (TBI) system, verify that there is a small squirt of fuel (equal to the "prime pulse") when MegaSquirt is powered up (by turning the ignition key to run), and that no more fuel is injected until cranking starts. If this is not the case for your system, find out what is wrong and correct it.
- Connect your laptop to your MegaSquirt using a DB-9 cable, turn the ignition to run (do not start it), and verify that all the sensors give reasonable values. The MAP should be about 100 kPa, the coolant and intake air temperatures should be approximately the same as the outside air, and the TPS should read from 0 to 100% as you open the throttle. Note that MegaTune has a two-step calibrating function for the TPS. Read about it in the MegaTune help file, and use it.

Get the Engine Started and Idling

You start, naturally enough, by getting your engine started. Typically, the first time someone tries to start their engine with MegaSquirt, it starts after about 5 minutes of alternating various cranking pulsewidth numbers to get started (on the Enrichments page), and REQ_FUEL to keep it from stalling (on the tuning page). It may take a bit of cranking.

Once you have it started and running, you can reset the REQ_FUEL value back to its original number. It is very easy to change without having to re-enter the VE numbers. Start up MegaTune, go to **Tools->Scale VE Table,** and enter your original and new REQ_FUEL values. This adjusts the VE table.

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

If you have been trying to start your engine for more than 10-15 minutes, you ought to investigate other sources of problems before continuing to try to start the engine. Properly tuned, MegaSquirt will start your engine quickly and reliably. If you have trouble with starting, either hot or cold starts (or both):

- Verify that the source you have chosen to supply +12 Volts to MegaSquirt with is receiving power **while cranking**. Some sources give 12 Volts in **RUN** but not **CRANK**. The engine will be very difficult to start if MegaSquirt is connected to such a source.
- Make sure that you have enough voltage during cranking to open the injectors. For cold starts, you have a cold engine, and a cold battery that make a lot of demands on the starting system. Make sure your battery/alternator, etc. are *"up to snuff"*.
- Make sure your PWM setting are not so low that your injectors no longer fully open for the commanded pulsewidth in worst-case scenarios, which cold starts definitely are! Note, however, that V3 code disables PWM during cranking. This was done so that PWM values (% and threshold) could be lowered under running conditions. However, the PWM set-up needs to be sufficient for a poorly charged battery that has just had to start a cold engine, with the heater/defroster running full-blast, etc.
- Remember that the cranking pulsewidths need to be with ~0.5 ms of the optimal value at both -40º and 170º F. Generally the-40º cranking pulsewidth should be about 3 to 5 times the 170º number. If you overestimate the correct values, you WILL flood the engine.
- For tuning, the engine needs to be it a true "cold-start" state. That means not flooded - which can easily happen when you are playing with the numbers. If you suspect you may have flooded the engine, disconnect MegaSquirt and crank the engine for at least several seconds or more. Keep a battery charger handy!
- Check to make sure the injectors are actually firing, so that you are sure there is not a fault in the wiring causing you to run without a full deck of injectors. This is easy with throttle body injection, just look at them with the air cleaner off. With a port injection system, see if you can smell gas at the exhaust.
- If the engine tries to start, but dies right away, you need to adjust the after start enrichment (ASE). Generally this should be between 20-30% for 100 to 250 cycles.
- If the engine starts but dies after a several seconds or minutes, then you need to adjust your warm-up enrichment.
- Check a datalog of your cranking to verify that your cranking speed is 300 rpm or less. If it is more then 300 rpm (not very common, but possible), you need to make adjustments to the code to continue to use the cranking pulsewidths while the engine is cranking. Consult the Yahoo! list for details.

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

If it is cold out, you may need to adjust the warm-up enrichments before you can get the engine warmed-up so that you can adjust the idle mixture, etc. The easiest way to do this is to use the Warm-Up Wizard in MegaTune.

If you do not use the "correct" REQ_FUEL value, the VE numbers in the VE table will be skewed by the amount REQ_FUEL is "incorrect".

Setting the PWM Criteria

To tune the PWM [pulse width modulation] values for your engine, you need to know what kind of injectors you have- low impedance or high-impedance. If you are running **high-impedance injectors** (greater than 10 Ohms), then set the PWM time to a number like 25.4, in essence you are disabling the PWM mode. This allows full voltage to the injectors throughout the pulsewidth.

For **low-impedance injectors** (less than 3 Ohms), you need to limit the current to avoid overheating the injectors. To do this, there is a period of time that you apply full battery voltage [peak] current, then switch over to a lower current-averaged [hold] current, i.e. peak and hold. Alternatively, you can add resistors in series with the injectors. See the Injectors and Fuel Supply section of this manual for more details.

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

Start with 75% PWM and 1.0 millisecond time threshold. Once you get idling, then first adjust the PWM duty cycle down in 1% increments until you notice a change in idle quality (be sure to hit the "send to ECU" button each time you change the value). This is the point where the current limit is too much and the injectors are not being held fully open. Then move the value back up 3 - 5% (for example, if the idle falters at 45%, then put in a number of 48% to 50%) and move on to adjusting the time threshold. Lower the time threshold by 0.1 milliseconds at a time until the idle quality deteriorates. Then increase it 0.3 ms. Adjust the duty cycle and time threshold alternately to get the optimum values for your set-up.

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

Now, repeat the two steps again until you converge on a set of numbers that work for your set-up. For some setups, 75% may be too low, so they will need to increase this value - same for the time threshold. **Use PWM time threshold values greater than about 1.5 to 1.7 milliseconds only with great caution – it is possible to burn out your injectors!**

Setting the Cold Start and Warm-Up Enrichments

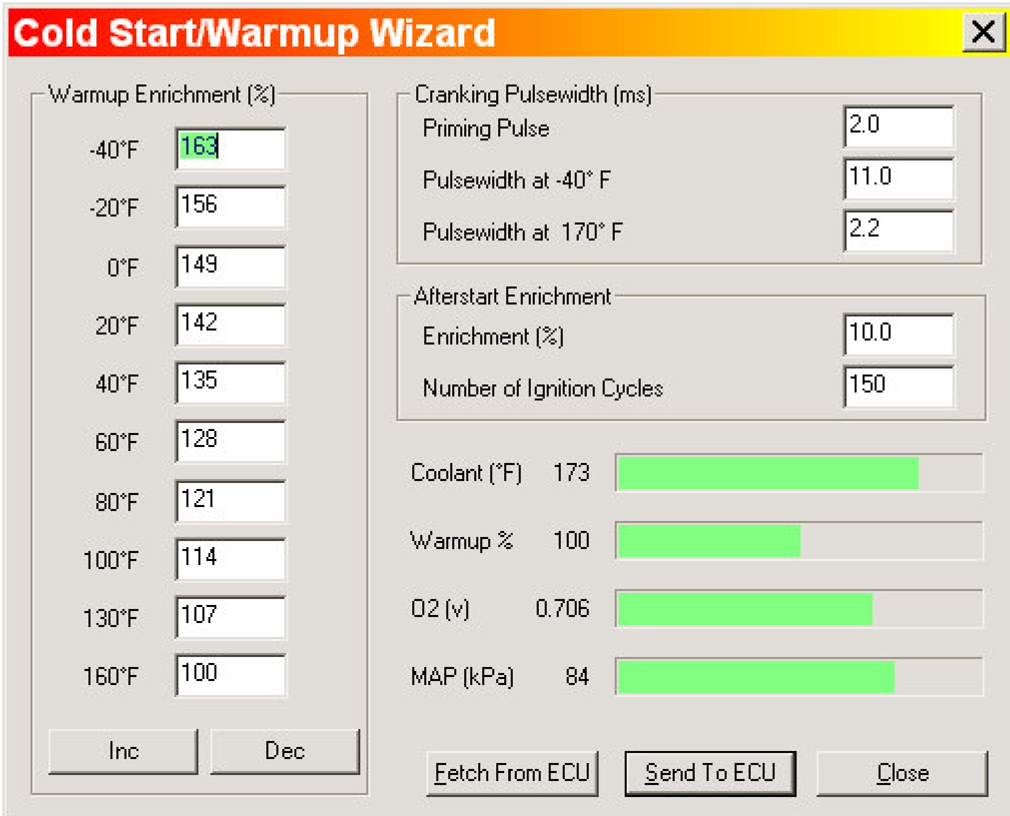
If it is cold out, you have to figure out the cold start enrichments/warm up enrichments right away to keep the engine running as it warms up. Otherwise you can leave this until you experience some cold weather. During cranking mode (defined when RPM is less than 400), MegaSquirt shoots out cranking pulsewidths that are calculated by a linear interpolation of two end-point values defined by the user, one at - 40 degrees F and one at 170 degrees F.

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

Once the engine fires up (defined by engine RPM greater than 400 RPM), the engine goes into after start enrichment. The after start enrichment starts out at a user-defined percentage enrichment value (typically around 20%), and ramps down to 0% after so many ignition trigger events, which is user-defined (use about 200 for this number to start). This is an enrichment above the normal warm-up enrichment, which is temperature dependent.

You can also set your Fast Idle Threshold (°F) if you have installed a fast idle solenoid. Enter a coolant temperature to turn on the fast idle solenoid. A typical value is 145º Fahrenheit. The Fast Idle valve will be activated below this temperature (145º) and turned off above 145º. The Fast idle Threshold is independent of any warm-up enrichment, though generally has a similar value.

To set the Warm-Up Enrichments, use the Warm-Up Wizard in MegaTune. This wizard lets you adjust the cold start and the warm-up bins while indicating which bin(s) are currently active. It makes tuning the cold starts MUCH easier



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

You can do this as the engine warms by adjusting the warm-up bins, loading it to the ECU, and noting the effect on idle quality. It will take several starts {from a cold soak} to get this close. Then you can play around with revving the engine in neutral and adjusting the mix to stoichiometric. Up to here it easy enough to do without an O2 sensor by adjusting for maximum vacuum (lowest MAP kPa) ant any given rpm.

Setting the VE Table

To set up the fuel curves for the engine with MegaSquirt, you have a number of parameters to work with. The most important of these are the Req_Fuel value and the VE table (8x8 volumetric efficiency table). You are aiming to achieve 12.5-13.1:1 air/fuel ratios under full throttle, and 15-17:1 under light loads for a naturally aspirated engine. Boosted engine may require a richer mixture under power.

To start you tuning efforts with MegaSquirt, you can calculate an initial VE table that has sufficient RPM and kPa bins, as well as an estimate of the VE based on your maximum torque and horsepower figures. See the FAQ site to run the estimator. This calculated VE table needs to be tuned carefully to avoid damage to your engine, however.

Tuning the VE table involves richening (by increasing the VE) or leaning (be decreasing VE) at each point in the VE table. Most of your driving will occur in a diagonal strip of the VE table, from low rpm, low kPA to high rpm, high kPa. You can adjust these values using the O2 sensor, datalogs and MSTweak, and/or the seat of your pants. Low rpm and low kPa (say less than half of the max rpm and max kPa) might be able to use stoichiometric or leaner. Richer mixtures would be used at high rpm and high kPa.

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

From this frequently used diagonal strip of the VE table, you will be able to see how much the VE rises from one rpm bin to the next, and use these differences to estimate the low rpm, very high kPA numbers and the high rpm, very low kPa numbers. Since you rarely (if ever) run in these parts of the table, the actual numbers will not make much difference, but they will be there "just in case". You are looking to create a smooth VE map wherever possible.

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

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

Volumetric Efficiency (VE) entries in 8x8 MegaSquirt VE table actually are **VE * gamma**, where **gamma** is the (stoichiometric AFR)/(actual AFR), and **VE** is expressed as a percent (i.e. 65 represents 65% volumetric efficiency at 14.7:1 AFR).

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

You can tune your engine to a stoichiometric mixture with NB O2 sensor, but not at high loads/rpms. You can then use a little math to "correct the mixtures". For example, if you get a stoichiometric mixture with 65% VE at a certain RPM and kPa, then to lean the mix to 16.0:1 you need:

65% * (14.7 / 16.0) = **60%**

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

80% * (14.7 / 12.5) = **94%**

Note that with MSTweak3000, you will get stoichiometric mixes if you set the crossover voltage to 0.45 - 0.50 volts with a narrow band O2 sensor. This is where you should have the EGO switch point set on the enrichments page in MegaTune as well. You can then adjust the MSTweak suggested VE table as described above to get other mixtures. **Note the you will want to be sure of running rich mixture under high load/high RPM conditions.** This makes a narrow band sensor somewhat less useful. As a starting guide, make sure you have at least 0.8 - 0.9 volts from the sensor under "wide open throttle" (WOT).

MAP sensor values can be between 0 and 250 kPa for all V2 and "turbo" V1 MegaSquirts. Naturally aspirated V1 MegaSquirts (from the first group buy) can have MAP values between 0 and 115 kPa. Idle RPMs below 300 rpm will induce "cranking mode", so should be avoided.

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

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

PW = REQ_FUEL * VE * MAP * E + accel + Injector_open_time

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

In essence, the mass of the air is computed using the ideal gas law (**PV=nRT**), where the pressure **P** is a function of VE and MAP, the volume **V** = cylinder displacement, the air temperature **T** is a function of E, **R** is the gas constant. We are looking for **n**, the mass of inducted air) and then that result is combined with a characteristic number for a given injector.

If you get the injector opening time correct, and the REQ_FUEL accurately represents the flow rate of your injectors, then the VE entries will be close to the VE*gamma noted above. **However**, if your opening time is not right, or your REQ_FUEL is not, then the numbers will be skewed by the amount the values are in error. In general, except for when you are first trying to get your engine started, use the calculated value for REQ_FUEL and do not change it.

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

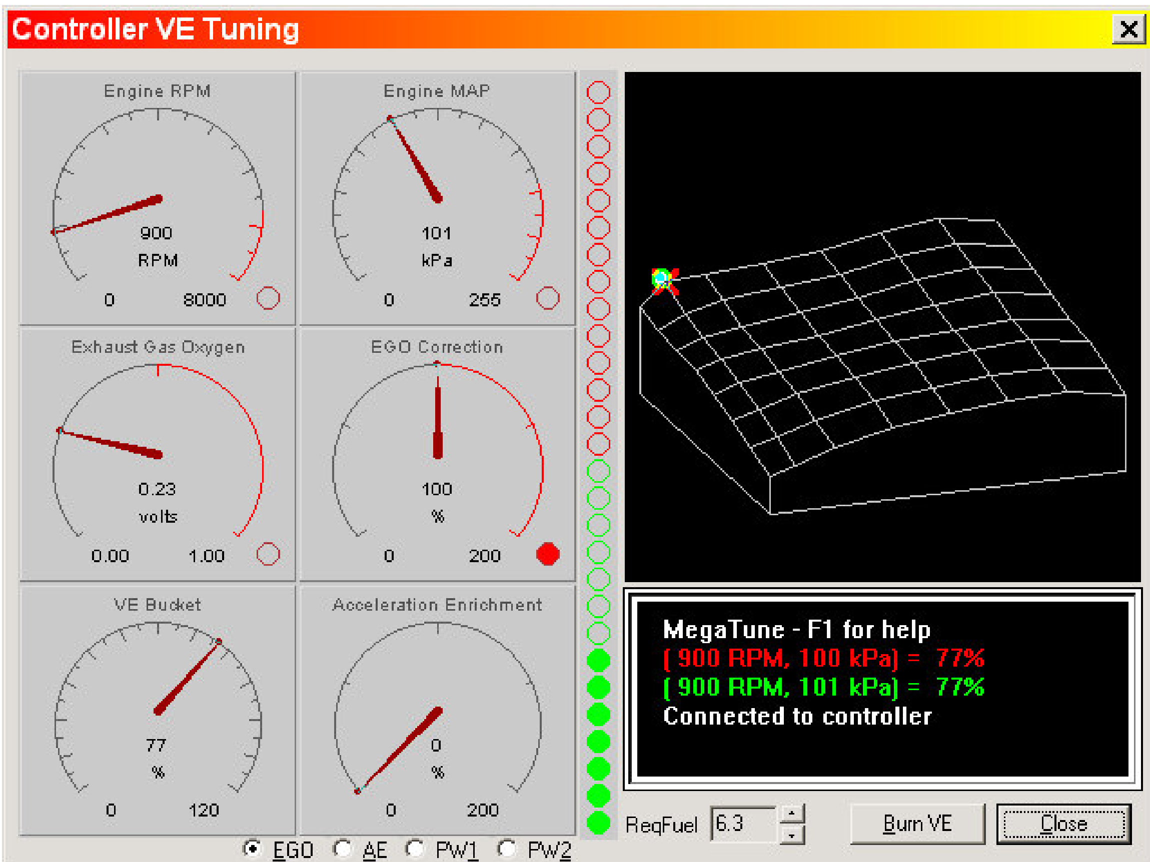
idle and cruise - lean	~stoichiometric - 14.7:1	WOT and acceleration - rich	not normally seen

	20	39	40	41	44	44	44	45	45
	30	47	47	51	51	50	50	50	50
	40	52	55	55	57	60	61	61	65
	50	59	60	60	65	66	70	70	70
kPa	60	61	63	65	65	68	70	72	75
	75	65	72	72	74	74	75	75	77
	90	70	74	74	75	75	77	77	78
	100	75	77	79	82	82	82	82	85
		500	1000	1500	2000	2800	3600	4400	5200
					RPM				

Having an O2 sensor makes the driving part of the setting up much easier, as you can datalog and use MegaTweak to get the VE table set up with a few easy drives up and down the street, a bit more tuning, and you are ready to go a bit harder. You do not go harder if there are any problems [typically a backfire means too lean, sluggish revving means too rich]. Read the "Datalogging and MSTweak3000" section for more information.

Have someone ride with you and bring up the tuning page. See where the "dot" hangs around when you are under load - this is where you need to focus on tuning. Use the **up-**

arrow + shift to richen the VE values - enrich (with increased VE number) the four corners around where the dot is - give each corner five up-arrow-shifts, and see if this helps. Turn off the O2 closed-loop mode by setting the step size to zero. Watch the O2 gauge on the tuning page and use this as feedback for rich and lean. The 02 gauge may move to fast from rich to lean to be able to tune. Another strategy that works is to turn on EGO correction, and then tune using the EGO correction gauge rather than the EGO voltage gauge. If correction is below 100%, then raise VE to raise correction and so on.



Alternatively, using the O2 sensor makes the driving part of the tuning much easier. You can datalog the engine parameters (including O2 volts) and use MegaTweak to improve the VE table by taking few easy drives up and down the street. Run the datalog through MSTweak and modify the VE table. Do a bit more datalogging/tuning, and you are ready to go a bit harder. You do drive any harder if there are any problems [typically a backfire means too lean, sluggish revving means too rich]. Figure out why, and fix it.

Idle Pulse Width

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

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

To illustrate, suppose you have established that your engine produces the lowest MAP reading at an idle pulsewidth of 1.2 milliseconds, and your opening time is 1.0 millisecond (considered the "standard opening time"). Recall that MegaSquirt can only change fuel by 0.1 milliseconds at a time.

Also, recall that MegaSquirt assumes NO fuel is injected during opening (which is close to true, since the injectors remain closed until the coils charge, then they snap open at the end of the opening time). Now if the net effect of the enrichments changes by 2%, the pulsewidths do not change at all. Even if they change by 49%, nothing changes. However, once they change by 50%, the pulsewidth suddenly changes to 1.3 seconds.

So the next leaner possibility is 1.1 seconds, and the next richer is 1.3 seconds. However 1.3 milliseconds is not 1.3/1.2x100% = **8.3%** richer, instead it is (1.3-1.0)/(1.2-1.0) = **50%** richer! The mixture becomes very, very rich, and the engine runs poorly.

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

But does not the EGO correct? Actually, it cannot. Even if you set the step size to 1%, nothing happens until the 50% (i.e. 1.3 milliseconds) threshold is reached. That is, the step size only takes effect once the 0.1 threshold of PW is reached. If the number of ignition events between steps is large, the engine may stumble and die before it recovers and leans out. So in fact you may be better to set the O2 step high (50%), and the number of ignition events low (say 2) so that the average over just a few injections is correct. It is a band-aid approach, however, and likely to induce ignition related problems.

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

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

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

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

This is why several aftermarket ECU manufacturers recommend an idle pulsewidth of not lower than 1.7 milliseconds. If yours is lower than this, you need to address it before you will be able to tune your engine for all operating conditions. The high-resolution code, or lowered fuel pressure may help. Ultimately the best solutions are appropriately sized injectors or staged injectors.

Datalogging and MSTweak3000

Datalogging allows you to create a running record of the MegaSquirt real-time variables. Once you have enabled datalogging (by clicking on the Datalog menu item on the File list), MegaTune polls the MegaSquirt controller when any of the front page, runtime display or tuning page are active, and writes this data to a file. The file has a comma-separated value format and defaults to having an extension of ".xls", so Microsoft Excel will open them automatically. The datalogs can be used as input to the MSTweak3000 program to automatically correct your VE table. See the MSTweak3000 folder at the Yahoo site.

When datalogging is enabled, the second status box contains a bold "LOGGING" indicator. The rightmost indicator contains either greyed-out "CONNECTED", meaning that MegaTune is not communicating with MegaSquirt, dark "CONNECTED", indicating that MegaTune and MegaSquirt communications is working properly, or dark "RESET n", indicating that the MS controller has been erroneously re-booted n times since MegaTune started talking to it.

Note: the Logging item under the Communications menu is a different function, and does not need to be selected to enable datalogging of the real time variables. See the MegaTune help menu for details on the Comm Logging function. If you can drive the car at all, start datalogging. Look through the log and MAP-RPM pairs that are near grid points in your VE map, when they O2 sensor reading is significantly below 0.500 (say 0.014), jack up the VE at that point by 10%. When the O2 sensor is significantly above 0.500 (say 0.825) then drop it down by 10%. A couple runs around the block should get things running pretty well.

Or you can use MSTweak3000, which will sort through your datalogs and suggest what VE points need to be changed. Everybody (who is running and datalogging) should try MSTweak3000 - it is very powerful and easy to use. It allows you to read in your datalogs, get rid of outlier points, and then generate a new VE map. You can pick new bin values - rpm especially (at the peaks and valleys of your filtered datalog) - then calculate a new VE map with the push of a button! No more gazing with crossed eyes at Excel spreadsheets to pick data for tweaking your VE table. What MSTweak3000 does is determine what VE entry value will give you an AFR of 14.7, based on the O2 transition point recorded in the file. MSTweak3000 gives you a RegenVE, which is the VE value for 14.7:1. If you want another AFR, you can estimate it by taking the RegenVE value and multiply by the ratio of the stoichiometric over the desired AFR. For example, if MegaTweak3000 gives you a value of 50% for the VE table, and you want 12.5:1 instead, then 50 * (14.7 / 12.5) = 59 - this is what you plug into the VE table. See the MegaTweak software and help file for more information. Note that the latest versions of MSTweak allow for the setting of wide-band O2 sensor AFR targets for each MAP bin. See the MSTweak3000 manual (in the program ZIP file) for more details.

Do not get hung up on actual AFR numbers - for the example above to work, everything else must be dead on, including the injector offset, injector battery voltage correction, REQ_Fuel for your injector flow rate, and air temperature correction. It will get you close enough with the resolutions we are working with, but remember that the only AFR you can nail down with a NB O2 sensor is 14.7:1, everything else is an estimate from this point. If you have a WB-O2 sensor, then you can read the AFR directly from the sensor output voltage and use those results to tweak your VE table.

MSTweak3000 will not tune your MegaSquirt for you (yet) but it will suggest new VE table entries for you. It is a tool to help you visualize the VE map and choose better VE values and to better place the MAP and RPM bins for your engine. Keep in mind you need a good O2 sensor to do this though (the WB-O2 sensor will work great). To start, set the O2 +/- limit to 100% for a rough map. If your map is more or less tuned in then 50-70% will work too (keep this high though for tuning).

The critical settings are O2 step% and ignition events per step.

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

For fine tuning, keep the O2 adjustments per second between 3 and 5. For roughing in VE maps, set the O2 adjustments between 5 and 10 per second (depending on how good the O2 sensor is, if it is old, go lower).

Once the map is tuned in, set the:

- **O2 +/- limit = 5%** (it can go higher depending on how questionable the map is)
- **step% = 1**, and
- ignition events to a value that would switch about 4x a second at your average cruising speed.

You can calculate your:

O2 adjustments per second = ((rpm/120) * cylinders) / ignition events per step

Note that the datalog includes an 'EngineBit" field. This bit will tell you if the engine was accelerating, warming-up, etc., and can be used to sort unsuitable data lines (because O2 correction is not active under acceleration, warm-up, etc.) from the file.

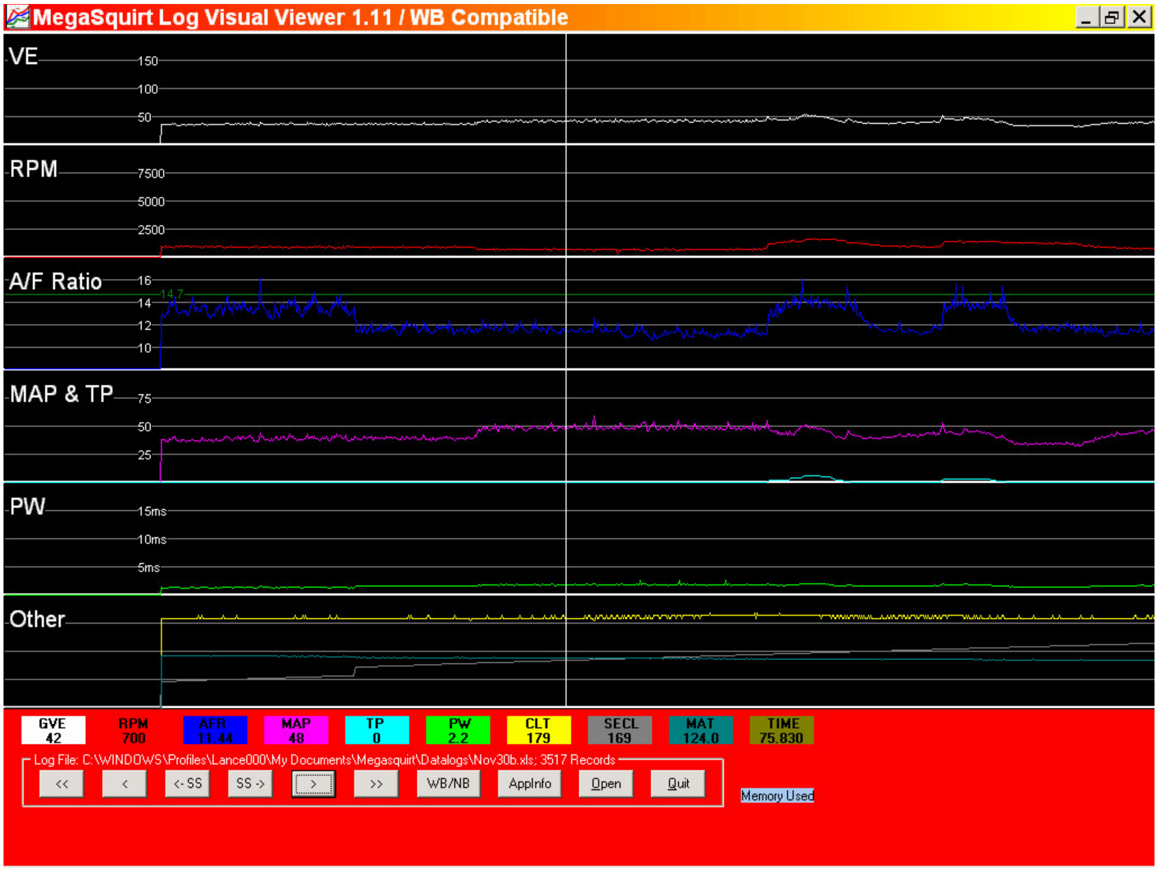
The enginebit has 6 binary bits. The rightmost bit represents running. It is 1 if running, zero if not running, so 000001 = 1 or 000000 = 0. The next rightmost value is for cranking, 000010 = 2 if cranking. Note that and engine is never both running and cranking, so you should never see 000011 = 3. The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

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

Note that the only suitable value for reading O2 sensor values is when the engine bit is equal to 1 (i.e. running and no enrichments).

You can view your datalog files in graphical form using MS Logfile Visual Viewer, available from the files section of the Yahoo! MegaSquirt group.

MSLVV can be set for either narrow-band or wide-band oxygen sensor readings. Using the viewer, you can see the trends in your datalog, and spot trouble areas more easily than viewing the numbers in a spreadsheet.



Setting the Acceleration Enrichments

After you have the VE table dialled in, then start adjusting the acceleration enrichment. You may want to try a short acceleration shot time (like 0.2 ms) and jack up the accel enrichment bins. Decel setting of 100% means no cut. 1% means reduce the pulse width by 99%, to 1% of what it normally would be. The low MAP part of your VE table is probably a touch lean, so the NB sensor drops below stoichiometric. If the car does not buck too hard, you are close to correct settings. If it bucks and stumbles, then it is going too lean and you need to richen that part of the table. Before tuning decel [or accel], make sure you have your VE table close to correct first! To get the VE table set up, set the delta-TPS setting very high (30v/s or something like that) so that **TPS enrich/enlean** never kicks in. Then, (in steady state) set up VE table.

To adjust the accel bins, start with them high, something like:

Bin	Default MegaSquirt (ms)	Start tuning at (ms)
2 volts/second (idle to WOT in 2.5 seconds)	0.5	1.0
4 v/s	2.0	4.0
8 v/s	4.0	8.0
15 v/s (idle>WOT in 3/10 sec.)	7.7	15.0

Then reduce the lowest bin (2 v/s) value by 0.1 milliseconds by 0.1 seconds at a time until the engine stumbles or coughs under gentle opening of the throttle. If it never stumbles, increase the rate at which you open the throttle and try again. If it stumbles even with the above values, double them and try again.

Then repeat with the next higher bin and slightly faster throttle movement. Continue with each higher bin and more aggressive throttle application until all the bins are satisfactory.

<u>Check Certain Resistors</u>

If you want your MegaSquirt to be reliable, do not skip this step. You need to tune two of the resistors to values appropriate for your ignition and injector set-up.

While then engine is running, check the temperature of R10 (kit supplied 390 ohm, 1/2 watt, orange-white-brown), which is used in the ignition input circuit from the coil. It should not be too hot to touch with your fingertip. If it is too hot, the value of this resistor may have to be changed depending on application - start with the supplied value (390 ohms), and if runs hot while running, then increase its value, in steps, up to 1K (like 470 ohms, 560 ohms, 680 ohms, 1K). Use 1/2 watt resistors.

Also check the temperature of R32 (270 ohm, 1/2 watt). This resistor is used in the flyback circuit to control the closing of your injectors. It should not be too hot to touch with your fingertip. If it is too hot, the value of this resistor can be increased, or the zener D21 can be replaced with a zener diode that has a lower breakdown value than the 36volt 1N4753 specified in the BOM. You might try 22 volts (1N4749).

<u>Tuning Issues</u>

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

This means you probably cannot run a stoichiometric [chemically correct] mixture of 14.7:1 with your long duration cam. You need to run richer. You tune your idle by ear rather than with a narrow band EGO [oxygen] sensor. Make sure you are not allowing EGO correction at idle if you have a rowdy cam! It will be trying to "correct" your mixture back to a lousy idle. If your engine will not idle well at stoichiometric mixtures, set the EGO Active Above RPM to a few hundred RPM above your idle speed. This will ensure that MegaSquirt does not try to lean the mixture back to stoichiometric to compensate for your adjustments.

Another tip you can try if you have a large overlap cam is to pinch off the MAP hose slightly while the engine is idling, and see if the idle quality improves. If so, then try a restriction in the MAP vacuum line. This has the effect of damping the vacuum pulsation the MAP sensor sees. You will have to experiment with restrictor sizes to see what works for your system.

A few more things to try:

1) Check your VE table entries near the idle point - if the RPM or MAP fluctuate, then you can get rolling idles, etc. You may have to move some of the bins around to bracket the idle RPM/MAP region, and keep flat VE values within this.

2) If you run low-impedance injectors, you need to tune your PWM current limit. Start with 75% PWM and 1.0 millisecond time threshold. Once you get idling, then first adjust the PWM duty cycle down until you notice a change in idle quality, then move the value back up 3 - 5%. Do the same with the time threshold. On the car it is very easy to do and only takes a few minutes. At idle, the overall injector pulsewidths are small compared to their close time, so this will allow you to adjust the values. In other words, adjust the PWM current limit before taking the car out on the street where injector pulsewidths become high.

Your engine will idle at a certain vacuum. It might help on a street use motor on the VE map to use a lower point for starting MAP than idle vacuum. For example you can have yours set at 20 even though you idle at 27 or so. This allows you to run less fuel on overrun deceleration and coast events (not just for a second like the TPS will do). This allows you a saving of 3-4 MPG on average driving and you might be able to run more advanced timing under this vacuum.

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

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

On the warm up enrichments page, the warm up enrichment only goes to 160º F. The 160º F bin value of the enrichment (which should ideally be 100%) is used at all temperatures above 160º F.

The system compensates automatically for any amount of idle solenoid bypass air because of the effect it has on the MAP value [i.e. the vacuum in the manifold is lowered by the bypass air, this is sensed by the Manifold Absolute Pressure sensor, and the processor decides to inject more fuel. The effect is the same as if you had cracked open the throttle a bit. The fuel goes around the throttle plates, which are never truly closed. They are set at the opening required for the slowest throttle speed desired for the engine under optimal conditions, which leave plenty of room for the fuel to get by. The fast idle air then adds to this baseline amount of air to raise the idle speed. In some circumstances, you may want to run without oxygen sensor feedback, called "open loop". The best way of forcing MegaSquirt to run open loop is to change the O2 sensor step to 0 [zero] on the enrichments page. It will still log the O2 voltage, but not do anything about it.

With the version 2.00 (and higher) code the MegaSquirt Fuel Pump output is programmed with a priming pulse option to shut off the unit in case of an engine stall, etc. It turns on the pump immediately when the power is applied and shuts it off 2 seconds later if the engine is not running. If you set the width of priming pulse in MegaSquirt to zero, then the system defaults to not turning on the pump until the first tach pulse. If this field is non-zero, then when the key is turned on, the injectors will fire once with a duration specified by the priming pulse field, and the pump is also activated, and will stay on for two seconds if there is no tach activity, or for as long as there tach activity plus two seconds.

On start-up MegaSquirt records the ambient barometric pressure. The barometer correction multiplier to VE increases as pressure decreases. If it the ambient baro pressure is low (high altitude) the algorithm adds fuel. This is mostly because at a given MAP, the engine will flow more air with less exhaust back pressure and therefore needs more fuel at higher altitudes. Once running the MAP sensor determines fuel based on you VE table entries which are then scaled by the baro correction recorded at start-up. The correction values used by MegaSquirt came from a code disassembly of a 1990 Corvette ECU.

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

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

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

You need Windows 95 and a conventional serial port to communicate with MegaSquirt. USB will NOT work, however some people have reported that they have been successful using a USB-serial adapter. Just about any computer that is capable of booting Windows 95 (or better) will be fast enough, but get the fastest machine you think is reasonably priced.

Other Tuning Software and Platforms

MS-Palm is available from the files section of the MegaSquirt Yahoo! site. It has worked well for some. MS-Palm uses the HOTPaw basic, and does data logging. It is limited to about 60 datalog lines or about 15 seconds or so at 4 Hz. It writes the data out as Memopad entries, which are limited in size to 4k. The source code is there for anyone to modify. It would be easy to cut back on the variable list, to get a log time up over a minute if someone so desired. MS-Palm does allow editing of VE table, enrichment bins, etc. as well. It worked fine with V2 code, but has not been tested yet with the new DT code. You can also use MSMiniTune, which requires the NSBasic files from the files section, but it may not be fully functional.

A Linux version of the tuning software is under development, check the Yahoo! list for details.

You might be able to use a Mac to tune MegaSquirt. Some people have successfully run PC Configurator and MegaTune hooked up to the MegaSquirt board with the Stimulator, on a Mac using VirtualPC and Win98. They report using a Mini DIN 8 to DB9 cable, selecting the Mac serial port as COM1, and "shared" the Mac hard drive with Win98 as volume (F). Their set-up includes an Airport wireless network (802.11b), sharing the DSL connection, setting up VirtualPC to utilize various resources (e.g. Mac serial/printer port as COM1, Ethernet, faking the video and sound cards, etc). MegaTune runs great and there is no lag between turning a MegaStim pot and seeing the results on the screen.

MegaView

The MegaView display/digital dashboard for MegaView offers two operation modes: **Runtime**, which displays the current engine operating parameters in "ticker-tape" scroll format, and **Configurator**, which allows the user to edit any of the MegaSquirt variables in real-time. For more information about MegaView check out:

www.bgsoflex.com/mv/megaview.html

MegaView has the following features:

- All runtime parameters are displayed in a scrolling fashion on the display. In Runtime Ticker-tape mode, the parameters displayed include:
  - Time since start [SECS] up to 65,535 seconds (2^{16}-1), over 18 hours,
  - Current engine operation state [ENGINE] (CRANK/RUN),
  - Warm-up [WRMENRICH] enrichment (ON/OFF),
  - Acceleration [ACCENRICH] enrichments (ON/OFF),
  - Engine speed [RPM],
  - Injector pulsewidth [PW(MS)].
  - Intake manifold absolute pressure [MAP(KPA)],
  - Barometric pressure [BARO(KPA)],
  - Coolant temperature [CLT(F)],
  - Intake air temperature [MAT(F)],
  - Throttle position sensor voltage [TPS(V)],
  - Battery voltage [BAT(V)]
  - Exhaust sensors voltage [EGO(V)]
  - EGO correction [EGOCOR(%)],
  - Air density correction [AIRCOR(%)]
  - Barometric pressure correction [BARCOR(%)],
  - Current volumetric efficiency [VECOR(%)]
  - Warm-up correction [WRMCOR(%)]
  - Acceleration enrichment correction [ACCOR(MS)]
  - All computed enrichments [GAMMA(%)], and

  It takes about 45 seconds for MegaView to scroll through all the variables. The automatic scroll mode can be frozen at any time in order to monitor any desired variable.

- Any variable outside of the normal operating range is flashed on the display, indicating something is wrong.
- Every variable (VE table and all constants) can be modified using two pushbuttons.
- The display is a vacuum fluorescent display (VFD) that has 2 x 20 lines. It is designed to be easy to see in automotive applications.

The MegaView display is based on the CU20025ECPB-W1J from Noritake. It is a 20 character by 2 row display. The outer dimensions are 116 mm x 37 mm, with a display area of 70.8 mm x 11.5 mm. Individual characters are 2.4 mm x 4.7 mm in size. Click the above links for more details.

You can purchase the MegaView PCB and programmed CPU for MegaView in the same you do for Megasquirt.

Order the PCB and processor at:

http://www.bgsoflex.com/mspo1.html

Then get the other parts from Digi-Key. The ordering page is at:

http://www.megasquirt.info/mvbom.htm

Here are there instructions for building MegaView. *Be sure to study the images before assembling your MegaView*

1) Solder the 2x7 male header to the back side of the MegaView PCB.

2) Solder the 2x7 female receptacle to the back side of the VFD PCB. This will allow you to plug the 2 boards together. However, to maintain stability, you need to install the 4 hex standoffs in between the 4 holes on each PCB. However, do not assemble the two boards yet. Leave this until the LAST step.

3) Install and solder **P1**, the DB9 connector.

4) Solder **JH1**, the single row, 6 pin header to the top side of the MegaView PCB. Mark the #1 pin (square pad) on the board (it is the pin closest the DB9 connector).

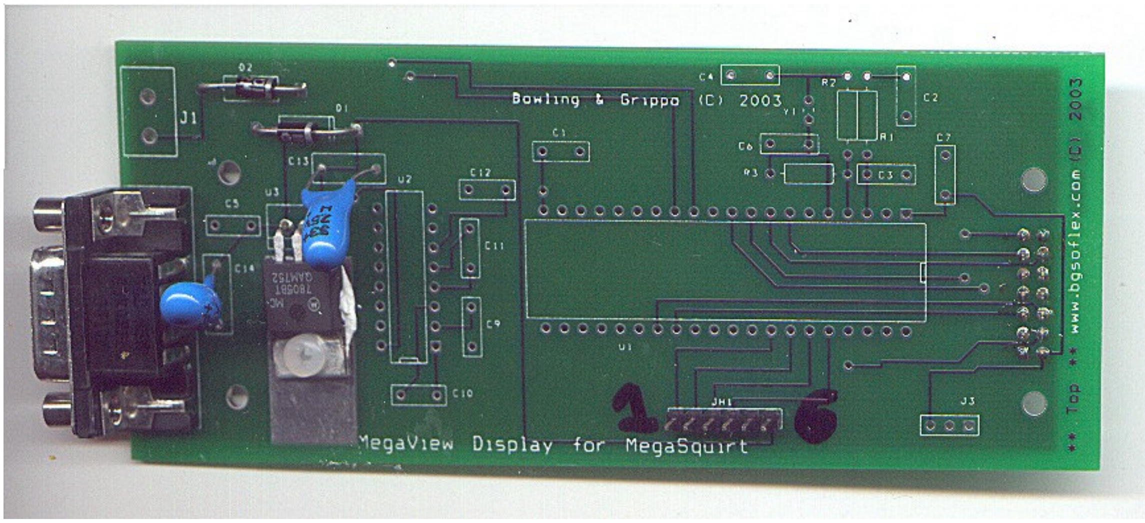
5) Assemble the power supply. Start by installing and soldering **J1**, the two position terminal block.

6) Insert and solder **D1, D2**. Note the polarity - the band on the diode matches the line on the PCB (i.e. away from J1).

7) Install and solder **C13** and **C14**, These are tantalum capacitors, which are polarized. Be sure that **C13** positive lead is towards the side of the board with the DB-9 (left-hand side on picture below - you can see the trace run from this to the voltage regulator). For **C14**, the positive lead is to the top of the board (see picture - look for the trace again which runs to the voltage regulator).

8) Install and solder **U3**, the voltage regulator. Bent the leads to match the PCB, and apply heat sink compound to the back of the regulator before screwing it to the PCB with one of the screws and nuts.

Below is a picture of the power supply components installed. Ground is furthest from the DB9, +12V is closest to the DB9. Here is a picture:



When done, verify there is 5V at the output of the LM7805 when you put 12V and ground into the power terminal block. The positive side of this terminal is closest to the DB9 connector and should be marked in some way to avoid mistakes when connecting it in the car.

9) Install and solder **C1, C5, C7, C9, C10, C11, and C12** (104 marking).

10) Install and solder **C2** (333 marking).

11) Install and solder **C3** (103 marking).

12) Install and solder **C4** (470 marking).

13) Install and solder **C6** (22 marking).

14) Install and solder **R1** (brown-black-orange marking).

15) Install and solder **R2** (brown-black-yellow marking).

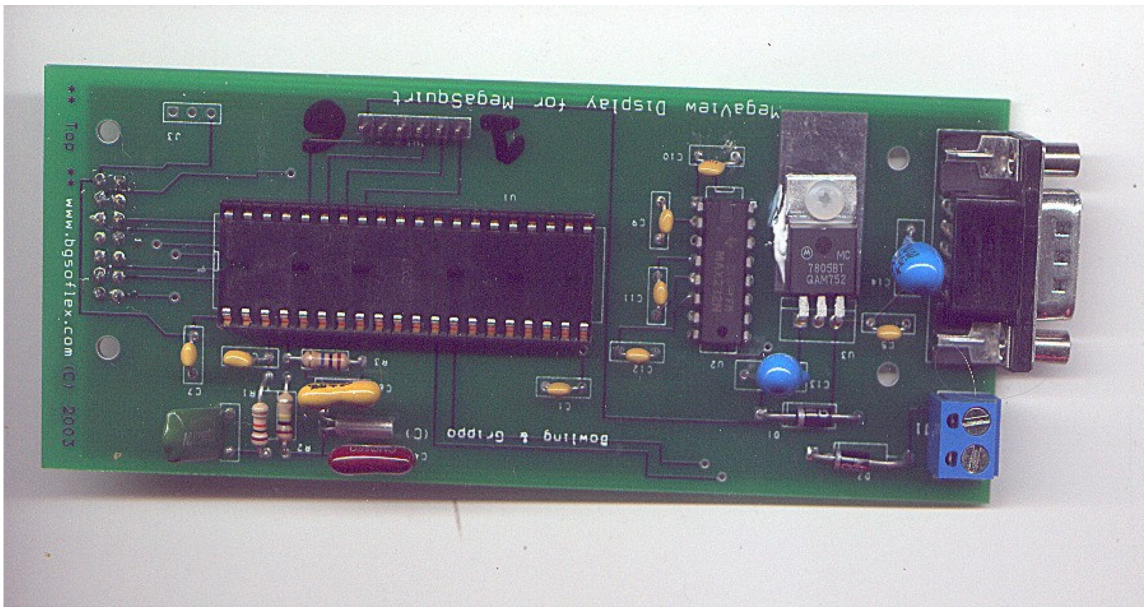
16) Install and solder **R3** (brown-black-blue marking).

17) Install and solder **Y1** (small metal can). Bend the leads so that it lies flat between C4 and C6.

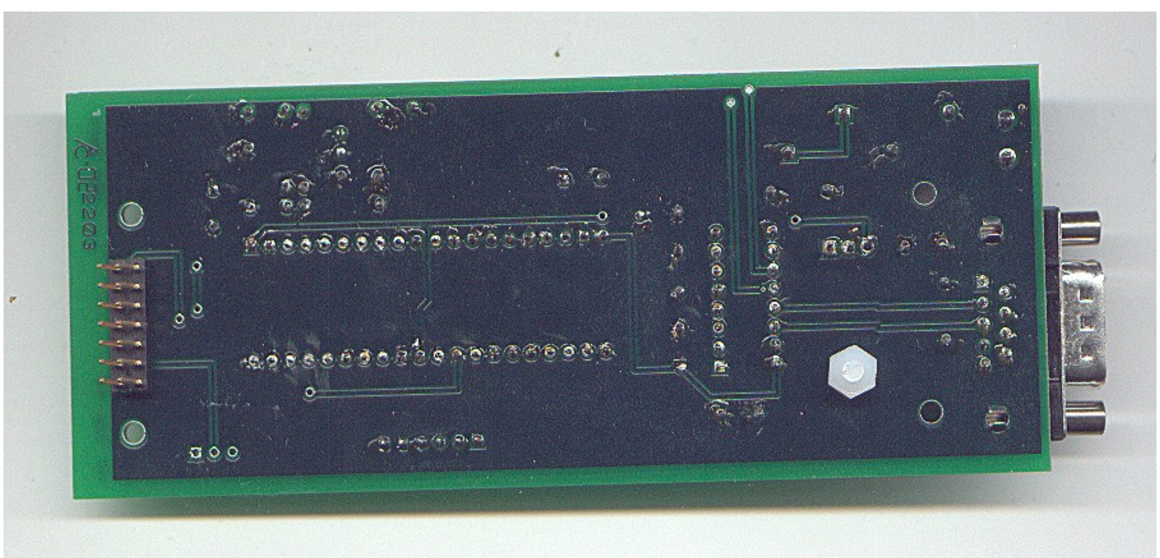
18) Install and solder the 16 pin socket, if you are using one. Otherwise install and solder **U2**, the MAX232.

17) Install and solder the 40 pin socket, if you are using one. Then insert the CPU. Otherwise install and solder **U1**, the CPU.

Here is a picture with the entire MegaView populated:

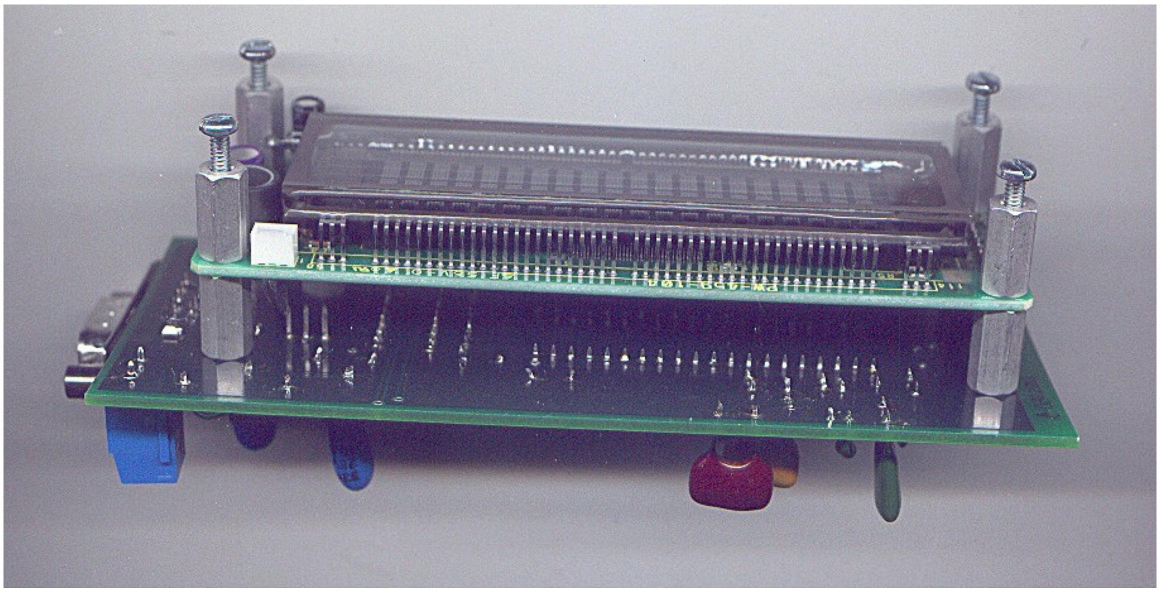


Next is a picture of the bottom side of the board. Note the header on the bottom of the board:



18) Install the stand-offs on the display. The male end of the stand-off goes through the front (display side) of the display PCB, and the female end of another stand-off is used to attach it in place. Leave them a little loose. Then attach the male ends of the remaining stand-offs through the back side of the MegaView PCB. Use the nuts to attach the PCB. Make sure the 7 position header is properly aligned. Tighten all the stand-offs and nuts.

Here is an image of the two boards together with the hex stand-offs holding them together:



You are done! Plug everything into each other (Stim/MegaSquirt/Cable/MegaView + battery or power supply) and it should come to life after one second.

To work the various functions of MegaView in the vehicle, you will need to install push buttons (though you can simply touch appropriate wires together for testing on the bench). The connections to the push buttons are:

- #1 = **Decrement** toggle.
- #2 = **Increment**,
- #3 = **Select**,
- #4 = **Mode**,
- #5 = **Ground**.
- #6 = **+12 V** which can be used for wireless key fob control (optional).

The four push buttons are connected to pins 1, 2, 3 and 4 respectively. The other side of each of the push buttons is connected to ground (pin #5). When a button is pushed, it connects the corresponding CPU pin, which is normally pulled up to +5V in the CPU, to ground. The pulse triggers an interrupt in the CPU and it then acts on the button push.

To install in a car, you need to get a Molex 5 or 6 pin connector and corresponding pins and make a cable. The plug, on which the no. 1 terminal should be marked, goes on the header, and the 5 wires go to the buttons which are mounted in a piece of sheet metal or plastic located wherever you want - generally close to the VFD display. Note that you can put the buttons in whatever order makes the most sense to you.

To make a bezel for MegaView, see this simple front panel bezel out of 3/16" (5mm) Lexan, go to the MegaView homepage

To operate MegaView, simply mount the unit on the dash or in an enclosure, supply +12V and ground wires to the power terminal block, and connect the DB9 sockets on MegaSquirt and MegaView with an RS232 cable. Turn on the ignition - you do not need to crank - and you should see the display scrolling.

When power is applied it takes about a second for MegaView to initialize the VFD and start up. By default, it comes up in Runtime Display Mode, as a ticker tape scroll, which is the primary intended usage mode.

If you want to freeze a particular variable, one may push the Select button. This causes the scrolling action to cease, so the selected variable may be viewed continuously. Pushing this button again unfreezes the scroll. The increment/ decrement buttons do nothing in this mode. The only other item of note is that, if any variable begins to flash, it is a sign that it is out of range, for example, the coolant temperature may be excessive or the sensor broken (railed).

By pushing the Mode toggle button one enters Configurator Mode. This mode starts by displaying the first of the configuration parameters. These are the parameters you change in the PC tuning programs. By pushing the increment/ decrement buttons you cause the display to scroll to the next or the previous parameter. Holding the button down causes a continuous scroll.

When you reach the parameter you want to modify, you can hit the Select button. This causes the word "Selected" to appear on the top line, and means that in this submode hitting the increment/ decrement buttons will cause the parameter to increase or decrease in value, ***and will affect operation of the vehicle. Clearly one should use CAUTION in doing this, especially while driving.***

When the variable has been modified as desired, hit the Select toggle again (Unselect). This will cause ALL parameter values currently in RAM to be burned into flash, so the modified parameter value will continue to be used on the next restart. The "Selected" string on the top line will disappear, and you can now move to another configuration parameter using the increment/ decrement buttons, or you can return to the Runtime Display Mode by pushing the Mode button.

Note: if you do not want the change burned in flash permanently, then do not hit the Select toggle to Unselect it, but instead hit the Mode toggle. However, if you later return to the configure mode and select and unselect another parameter, then both of the modified parameters, which are now in RAM, will be burned in flash. So if you make a change and do not want it to be permanent, then restore its value before exiting Configure mode. But note also that if you DO want the change to be permanent, you must Unselect it with the toggle.

Here is what you should check if your MegaView is not working:

1) If you have installed a socket for the CPU, REMOVE THE CPU after making sure that MegaView is not powered.

2) First - visually inspect all of the solder joints. Make sure none are bridged to other joints - especially at the DB9, headers, and IC pins. Make sure no bits of snipped off leads are trapped between pins, and that excess solder flux is not bridging pins.

3) Do you have the capacitors installed correctly? There are two polarized capacitors in MegaView: C13 and C14. C13 should be placed with the "+" lead (on the right when looking at the label with the leads pointed down) towards J1. If it is not, remove it and throw it away.

Get a replacement and solder it in correctly. C14 should be installed with the "+" lead toward the J1 terminal block - if it is not, throw it away and get a new one.

4) Make sure you have not swapped **C3**, with the **103** marking, for one of the other similar looking caps at C1, C5, C7, C9, C10, C11, or C12 (104 marking). They are not the same. If C3 is misplaced, remove the incorrect items and put them in correctly.

5) Is the **MAX232 (V2)** chip installed correctly? The notched end should be closest to the C10 capacitor at the bottom of the board.

6) Is the **68HC908 (V1)** installed correctly? The notched end should be opposite the DB9 connector. If it is not, turn it around (a lot easier if you have used a socket).

7) Are the diodes (**D1, D3**) installed correctly? They should have their "banded" ends furthest from the J1 connector. If they do not, turn them around.

8) Is the **DB9 connector (P1)** installed correctly? It should be on the same side as the CPU and J1 (i.e. away from the display). If it is the wrong way around, de-solder it and put it in right.

9) Is the display header installed correctly? It should be on the opposite side of the board to the CPU, J1, etc. It is the only component installed on the "back side" of the PCB.

10) Verify that resistor:

- R1 is brown-black-orange-gold,
- R2 is brown-black-yellow-gold, and
- R3 is brown-black-blue-gold.

Note that R1 and R2 may be quite similar in appearance.

10) Measure the resistance between pin 2, pin 19, and pin 32 of the CPU socket and the ground terminal of J1 (the terminal furthest from the DB9). You should get very low numbers.

12) Put a fresh 9 volt battery (or power supply) across the J1 terminal block. Do you have at least 8 volts coming into MegaView? Check across J1. You should have 9 volts across the two screw terminals, and positive should be nearest the DB9 connector. If you do not have sufficient voltage, get a fresh battery.

13) Do you have 5 volts from the **7805 regulator (V3)**? You should have ~5.00 volts across the two terminals of the 7805 nearest the DB9 connector.

14) Do you have ~5 volts on pin 1, pin 20, and pin 31 of the CPU? Measure between each these pins of the socket and the ground terminal of J1 (the terminal furthest from the DB9). If you do not have 5volts on all these pins, find out why and fix it.

15) Unplug the display, and leave unplugged for the remaining tests.

16) Turn on the board and check the heat level of the 7805 voltage regulator. If it is still hot after running a bit, then there is a problem on this board. The display takes up all of the current - with it unplugged the current level is in the low milliamps, and the 7805 should be cool to the touch..

17) Unplug the processor chip from MegaView, and hook up a null-modem cable between the MegaView and the PC. Run power and check for heat - if the heat goes away then the processor is at fault. Jumper the transmit/receive pins (12 and 13) on the processor socket (same pins as directed in the MegaSquirt manual for MegaSquirt - it is the exact same processor). Run Hyperterminal and check for character echo.

18) If you get echo, then you could carefully try the following: take the chip out of the MegaSquirt box and put it in the MegaView - make sure that the display is not plugged in. The chips are the same, and with the display unplugged none of the processor pins are held in contention - they are floating. Plug in the MegaSquirt chip into the MegaView board and fire up MegaTune on the PC. Hook up using the null-modem cable. Power up the board - you should see the seconds count up. Nothing else will be right, but if you see the seconds counting, then the MegaSquirt processor is running fine in the MegaView

socket. This checks out the oscillator circuit, serial port, etc. If this is the case, then either the MegaView processor is bad or the MV display is bad.

19) If you have access to an oscilloscope, you can use it to check more components. With just power to MegaView, you should see a nice oscillation at pin 4, with a "squarish" wave form. Pin 5 should have a sine waveform.

20) Hook up MegaSquirt, and you should be able to see data being clocked into MegaSquirt at pin 13 and 14 on your scope. This should flow through to pins 11 and 12, showing up on pins 13 and 14 on the proc. If this is working, and if the processor is functioning, you should see the data being driven at the VFD connector at pins 11-14. If this is the case, you can add the VFD and check the pins for the same signal.

If all of this checks out, then you will have to start tracing each circuit for continuity, etc. Use the MegaView schematics as a guide.

MegaSquirt and Turbocharging

This section looks at adapting MegaSquirt to a turbocharged engine. As well, there are a number of tips on adding a turbocharger/MegaSquirt combination to an engine that was previously naturally aspirated.

The MegaSquirt itself does not need any modifications to be used on a turbocharged engine, provided:

- **It has a MPX4250 MAP sensor** - all units from the current group buy (2003), all units from the second group buy (late 2002), and all 'turbo' units from the first group buy (early 2002) have the MPX4250 sensor.
- **You will not be using more than ~20 lbs of boost** - this is the maximum for the MPX4250 MAP sensor in the MegaSquirt. Above this level of boost you need a different MAP sensor and recompiled assembly code to match the new sensor.

However, you will need to consider a number of issues concerning the sensors, coding, and other hardware/software issues for turbocharged engines. These will be covered later in this section of the MegaManual.

Adding a Turbocharger to Your Engine

There are many considerations when turbocharging an engine. Fortunately, adding programmable fuel injection (such as MegaSquirt) at the same time makes some of these considerations easier to deduce.

- Your turbocharger needs to be the right size for your engine displacement and horsepower level.
- The compression ratio needs to be compatible with your intended boost level, charge cooling, and fuel.
- The physical space must be available to fit the turbocharging, intercooler, and plumbing.
- The cooling capacity of the vehicle must be able to handle the increased power.
- The transmission type, auto or manual, influences some decisions and set-up considerations.
- It helps to decide in advance if you will use intercooling and/or water injection, as these decisions can affect the space available.

This manual will not cover the all of above considerations. An excellent book covering many of these topics is Turbochargers by *Hugh MacInnes*, published by HPBooks, ISBN 0-89586-135-6. Another, more recent book is: Maximum Boost Designing, Testing, and Installing Turbocharger Systems by *Corky Bell*. Some on-line turbocharger selection and power calculators are at the Eric Fahlgren site and Ray Hall Turbocharging.

Using the above references as guides, you first need to choose a suitable turbocharger(s) for your engine. This manual will cover the design and construction of the turbocharger exhaust manifold, plumbing the turbocharger (and intercooler, if used), and tuning the turbocharged engine with MegaSquirt EFI.

Intercooling

The purpose of an intercooler is to cool the air charge. The turbocharger heats the intake air when compressing it because its adiabatic efficiency is not 100%. Hot intake air is detrimental to power and will increase the chance of detonation. An intercooler reduces the intake temperature by pushing the air through a heat exchanger (like a small radiator) that absorbs some of the heat from the intake air. Placing an intercooler in the air path between the turbocharger compressor and the intake manifold provides two advantages:

- It reduces the heat in the air charge, which increases the charge density, thus increasing the potential for making more power. You actually get more air and fuel into the cylinder for any given boost level. The power increase will typically be between 10 and 20% for the average (street) boost pressures of 5 to 15 lbs/in.
- It reduces the tendency of the combustion process to knock (detonation), allowing more boost to be run safely for a given fuel quality.

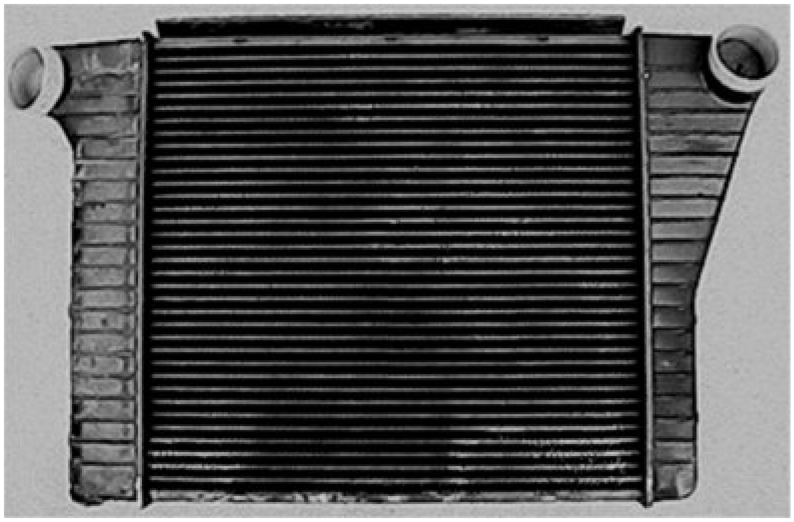
Not all intercoolers are created equal, however. The intercooler efficiency depends on the design of the intercooler. The two critical factors are:

- Thermal efficiency (how much heat is removed), and
- Flow restriction (lost pressure) created by the presence of the intercooler.

Regardless of the degree of thermal efficiency, if too much boost pressure is lost to a restrictive intercooler, the intercooler may actually decrease performance.

There are two basic styles of automotive intercoolers: **Air-to-Water**, whereby the intake air is cooled by water (usually the engine coolant), and **Air-to-Air**, whereby the intake air is cooled by (ambient) air in the same fashion as an engine radiator. Many intercoolers are available form factory vehicles, and those off Volvos, Saabs, and Ford 2.3l seem popular. Larger intercoolers were often used in pick-up trucks.

The Volvo intercooler is very large and efficient. The Volvo part number is **317319**. Its overall width is 28.75 inches (73 cm) at the top where the inlet/outlet are located and 23.125 inches at the bottom with the tanks. The core measures 17.75 inches (45 cm) wide X 17.00 inches (43 cm) tall. It is 1.25 inches (32 mm) thick. One of the inlet/outlet tubes is perpendicular to the core, the other is at approximately a 30° angle. The inlet and outlet tubes measure is 2.5 inch (6.35 cm) O.D. and 2.25 inch (5.72 cm) I.D. These often go for around $150 at salvage yards.



Saab intercoolers are commonly available from wrecking yards and eBay. They come in a number of sizes, depending on the model.

A large intercooler came on the 1993 Dodge Ram with the Cummins Turbo diesel engine. It is available from your Dodge dealer under PN **52004274** or **637714**. It weighs 20 lbs, and is 37" wide, 12-3/4" high. The core thickness is 1-5/8". The inlet/outlet inside diameter is 2-1/4", with an outside diameter of 2-5/8". Apparently these are available from dealers for about $200.

Another "giant" is the HUGE intercooler from a 1999 Ford Power Stroke Diesel engine. It is Ford part number **F81Z-6K775-BA** and cost about $300. The Ford intercooler is 39" wide, 18" tall, and 2.5 inches thick. The actual core measures 18" tall, 30" wide, and 2" thick. It has 3 inch inlet and outlet connections, which are about 35 inches apart (center to center).

You can see pictures of many OEM intercoolers at DDG - The Intercooler Identification Page.

<u>Water Injection</u>

Water injection is useful in preventing detonation in supercharged engines that produce more than about ~10 psi of boost. The water injection system is a completely separate system from the fuel injection system.

Typically, the water is mixed with methanol to improve its cooling effect. Mixtures up to 50% work well. Amazingly enough, regular windshield washer fluid works well, as long as you buy the blue stuff. If you can find one that says 50% methanol, 50% distilled water, that is great. Or you can add methyl hydrate to your water.

To set-up a water injection system, you can use a fluid tank, small pump (windshield washer pumps work well), and a Hobbs switch to inject fluid into the inlet tract. This switch closes at a specific pressure, and is installed in the intake manifold. One Hobbs switch is NAPA part# 7011577. This corresponds to a Hobbs part number **#76052**. It is a normally open 2 terminal switch, factory set to 15 psi. However it is adjustable from 14 psi to 24 psi. Both lower and higher pressure ranges are available from Hobbs 5000 series pressure switches.

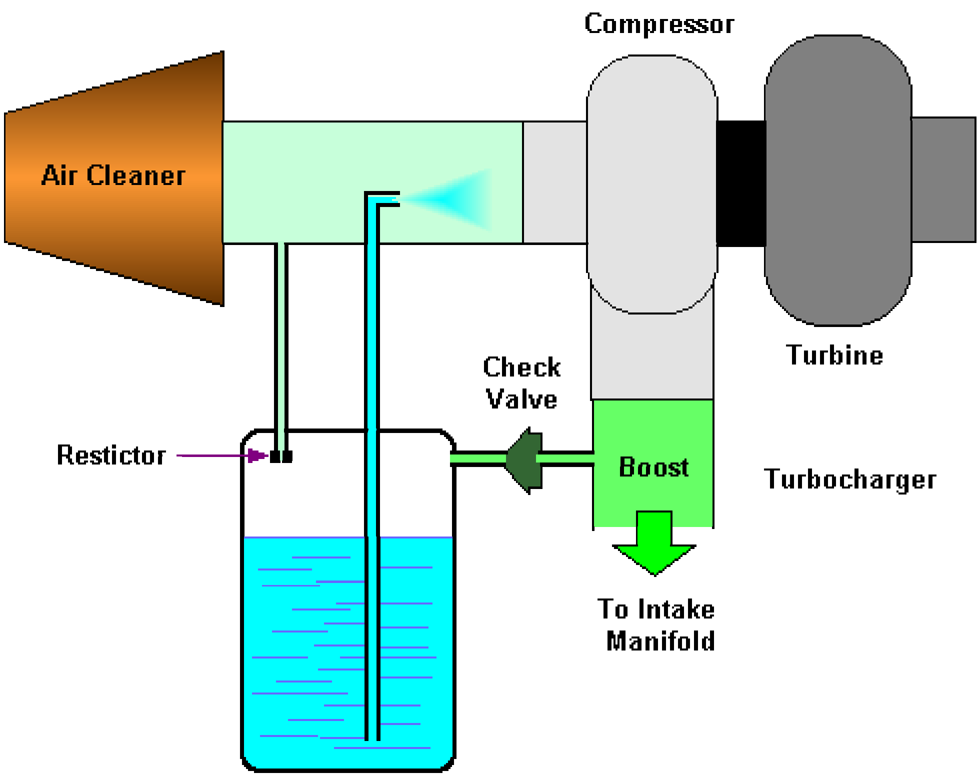
Another switch to consider is made by Len Gordon Genuine in Las Vegas. These are adjustable pressure switches with either barbed or 1/8 NPT fittings. They can be adjusted from 1 to 5 psi, and are factory set at 2.2 psi. PN **800120-0** is a 1/8" NPT, 25Amp, 24/240V SPDT. PN **800125-0** is the same, but with a barbed fitting for a vacuum hose. These are available at Spa and Pool centers.

Another alternative is the Summit Racing "Oil Pressure Safety Switch". It is made of steel and finished with zinc plating, for just $13. It opens at 7 psi (non-adjustable). Instead of being plumbed to the oil system, you can screw it into the manifold and use boost pressure to turn it on/off. Similar switches are available from Holley (PN 12-810, $20), and Mr. Gasket (MRG-7872, $13).

You need to install a restrictor (~0.030" to 0.050", 0.8 to 1.3 mm) in the line from the pump to the manifold. However, if you have an electrical problem that causes the injection system to stay in the open position while the engine is not running, you can have a "hydraulic lock" which can seriously damage your engine.

Alternatively, you can use a sealed fluid container, pressurized by boost pressure, to inject the fluid. The container must be capable of withstanding the boost your engine will produce. You have one boost line from the intake manifold to the top if the container to supply boost, and a fluid line from the bottom of the container to the compressor inlet to inject fluid. The boost line needs to have a one-way check valve installed so the engine vacuum is not applied to the container. Again, a restrictor is necessary, and it is usually placed on a third "vent" line.

In this case, larger restrictors mean **less** fluid is injected. This design has the advantage of no moving parts to fail, however it has the disadvantage of injecting the fluid before the intercooler, where there is a possibility it could condense on the inside, rather than flow smoothly to the manifold.



In either case, you must always make sure the container **is not emptied under boost!**

Note that some people have used MegaSquirt to control very sophisticated water injection schemes. They use one injector bank to control fuel, and the other bank to control water injection. This requires using the Dual Table (DT) code. See the archives for more details.

Wastegates and Blow-Off Valves

A **wastegate** is a valve that allows the exhaust gasses to bypass the turbine whenever the boost pressure is above the maximum desired level. The wastegate prevent the turbocharger from over boosting the engine, which would destroy it. Many modern turbochargers have the wastegate built into the exhaust turbine outlet, and require just a vacuum hose from the compressor or manifold to operate. Other turbochargers are built without integral wastegates, and require a separate wastegate plumbed into the exhaust manifold to vent excess exhaust to the exhaust system downstream of the turbocharger.

A **blow off valve** (BOV) prevents excessive pressure in the inlet system. While this sounds superficially similar to a wastegate, it operates differently, and is used for a different purpose. The blow off valve is situated in the inlet tract before the throttle blade(s) and is used to prevent surge (excessive pressure in the compressor housing) when the throttle is closed suddenly while the turbocharger is at speed. The blow-off valve opens at a few psi above the maximal boost level, and prevent damaging excessive pressure (called **surge**) in the compressor.

Common BOVs are the Bosch part numbers:

- 0 280 142 001,
- 0 280 142 102,
- 0 280 142 103,
- 0 280 142 104,
- 0 280 142 105,
- 0 280 142 106,
- 0 280 142 108,
- or a similar unit used in turbo Porsches with Bosch PN **0 280 142 108**.

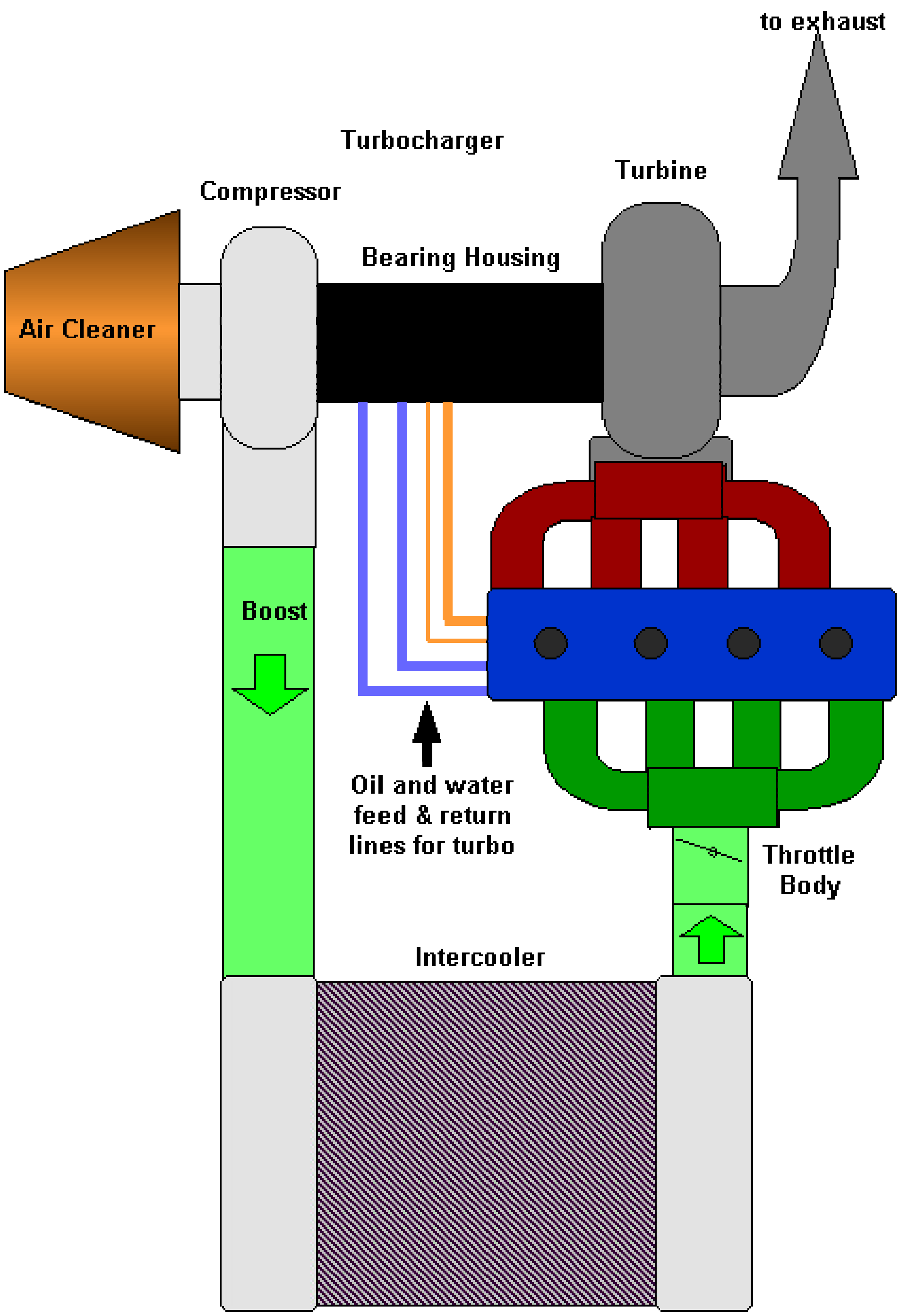
The Porsche part number is **993.110.337.50**, and they call it an "air cut-off valve". 1996 9000 Saab Turbos use the Bosch PN **0 280 142 103**. You might also consider Bosch PN **0 280 142 110** (Saab dealer PN **4441895** - called a "bypass valve" or "compressor over-pressure valve"), which offers a higher boost threshold. All of these have connections for 1" inlet and outlet hoses. The 0 280 142 103 BOV costs about $37. In Canada, you order Saab part number **30544792**, for about $75Cdn.

A well-engineered turbocharger set-up needs both a wastegate and a blow-off valve if high boost levels will be used.

Plumbing Your Turbocharger

A turbocharger requires a number of tubes to connect it to the engine intake manifold, exhaust manifold, air cleaner, exhaust system, oil supply, and possibly to the engine cooling system (depending on your particular turbo).

These tubes must flow well, and withstand significant temperatures, boost or exhaust pressure, and a lot of vibration.



Sharp bends cause a restriction in the flow of air, so try to put the turbo where the bends in the exhaust and intake tracts will be least restrictive. This will require compromises with exhaust tubing length, etc., and you are looking for the best overall solution.

With the oil supply to the turbo, a somewhat restrictive fitting on the pressure side is generally okay because most engine oiling systems can supply much more pressure than the turbo needs. However, a restriction on the drain side of the turbo can back up oil in the cartridge and cause many problems. The returning oil can be whipped into a froth by the speed of the bearings and the slight blow-by from both the compressor and exhaust housings. If allowed to build up, this oil can be pushed past the seals into the compressor section when not under boost. To prevent any problems, the drain line should be at least 3/4" (19mm) inside diameter, and must flow continuously down, it should not have horizontal or up-hill sections. In addition, the return line must not feed the return oil back into the crankcase below the sump oil level.

For the turbine side, the exhaust gasses entering the turbine will be at a much higher temperature and pressure than in the exhaust system after the turbo. You try to compromise the least number of these things, given the space you have to work with. This may require relocating some under hood components and/or protecting others.

Other Considerations

The turbo should not be positioned too near any engine, steering, brake, or other components that will be affected by radiated heat from the turbo or its plumbing. Note that the engine also moves on its mounts as torque is applied to the wheels. You will need at least 2" to 3" (50mm to 75mm) of clearance. This applies to the compressor housing as well as the turbine (exhaust) housing.

The compressor housings is relatively cool while the engine is running due to inlet air cooling, though this temperature is increased by the inefficiency of the compression (this is why we have an intercooler, after all!).

However when you shut down the engine, exhaust heat will soak through the cartridge and heat the compressor side nearly as hot as the turbine housing. When an engine shuts down, there is little to no air movement under hood. The entire turbocharger assembly can get very hot. You might consider making or purchasing a turbo insulating shield(s). These can be made from sheet metal. Properly designed, they work very well and cover the turbine housing to make it look better.

A turbocharger is driven by exhaust gas velocity. When temperature of the exhaust gas is allowed to drop before reaching the turbine, its velocity drops as well. Thus heat retention in the exhaust system between the cylinder head and turbocharger is important. Locating the turbocharger as close to the exhaust ports as practical will give best turbo performance. Sometimes is it not possible to locate the turbo very close to the engine. In that case, making the manifold (or header) from a material with a strong fatigue resistance will allow you to insulate the exhaust manifold, retaining exhaust heat.

When deciding where to mount the turbo, consider the effect each possible mounting location/orientation on routine maintenance. If you have a solid cam that requires periodic valve adjustments, it would be nice to be able to remove the valve cover(s) without removing a turbo. Make sure you can get to your spark plugs without too much trouble. When you are mocking up a manifold, plugs and wires should be in place and checked for enough clearance. Also check the engine oil dipstick for adequate access to check the oil. One idea is to take a few pictures of the engine bay before taking things apart as a reference. It is easy to forget the little things that make a big difference.

Making a Turbo Exhaust Manifold

Your first decision will be what material you will use.

Material	Yield Strength (lb/in^2)	Density (lb/in^2)	Thermal Conductivity (BTU/FT-hr-°F)
Aluminum 6061-T6	40,000	0.098	96.5
Aluminum 6061-T0	8,000	0.098	104.0
Mild Steel	40,000	0.283	26.98
304 Stainless Annealed	35,000	0.290	9.40
321 Stainless Annealed	35,000	0.290	9.30
Titanium	40,000	0.163	12.0
Inconel 625	77,000	0.305	5.65

Thin walled mild steel header (generally 16 to 18 gauge) tubing is inexpensive and easy to work with, but is not strong and will fatigue (and crack) quickly from the high temperatures and mechanical stresses a turbocharger will put on it. Thin mild steel also dissipates heat quickly, reducing the turbocharger efficiency. You can wrap the tubes with insulating material, but more heat means the metal fatigues and breaks more quickly.

Stainless steel tubing is an excellent choice for both reliability and heat retention, but you will also need stainless steel flanges and the skill and tools to weld it all together. The extra cost of stainless, and the difficulty of welding it, makes stainless steel a poor choice for some people.

An alternative to stainless steel is to use thick-wall mild steel. The mechanical and thermal properties can be substantially improved with thicker material.

Schedule 40 butt weld pipe fittings are a practical choice. They are inexpensive, readily available from any local plumbing supply house and very easy to weld. They also come in a few different sweeps. The 0.125+" thick weld fittings are very strong and last "forever" if built right.

The turbocharger exhaust manifold can be constructed from Schedule 40 steel weld "els" (short for elbows) and Schedule 40 steel tubing. The els are available from most industrial plumbing and gas fitting shops and are very inexpensive. They are made from a high strength, weldable alloy steel and have a nice V at each end to pour in a good, strong weld. They are available in 45° and 90° bends and standard and long radius styles. Use the "long radius" elbows whenever possible as they are less restrictive. The els are available in different inside diameters (ID) to match the pipe sizes below:

Nominal Size	Actual ID	Approx. OD	Wall
1"	1.049"	1.315"	0.133"
1¼"	1.380"	1.660"	0.140"
1½"	1.610"	1.900"	0.145"
2"	2.067"	2.375"	0.154"
2½"	2.469"	2.875"	0.203"
3"	3.068"	3.500"	0.216"

Straight schedule 40 NSP tubing is used between els. These pipes have very thick walls, o the turbo manifold will probably weigh almost as much as a regular cast iron exhaust manifold.

One place that sells els and tubing online is McMaster-Carr at www.mcmaster.com. For the els, see, page 38 of their online catalog.

Turbo flanges should be at least 5/16" (8mm) thick, but up to 1/2" (12mm) is even better. The problem is the heat of welding, which can easily warp them. The actual operating heat is less of a problem as it is more evenly applied.

If you decide use to fabricate flanges from the thinner material, clamp the flange in a vise. This will dissipate welding heat from the flange faster. An even better idea is to bolt them to an old turbine housing, if you have one available. If you are not a professional welder, thicker flanges are easier to work with. Make your turbo flanges at least 1/16" (1.5mm) thicker than the turbine housing thickness (at the mounting holes).

Layout the flange on the material, and mark all the centers of the port and bolt holes with a center punch. Then use the center punch to mark the outline of the flange with a punch mark every 1/4 inch (6 mm) or so. This will allow you to remark the flange at any pint, like after it has disappeared from the fluids used to cool the hole-saw! A drill press and hole saw are used to cut the holes.

A hand drill can be used, but will be slow and frustrating. For rectangular holes, 4 smaller holes may have to be drilled and then hand filed to obtain the correct shape. An oxy-acetylene torch or plasma arc cutter will make this job will go much faster! If you are making your own exhaust manifold head flanges, 5/16" (8mm) thick flanges are a good choice. You can use an exhaust manifold gasket as a template for cutting the flange.

If you cannot, or do not want to make your own flanges, there are a few places you can buy them. Turbo Techniques, at www.turbocharged.com, sells very nice 1/2" (12mm) thick flanges, as well as most other things you will need to complete your turbo system. For example, they have a T04B flange for $28.00 as PN **20167**. They also have some outlet flanges for starting your exhaust system fabrication.

You may be able to purchase ready-made head flanges from Hedman, Hooker and other manufacturers that offer flanges. Often they have flanges for most popular American engines that are 5/16" (8mm) thick.

If suitable flanges are not available for your engine and you do not want to make your own, Headers by Ed will custom cut flanges to your specifications. Stainless Works offers a flanges for popular American V8 engines in stainless steel for about $125, and they will cut custom flanges to your gaskets or drawings in material as thick as 3/4" (19mm) thick for mild steel or 1/2" (12mm) for 304 stainless steel.

Only you can decide how best to configure your turbocharger manifold. If you buy a good selection of 90º els, you can cut them later to any lesser angle, or weld two together to get larger angles. 90º elbows are quite a bit cheaper and easier to find than either 45º or 180º els.

With a turbocharged engine, the oxygen sensor should be placed after the turbo, where it does not see the high exhaust gas pressures that affect the accuracy of the sensor. If you decide you want to have an oxygen sensor before the turbo (generally not recommended), you will need to weld a bung into your manifold. It should be as close to the turbo as possible, so that it can read exhaust gases from all cylinders. Your turbocharger may have an oxygen sensor fitting on the outlet housing, and this is fine to use.

You do not need additional plumbing on the manifold (other than for the exhaust ports to turbo, of course) if you are using a turbocharger(s) with an internal waste gate. A flange that matches the turbocharger exhaust housing flange can be welded directly on the collector.

Some turbochargers use external waste gates. For these, you must fabricate a mount for the wastegate before the turbo so excessive exhaust gases can bypass the turbine.

MegaSquirt Hardware/Software Considerations

Injector Sizing - Injectors for turbocharged engines need to be 10% - 20% larger than for a naturally aspirated engine of the same horsepower. This is because turbo engines have a lower **BSFC** (**b**rake **s**pecific **e**ngine **c**onsumption = the amount of fuel need to produce one horsepower for one hour on an engine dynamometer at WOT [wide open throttle]), and they benefit from a rich Air/Fuel mixture that cools the piston and valves and provides a measure of anti-detonation. As well, a rich mixture that continues to burn in the exhaust heats sin the turbo up faster.

Use the chart below as a guide when selecting injectors for your turbocharged engine.

Injectors Rating Required for Specified Horsepower
for Turbocharged Engines
in lbs/hr and (cc/min)

	Number of Injectors					
Horsepower	**1**	**2**	**4**	**5**	**6**	**8**
100	65 (682)	32 (335)	16 (174)	13 (139)	11 (115)	-
150	97 (1016)	48 (508)	24 (254)	20 (208)	16 (174)	12 (128)
200	-	65 (682)	32 (335)	26 (277)	22 (231)	16 (174)
250	-	81 (855)	41 (428)	32 (335)	28 (289)	20 (208)
300	-	97 (1016)	48 (508)	39 (405)	32 (335)	24 (254)
350	-	-	56 (587)	45 (474)	37 (392)	29 (300)
400	-	-	65 (682)	52 (543)	43 (451)	32 (335)
450	-	-	73 (762)	58 (613)	48 (508)	36 (382)
500	-	-	81 (855)	65 (682)	54 (567)	41 (428)
550	-	-	89 (936)	72 (751)	59 (624)	44 (462)
600	-	-	97 (1016)	78 (821)	65 (682)	48 (508)

based on 0.50 BSFC and 85% duty cycle

MAP sensor - boost range, alternate sensors. The MPX4250AP was supplied with the 'turbo' units from the first group buy, and ALL the units from the second and subsequent group buys, is in the Digi-Key catalog on page 1098. This is a 2.50 bar **absolute** pressure unit. That means it measure from a full vacuum to 2.50 bars (i.e., up to ~1.5 above normal atmospheric pressure). The stated pressure range is from 2.9 to 36.3 psi, equivalent to ~21.6 psi of boost.

Any sensor you replace the MPX4250 with must also be an absolute pressure type (so that it can measure engine vacuum as well as boost). Other sensors you might want to adapt for higher boost levels are shown on page 1096 of the Digi-Key catalog, with units up to 100psi, such as 287-1032-ND for $25. Digi-Key also has a PCB mountable 0-50 psi (absolute unit) under part numbers MSP6808-ND and MSP6810-ND for $20.

However, for the most reliable operation, you might also look at commercially available MAP sensors that have been used in automotive applications with high boost ranges. GM makes a 3.0 boost MAP sensor that can be made to work with MegaSquirt. This sensor can be used up to ~29 psi of boost. It was used on the 1989 turbo Trans Am with the 3.8L turbocharged V6 engine, and is GM part number **16040749**, also available as Holley PN **538-23**. The Echlin equivalent 3 bar sensor is PN **CRB219481**. They cost around $60 to $80. They have Pin A = Signal Ground, Pin B = Sensor Output, and Pin C = +5 volts (Vref), and the pins are marked A-B-C on the sensor.

To use any "non-standard" MAP sensor (anything but a MPX4250) you would have to:

- Physically adapt the sensor to the MegaSquirt PCB by comparing pin-outs and fabricating wires, daughter boards, or whatever else is needed,
- Electrically adapt the new sensor, making sure such things as supply voltage, etc., are correct,
- Find the "characteristic curve" for the output of your new sensor (volts versus kPa),
- Rewrite the kpafactor files for MegaSquirt and MegaTune,
- Recompile the megasquirt.s19 file using the new kpafactor file,
- Load the new megasquirt.s19 to the MegaSquirt hardware.

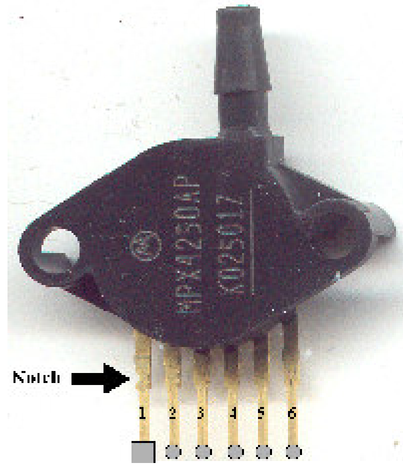
The 3-bar GM MAP sensors can be adapted to MegaSquirt. They use a 5 volt reference, just like MegaSquirt.

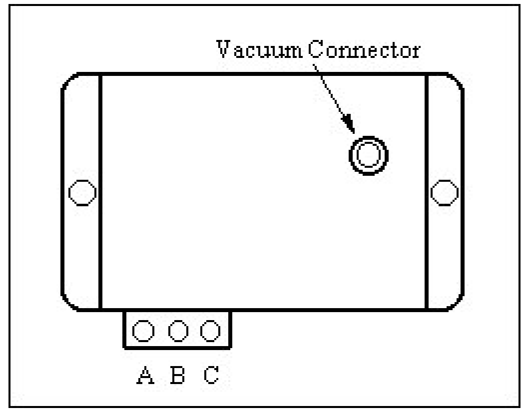
MPX4250/4115 Sensor

- Sensor output on Pin **#1**,
- Ground on Pin **#2**, and
- +5 Volts on Pin **#3**
- Pins 4, 5, & 6 are not connected.

3-bar GM Sensor

- Ground on Pin **A**,
- Sensor output on Pin **B**, and
- +5 Vref on Pin **C**.





To wire a GM sensor 3 bar sensor, you need to:

- Run a single **sensor output** wire from Pin #1 (square) of the MAP holes on the PCB to a free pin on the DB37 (use #25, which can be connected by running the sensor output wire you just installed to **X11** on the PCB),
- Then run a wire from this pin (#25) on the DB37 to Pin B on the sensor.
- **Ground** can be connected to Pin A the sensor from a common point on the engine where you ground the other sensors, etc.
- **+5 Vref** for Pin C can be taken from the supply for the TPS (DB37 Pin 22).

Then you will need to rewrite the kpafactor file and recompile a .s19 file for downloading to MegaSquirt. Importantly, you will need to devise a "proxy" file for the MAP sensor values. The internal values for kpa (the name of the variable for the intake manifold pressure in the MegaSquirt code) are restricted to eight bits. This means they can range from 0-255. Simply recompiling will not get around this fact. You could rewrite the code with an "offset", say 50 to 305, which would work (if you also rewrite all the corresponding variables, like kpaverange, etc.), or you could read 0-5 volts from the MAP sensor to an arbitrary range from 0-255, then "interpret" these numbers within rewritten MegaTune code. Neither of these are recommended for those not familiar with assembly language programming.

More details are at: http://www.bgsoflex.com/megasquirtmap.html.

IAT sensor - this needs to be located in the intake system somewhere **after** the compressor. You can put it before the throttle body or in the intake plenum, either location will be fine. Your intake temperature sensor **must** be the "open-element" type. Regular closed sensors are shielded within a brass housing, and will respond too slowly to the rapidly rising intake temperatures that occur when boost comes on. See the Sensors and Wiring section for more details.

SD vrs. Alpha-N For turbocharged engine, you must use the **speed density** control algorithm only for turbocharged engines. Turbocharged engines **do not** have a linear relationship between throttle position, rpm, and fuel requirements, and thus cannot use alpha-N.

Turbo Tuning with MegaSquirt

To set up the fuel curves for your turbocharged engine with MegaSquirt, you have a number of parameters to work with. The most important of these are the Req_Fuel value and the VE table (8x8 volumetric efficiency table). You are aiming to achieve 11.0-12.5:1 air/fuel ratios at full boost, and 15-17:1 under light loads for a turbocharged engine.

If you did not have MegaSquirt, you would need an add-on fuel controller, a rising rate fuel pressure regulator, or some other trick to add extra full when the boost comes on. With MegaSquirt, though, you simply program in longer pulsewidths via the VE table.

Having an O2 sensor makes tuning much easier, as you can datalog and use MegaTweak. With a turbocharged engine, the oxygen sensor can be placed either in the exhaust manifold, or downstream of the turbo. Frequently, the outlet housing that bolts to modern turbochargers (an that cover the wastegate port), provide both a 90° bend in the exhaust path (making the fabrication of an exhaust system a great deal simpler) and often have a suitable threaded bung for an oxygen sensor.

To get the VE table set, adjust the boost as low as you can, if you have an adjustable wastegate. Turn on datalogging in MegaTune. Take a few easy drives up and down the street, keeping the revs down and the throttle light. Adjust the VE table according to what MegaTweak tells you. A bit more tuning, and you are ready to go a bit harder. Increase the revs, or increase the boost a bit. **Do not** go harder if there are any problems [typically a backfire means too lean, sluggish revving means too rich]. Read the Datalogging and MSTweak3000 section for more information.

Once you get the engine started and idling, you proceed with tuning it.

When you start tuning, make sure you:

- Install a **boost gauge** and fuel pressure gauge. Invest in these if you plan to run significant boost (above 5 - 7 psi), you will be glad you did.
- Do not change more than one thing at a time and always be able to get back to where you started,
- Do not try to drive the car if you cannot get it to idle properly, fix the idle first,
- Do not try to tune accel before you have tuned VE,
- Do not drive the engine if you experience **detonation** (rattle). Find out why and fix it. It could be too lean, too much ignition advance, too hot spark plugs, or too much compression,

- Always have enough fuel. Your entire fuel supply system, from the fuel pump and lines to the injectors themselves, must have enough capacity for your maximum fuel flow. Even one restrictive component can cause your engine to destroy itself,
- Install a 180º or 160º thermostat, if you have not already. Keeping the engine a few degrees colder will help avoid detonation,
- Retard your ignition timing. Try 5º to 8º retarded from the stock setting to start with. You can experiment later.
- Buy good gas. At least for your tuning efforts, buy the best gas you can get, 92 or 93 octane rating, at least. Tuning time is not the time to figure out what you can "get away with"!
- Let the engine idle for at least 2 minutes after you have operated under boost before shutting the engine off. This will cool the turbo down, let it slow down, and help prevent coking. A turbocharger is cooled by engine oil (and possibly engine coolant). Turbochargers get very hot when making boost. When you shut the engine down, the oil and coolant stop flowing. If you shut the engine down when the turbo is hot, the oil can burn and slowly build up in the turbocharger center section (known as "coking"). This will eventually cause the turbocharger to leak oil (the most common turbocharger problem).

To tune all the parameters of MegaSquirt so that your engine runs the best it can, you will need to do the following:

1. First, learn to use MegaTune,
2. Next, set the constants,
3. Get the engine started and idling,
4. Then set the PWM criteria,
5. Then set the cold start and warm-up enrichments,
6. Then set the VE table,
7. Set the acceleration enrichments,
8. Check that certain resistors are not getting too hot while driving.

These are the same steps as for a naturally aspirated engine, and the procedures are the same for a turbo engine *except* setting the VE table. All the other steps are covered in the Tuning section of this manual, so follow the instructions there for those steps.

<u>Setting the VE Table on a Turbocharged Engine</u>

To set up the fuel curves for the engine with MegaSquirt, you have a number of parameters to work with. The most important of these are the Req_Fuel value and the VE table (8x8 volumetric efficiency table). You are aiming to achieve 12.5-13.1:1 air/fuel ratios under full throttle, and 15-17:1 under light loads for a naturally aspirated engine. Boosted engine may require a richer mixture under power.

Volumetric Efficiency (VE) entries in 8x8 MegaSquirt VE table actually are **VE * gamma**, where **gamma** is the (stoichiometric AFR)/(actual AFR), and **VE** is expressed as a percent (i.e. 65 represents 65% volumetric efficiency at 14.7:1 AFR).

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

You can tune your engine to a stoichiometric mixture with NB O2 sensor, then use a little math to "correct the mixtures". For example, if you get a stoichiometric mixture with 65% VE at a certain RPM and kPa, then to lean the mix to 16.0:1 you need:

65% * (14.7 / 16.0) = **60%**

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

80% * (14.7 / 12.5) = **94%**

Note that with MSTweak3000, you will get stoichiometric mixes if you set the "crossover voltage" to 0.45-0.50 volts with a narrow band O2 sensor. This is where you should have the EGO switch point set on the Enrichments page in MegaTune as well. You can then adjust your VE to reflect the VE table suggested MSTweak as described above to get other mixtures.

However you cannot use the O2 sensor to guide you under boost or at high rpm. **You can seriously damage your engine if you try!** You will want to be sure of running rich mixture under high load/high RPM conditions. This makes a narrow band sensor somewhat less useful. As a starting guide, make sure you have at least 0.8 - 0.9 volts from the sensor under wide open throttle (WOT). Start with very rich mixtures under load, and lean them cautiously to reach your target.

To tune your VE table, you must proceed with caution in the upper ranges of boost and rpm. Do not rush yourself, and jump ahead of a proper procedure. You can destroy your engine if you do not "sneak up" on the proper VE numbers. To start tuning the VE table, warm the engine to full operating temperature first. Install new spark plugs, and then go for a "spirited" drive.

Let up on the throttle **immediately** if you hear the rattles of detonation, or if boost rises higher than you planned. Then remove and inspect your spark plugs. Look for evidence of detonation on the porcelain nose of the spark plug that surrounds the center electrode. Detonation will show as "salt and pepper", tiny flecks of carbon and/or aluminum that indicate detonation has occurred.

If there are no rattles and no "salt and pepper", increase the boost by a few psi, and repeat. Check the spark plugs after each drive. As you continue to increase boost, you will eventually either hear detonation (let off the gas immediately!) or you will have evidence on the plugs that it has occurred. At this point, increase the VE at that point of the VE table, decrease the timing, or reduce your boost levels. Do not continue to operate an engine the shows signs of detonation, even if it is brief.

You can set RPM and MAP sensor bin values on the VE table wherever you want them, but they must be in the same order as in the table supplied with the software. MAP sensor values can be between 0 and 250 kPa for all V2 and "turbo" V1 MegaSquirts. Put them so they cover entire rpm/boost range of your engine. That is, you want to cover from your slowest idle speed to your redline, and from the kPA at idle or deceleration (whichever is lower) to full boost. Evenly spaced values work well, but you may choose different values to suit your combination.

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

PW = REQ_FUEL * VE * MAP * E + accel + Injector_open_time

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

If you get the injector opening time correct, and the REQ_FUEL accurately represents the flow rate of your injectors, then the VE entries will be close to the VE*gamma noted above. **However**, if your opening time is not right, or your REQ_FUEL is not, then the numbers will be skewed by the amount the values are in error. In general, except for when you are first trying to get your engine started, use the calculated value for REQ_FUEL and do not change it.

The tuning numbers within the 8x8 VE grid are gamma values composed of (lambda * VE), where lambda is the product of [air/fuel ratio divided by stoichiometric] multiplied by VE, which is the volumetric efficiency. Values beyond the table bounds are extrapolated at the boundary value, so the surface beyond the table is "flat". Note that you can change the RPM and MAP bins to suit your operating ranges.

Here is a sample VE table for a hypothetical turbocharged, intercooled, and water injected 250+ horsepower 4 cylinder 2.0 liter engine with 500cc/min injectors capable of 6500 rpm and about 20 psi of boost:

idle and cruise - lean	~stoichiometric - 14.7:1	WOT and boost - rich	not often used

kPa								
50	43	57	61	65	79	81	71	66
70	52	65	68	70	82	83	75	76
100	68	75	77	79	89	91	84	80
130	75	80	83	84	94	96	89	84
160	77	82	85	86	96	98	91	86
190	79	84	87	88	98	100	93	89
220	82	87	90	91	101	102	95	92
250	85	90	93	94	104	105	97	95
RPM	500	1200	1800	2500	3500	4500	5500	6500

Note in the above VE table that VE values continue to rise slowly above 100 kPa. The intent is solely to richen the mixture as boost increases (an effect similar to that given by a rising-rate fuel pressure regulator). For example, at 2500 rpm, we have a VE of 79% at 100 kPa, and 94% at 250 kPa. The 79% represents the VE of this engine if it were naturally aspirated, and lets assume is has an AFR of 13.0:1 at that point. By raising the VE value to 94%, we get:

$$AFR(250) = VE(100) / VE(250) * AFR(100)$$

$$AFR(250) = 79\% / 94\% * 13.0 = 10.9:1$$

This very rich mixture accomplishes a number of things:

- it cools the pistons, valves and combustion chamber,
- it provides a measure of detonation protection by forcing the air/fuel mix to burn more slowly

Having an O2 sensor makes the driving part of the setting up much easier, as you can datalog and use MegaTweak to get the VE table set up with a few easy drives up and down the street, a bit more tuning, and you are ready to go a bit harder. You do not go harder if there is any problems [typically a backfire means too lean, sluggish revving means too rich]. Read the Datalogging and MSTweak3000 section for more information.

Do not get hung up on actual AFR numbers - for the example above to work, everything else must be dead on, including the injector offset, injector battery voltage correction, REQ_Fuel for your injector flow rate, and air temperature correction. It will get you close enough with the resolutions we are working with, but remember that the only AFR you can nail down with a NB O2 sensor is 14.7:1, everything else is an estimate from this point. If you have a WB-O2 sensor, then you can read the AFR directly from the sensor output voltage and use those results to tweak your VE table.

On a turbocharged engine, it is very easier to achieve too much boost and too little fuel, which **can seriously damage your engine**. In order to safely tune your engine with MegaSquirt, you need to be especially cautious about tuning in high boost/high rpm ranges. Where possible, limit boost to lower levels with reduced wastegate settings (for those that have adjustable wastegates) until you are satisfied that you have "mapped" that boost range satisfactorily. Then increase the boost a bit, perhaps 1-2 psi, and map that range.

Have someone ride with you and bring up the tuning screen. See where the "dot" hangs around when you are under load - this is where you need to focus on tuning. Use the **up-arrow+shift** to richen the VE values - enrich (with increased VE number) the four corners around where the dot is - give each corner five up-arrow-shifts, and see if this helps. Turn off the O2 closed-loop mode by setting the step size to zero. Watch the O2 gauge on the tuning screen and use this as feedback for rich and lean. The 02 gauge may move to fast from rich to lean to be able to tune. Another strategy that works is to turn on EGO correction, and then tune using the EGO correction gauge rather than the EGO voltage gauge. If correction is below 100%, then raise VE to raise correction and so on.

MegaManual Appendices

This manual contain the following appendices:

- Embedded Software Upgrade Instructions
- MegaSquirt Glossary
- MegaSquirt Schematics
- MegaSquirt 68HC908GP32 Memory Map
- Some MegaSquirt Assembly Language Variables
- MegaSquirt MC68HC908GP32 Instruction Set

Embedded Software Upgrade Instructions

You can use Hyperterminal, download.exe, or EasyTherm to upgrade your embedded software. Each is described below.

Hyperterminal

Here are instructions for using Hyperterm.exe for updating the embedded software (all Windows installations has the Hyperterminal application - use a "find-file" function to search for "hypertrm.exe"):

1) Put the **bootloader jumper pin** in (short R6 for V1 boards), hook up a serial cable from the computer to the MegaSquirt box, and fire up Hyperterminal (Hypertrm.exe).

Note: you do not use the PC Configurator to perform the firmware upload - this is done with the terminal program Hyperterm (or similar, see below), and do not have PC Configurator, MegaTune, or any other serial data application running on your PC. At this point, leave the MegaSquirt unit un-powered.

2) You will see a Hyperterminal screen when you execute - type in any name you want in the box, and make sure the Red telephone with the little yellow telephone next to it is highlighted.

3) A new window appears. On the "Connect Using" selection, select either COM1 or COM2, depending on your serial connection.

4) Then another window with comm port settings pops up. Select 9600 baud, 8 data bits, no parity, 1 stop bit, and set flow control to "None" - this is very important. Hyperterm terminal is now up.

5) Apply power to the MegaSquirt board, then hit <Enter>. You should see the "Boot>" prompt appear in the terminal screen.

6) Type "H" and you will be shown the options available in bootloader mode.

7) Hit "W" for "Wipe" - this erases the entire flash array (except the section running the bootloader).

8) Hit "P" for "Program," which will respond with the text "wait ...".

9) Then under the "Transfer" menu, select "Send Text File..." (do not use the "Send file" mode - you are sending a text file).

10) Set "Files of type" to "All files" and select the .s19 file containing your assembled code (megasquirt.s19). You will see no activity on the screen for about 40 seconds.

11) Then the prompt will come back, which means the operation is finished.

12) Turn off power to MegaSquirt and shut down Hyperterminal.

13) Remove the jumper, and you are ready to go.

Download.exe

OR if you would rather use something simpler than Hyperterminal,

1) Grab the latest megasquirt.s19 file from the www.bgsoflex.com website.

2) Get http://groups.yahoo.com/group/megasquirt/files/MegaTune/tools.zip. This will contain a file called "download.exe". Extract download.exe wherever you saved the .s19 file.

3) Start up an MS-DOS command window [i.e. click the Start button, chose Run, then type in **command** and press "enter"], change the current directory (cd\) to the directory containing download.exe and the .s19 file.

4) Put in the H1 jumper, (or short out R6), boot up the MegaSquirt and type: **download megasquirt.s19**

5) Watch it report status as the download proceeds. It will automatically reboot MegaSquirt, so your LEDs will start flashing on the MegaStim, just like usual.

6) Pull the jumper off R6 and start tuning.

EasyTherm

OR simpler yet,

Use EasyTherm. It includes the most recent embedded software versions for MegaSquirt. The brief instructions are in the EasyTherm help file.

MegaSquirt Glossary

Also check the *Some MegaSquirt Assembly Language Variables* in this section.

AE - *Acceleration Enrichment*, the enriched mixture provided when the throttle position sensor signal changes at various rates.

AFR - *Air Fuel Ratio*, the mass ratio of air to fuel in the combustion chamber. See NB- and WB-EGO sensors, below.

ASE - *After Start Enrichment*, the enriched mixture provided for a number of engine cycles when MegaSquirt detects that the engine has transitioned from cranking to running.

Closed loop - refers to those times when an EFI computer is using the feedback on the mixture provided by the oxygen sensor to effectively control the injected amounts.

CTS - *Coolant Temperature Sensor*. Usually the CTS is an NTC (Negative Temperature Coefficient) thermistor, or a resistor whose resistance varies with temperature (NTC means the resistance goes down as the temperature goes up.

DMM (*digital multimeter*) electronic current/resistance/potential measuring tool.

DT - (*dual table*) the dual table embedded code that has a number of additional features over the standard B&G embedded code.

Duty Cycle (DC)– A number indicating the amount of time that some signal is at full power. In the context of MegaSquirt, duty cycle is used to describe the amount of time that the injectors are on, and to describe the "hold" part of the peak and hold injector drivers (see Low Impedance Injectors, below).

EasyTherm (ET) - A Windows program that simplifies configuring your MegaSquirt to accept the substitution of non-standard temperature sensors and to upload software revisions.

EDIS - *Electronic Distributorless Ignition System* is the Ford wasted-spark computer-controlled ignition module, which has been made to work with modified versions of MegaSquirt.

EGO Sensor - *Exhaust Gas Oxygen sensor*, used to describe the sensor in the exhaust that measures the lean/rich state of the AFR. Used to control the via a feedback algorithm called "closed loop".

FET (*field effect transistor*) - In MegaSquirt, the transistors (Q2 and Q7) used to control the activation of the injectors.

FIdle - *Fast Idle*. A device used to control idle speed with additional air supplied by a vacuum solenoid. MegaSquirt has a simple on-off fast idle control, and does not have the ability to drive a PWM IAC (Idle Air Control) device.

Gamma - Used to indicate the ratio of the calculated (or indicated) AFR to the stoichiometric value.

GM - *General Motors*, the manufacturer for the default coolant and air temperature sensors used with MegaSquirt.

High Impedance Injectors - (a.k.a. hi-Z) Fuel injectors designed to work with a simple switch in a 12 volt circuit, no special signal conditioning is required to drive them. The resistance of a high impedance injector is about 10-15 ohms.

HR - (*high resolution*) the high resolution embedded code that gives higher injector pulsewidth resolution than the standard B&G embedded code.

IAC – *Idle Air Control*. Typically a "stepper motor". MegaSquirt does not have the circuitry to control these.

IAT sensor - *Intake Air Temperature sensor*, same as MAT, see below.

kPa (*kiloPascals*) - the measurement of air pressure used in MegaSquirt computations. Average pressure at sea level is 101.3 kPa.

Kurt staging - those of you wanting to do staged injection you have also got an alternative way, using the standard MegaSquirt hardware and code. "Kurt staging" (named after the originator, *Kurt Heintz*) is a method of improving the dynamic range of a set of injectors. It takes advantage of the fact that the injectors timers are independent, and thus they can overlap. This means that one injection event does not have to finish before the next starts.
To implement Kurt staging, you can use a second set of identical injectors that feed each cylinder and hook the INJ driver #1 to the first set and INJ driver #2 to the second set. What will happen is at idle the injectors will alternate their pulses but as your VE values increase they will start to overlap pulses and allow full flow from both injectors at the same time. In essence, you progress from alternating to simultaneous as pulsewidths increase.
The available time, in seconds, to inject (for a 4 stroke cycle) is:

$$\textbf{time} = {}^{120}/_{RPM} * \textbf{duty\_cycle}$$

Whenever the pulsewidth is greater than ½ of this, Kurt staging will be in effect.
For example, at 6,000 RPM on a with port injection you have a maximum of 85% of 720° to inject, or 17 milliseconds. If you change this to 2 squirts you have 8.5ms per squirt (ignore inj_on). For example, if you had two 19lb injectors per cylinder and suppose VE=100 when the pulse width was 8.5ms. Up to this point each injector is on seperately, i.e. one squirts for 8.5ms, then the other squirts for 8.5 ms. Above this they start

overlapping, up to the point that, at VE=200 you have 17ms of injection at 38Lbs. Kurt staging gives twice the dynamic range of a single large injector on standard code.
The main criteria is that the engine must be set up so that it could conceivably run on either bank. For port injection, you must use two injectors per cylinder. For throttle body injection, you do not have any special hardware requirements. All injectors must have the same flow rating. They are then wired up, half to INJ1 bank, and the other half to INJ2 bank.
The injectors are set up to run alternately with the "injector staging" parameter in MegaTune. For example, on an independent runner 4 cylinder engine you set the MegaSquirt to 1 squirt/alternating. Each runner will have 1 injector from each bank squirting into it. This will in effect squirt once per cycle into each runner, first from one injector, then from the other on the next cycle. But, these squirts can overlap, so at higher revs, you can have both injectors squirting during the same cycle, injecting more fuel than one injector could.
Kurt staging works with the MegaSquirt as is, requiring no additional coding. You will need to have all the same size injectors placed as close as you can get them to each other and might need to alternate the injector banks for each INJ driver to get a smooth idle (IE. INJ driver #1 drives "A" injector for cyl #1, drives B injector for cyl #2, drives A injector for cyl #3 and drives B injector for cyl #4; INJ driver #2 would drive the opposite injector as the first INJ driver).
So if you have two equal injectors feeding the same cylinder (with a port injection set-up - TBI are almost always the same size injectors) you can use the above mentioned method, if you are running an extra set of different injectors or up stream injector/injectors you will need to use the dual table code, rather than Kurt staging.
Kurt staging is useful for turbos and also for high revving motors, as well as when it is more convenient to get another set of small injectors to get desired fuel flow (IE. Doubled up 19# injectors on a high powered 351W might be more cost effective than a set of 40#"ers.

Low Impedance Injectors - (a.k.a low-Z) Fuel injectors that are designed to run at a much lower current than would be supplied by a direct 12 volt connection. They require a special signal that is initially at full current (4-6 amps, a.k.a. "peak current") for about 1.0-1.5 ms, but then drops down to about 1 amp ("hold current") for the rest of the opening pulse. The resistance of a low-impedance injector is typically 1-3 ohms.

LSU-4 - Bosch wide-band oxygen sensor, planned for use in the UltraMegaSquirt fuel injection controller.

MAP sensor - *Manifold Absolute Pressure sensor*. Measure the absolute pressure in the intake manifold (related to the engine vacuum), to determine the load on the engine and the consequent fuelling requirements. The standard MAP sensor in MegaSquirt is the MPX4250 (2.50 BAR or 21 psig).

MAT Sensor - *Manifold Air Temperature sensor*, the same as IAT. The MAT circuit is identical to the CTS circuit, see CTS, above.

MJL - *MegaJolt Lite*, used in this document to refer to the ignition supplement to the MegaSquirt fuel injection controller.

MJLJr - *MegaJolt Lite Junior*, used in this document to refer to the ignition supplement to the MegaSquirt fuel injection controller.

MPX4250AP - the internal MAP sensor used in MegaSquirt.

MT - *MegaTune*, a Windows-base configuration program for the MegaSquirt EFI controller.

MS - *MegaSquirt*, used in this document to refer to the MegaSquirt fuel injection controller or its embedded software.

MSS - *MegaSquirt'n Spark*, used in this document to refer to the MegaSquirt and Spark variant of the MegaSquirt fuel injection controller or its embedded software.

MSTweak3000 - a Windows program which will sort through your datalogs and calculate VE points that need to be changed.

NB-EGO Sensor - *Narrow Band EGO sensor*, gives a switch at the stoichiometric ratio (the chemically correct mixture of air and fuel), but unreliable for AFR other than stoichiometric.

OEM (*original equipment manufacturer*) - refers to parts produced for initial assembly of a new vehicle.

Open Loop - refers to those times when MegaSquirt ignores the feedback from the oxygen sensor.

PCB (*printed circuit board*) - the fibreglass board that has the MegaSquirt component layout and circuits imprinted on it.

PC Configurator (PCC) - The original tuning software from Bowling and Grippo, it has fewer features than MegaTune. Having two independent tuning packages can be useful to determine if issues that arise are related to the tuning software or the MegaSquirt code.

P&H Injectors - *Peak and hold injectors*; see Low Impedance injectors.

PIP - *Profile Ignition Pick-up* is the term used for the signal sent from the Ford Electronic Distributorless Ignition System (EDIS) to the electronic control unit. This is a digitally modified alternating current (AC) signal that originates from a crank angle sensor. The PIP signal into the ECU is a square wave switched at 12 volts. It provides information about both the engine speed and position.

Pulse Width Modulation (*PWM*) - A signal with a fixed pulse width (frequency), which is turned on for part of the pulse. The percent of time that the signal is on is called its duty cycle. PWM is used to control voltage (and consequently current) to fuel injectors.

Required Fuel – (Req_Fuel) The injector pulse width, in milliseconds, required to supply the fuel for a single injection event at stoichiometric combustion, 100% volumetric efficiency and standard temperature.

SAW - *Spark Advance Word* is the "returning" signal to a Ford EDIS ignition unit from the ECU that sets the amount of ignition advance requested. It is in the form of a 5 volt square wave.

Stim (MegaStimulator) - the Stimulator is a small board which plugs into the connector of the Megasquirt. It simulates all the sensor the inputs that MegaSquirt would normally see and provides power to the Megasquirt. The Stimulator also allows you to monitor the MegaSquirt injection pulses [actual], fuel pump relay operation, and fast idle solenoid output with four LEDs.

TPS - *Throttle Position Sensor*, a voltage divider that gives information to MS about throttle opening, from which it computes rate of throttle opening for acceleration enrichment.

VE - *Volumetric Efficiency*. The actual amount of air being pumped by the engine as compared to its theoretical maximum. A 200 cubic inch motor will theoretically move 200 cubic inches of air in one cycle at 100% efficiency. If the engine is actually running at 75% VE, then it will move 150 cubic inches of air on each cycle.

WB-EGO Sensor - *Wide Band EGO sensor*, can be used to derive real AFR data with mixtures from 10:1 to 20:1, i.e. anything you are likely to be interested in.

WOT - Wide open throttle.

WUE - *Warm Up Enrichment*, the enriched mixture applied when the coolant temperature is low.

MegaSquirt Schematics

Load the MegaSquirt ".pdf" file directly from Bowling and Grippo official MegaSquirt site at:

http://www.bgsoflex.com/v22/megasquirt_ShemV2.2.pdf

MegaSquirt 68HC908GP32 Memory Map

$0000 - $003F = I/O Registers: 64 Bytes

$0040 - $023F = RAM 512

$0240 - $7FFF = Unimplemented 32,192 bytes

$8000 - $FDFF = FLASH Memory: 32,256 bytes

$FE00 = SIM Break Status Register (SBSR)

$FE01 = SIM Reset Status Register (SRSR)

$FE02 = Reserved (SUBAR)

$FE03 = SIM Break Flag Control Register (SBFCR)

$FE04 = Interrupt Status Register 1 (INT1)

$FE05 = Interrupt Status Register 2 (INT2)

$FE06 = Interrupt Status Register 3 (INT3)

$FE07 = Reserved (FLTCR)

$FE08 = FLASH Control Register

$FE09 = Break Address Register High (BRKH)

$FE0A = Break Address Register Low (BRKL)

$FE0B = Break Status And Control Register (BRKSCR)

$FE0C = LVI Status Register (LVISR)

$FE0D - $FE0F = Unimplemented: 3 bytes

$FE10 - $FE1F = Unimplemented: 16 bytes Note: Reserved for compatibility with monitor code for A-Family parts

$FE20 - $FF52 = Monitor ROM: 307 bytes

$FF53 - $FF7D = Unimplemented: 43 bytes

$FF7E = Flash Block Protect Register (FLBPR)

$FF7F - $FFDB = Unimplemented: 93 bytes

$FFDC - $FFFF = Flash Vectors: 36 bytes

Some MegaSquirt Assembly Language Variables

ACMULT = Acceleration cold multiplication factor (percent/100)

adsel = ADC Selector Variable

aircor = Air density correction is computed from MAT.

asecount = Counter value for after-start enrichment counter - every ignition

AWC = After-start number of cycles

AWEV = After-start Warmup Percent enrichment add-on value

baro = The barometric pressure as measured by MegaSquirt.

barocor = Barometer Lookup Correction - percent, based on the initial MAP sensor reading.

batt = Battery Voltage ADC Raw Reading - counts

BATTFAC = Battery Gamma Factor

clt = Coolant Temperature ADC Raw Reading - counts (0 - 255)

coolant = Coolant temperature in Degrees F plus 40 (allows -40 degress to fit in integer)

CWH = Crank Enrichment at 170 F

CWU = Crank Enrichment at -40 F

ddra = Port A Data Direction Register

ego = Exhaust Gas Oxygen ADC Raw Reading - counts

egocorr = This is the correction factor computed from O2 sensor readings.

egocount = Counter value for EGO step - incremented every ignition pulse

egotemp = Coolant Temperature where EGO is active

egocountcmp = Counter value where EGO step is to occur

egodelta = EGO Percent step size for rich/lean

egolimit = Upper/Lower EGO rail limit (egocorr is inside 100 +/- Limit)

engine = Variable bit-field to hold engine current status

FASTIDLE = Fast Idle Temperature

gammae = Total Gamma Enrichments - percent

InjOpen = Injector Open Time

InjOCFuel = PW-correlated amount of fuel injected during injector open

INJPWM = Injector PWM duty cycle at current limit

INJPWMT = Injector PWM millisec time at which to activate.

kpa = MAP value in units of KPa

KPARANGEVE = VE Table MAP Pressure Bins for 2_D interp.

last_tps = TPS reading updated every 0.1 seconds

lmap = Manifold Absolute Pressure ADC last Reading

lmat = Manifold Air Temp ADC last Reading

lclt = Coolant Temperature ADC last Reading

ltps = Throttle Position Sensor ADC last Reading

lbatt = Battery Voltage ADC last Reading

lego = Last EGO ADC reading

map = Manifold Absolute Pressure ADC Raw Reading - KPa (0 - 255)

mat = Manifold Air Temp ADC Raw Reading - counts (0 - 255)

mms = 0.0001 second update variable

ms = 0.001 second increment

porta = Port A Data Register

portb = Port B Data Register

portc = Port C Data Register

PRIMEP = Priming pulses (0.1 millisec units)

pulseigncount = Ignition pulse counter

pw = The injector pulse width being used by MS to squirt fuel into your motor.

pwcalc = Computed pulse width - move into variable PW at pulse time

pw = Injector squirt time in 1/10 milliseconds (0 to 25.5 millisec) - applied

pw2= The other PW comparison (injector #2)

pwrun1 = Pulsewidth timing variable 1 - from 0 to 25.5ms

pwrun2 = Pulsewidth timing variable 2 - from 0 to 25.5ms

REQ_FUEL = Fuel Constant

RPMOXLIMIT = Minimum RPM where O2 Closed Loop is Active

rpm = Computed engine RPM - rpm/100

rpmch = Counter for high part of RPM

rpmcl = Counter for low part of RPM

rpmpl = Low part of RPM Period

rpmk = Constant for RPM = 12,000/ncyl - downloaded constant

rpmph = High part of RPM Period

rpmphl = last rpmph value (for odd-fire)

rpmpll = last rpmpl value (for odd-fire)

RPMRANGEVE = VE table RPM Bins for 2-D interpolation

rxoffset = offset placeholder when receiving VE/constants vis. SCI

secl = Time in seconds since MegaSquirt last booted. Low seconds - from 0 to 255, then rollover.

sech = High seconds - rollover at 65536 secs (1110.933 minutes, 18.51 hours)

squirt = Event variable bit field for Injector Firing.

tenth = 1/10th second

tmp1,...,tmp19 = Temporary storage.

tps = Throttle Position Sensor ADC Raw Reading - counts, represents 0 - 5 volts

tpsaccel = The acceleration enrichment.

tpsaclk = TPS enrichment timer clock in 0.1 second resolution

TPSAQ = TPS acceleration amount (fn TPSDOT) in 0.1 ms units

tpsacold = Cold acceleration amount (at -40 degrees) in 0.1 ms units

TPSASYNC = TPS Acceleration clock value

TPSDQ = Deacceleration fuel cut

tpsfuelcut = TPS Fuel Cut (percent).

tpsthresh = Accel TPS DOT threshold

txcnt = SCI transmitter count (incremented)

txgoal = SCI number of bytes to transmit

txmode = Transmit mode flag

T1SCX_NO_PWM = No PWM

VE = 64 bytes for VE Table

vecurr = The current computed VE value determined by look up in the VETABLE using

RPM and MAP.

VOLTOXTARGET = O2 sensor flip target value

warmcor = The warm-up correction factor applied due to start-up and coolant temperature status.

WWU = Warm-up bins (fn temp)

MegaSquirt MC68HC908GP32 Instruction Set

ADC = Add with Carry

ADD = Add without Carry

AIS = Add Immediate Value (Signed) to Stack Pointer

AIX = Add Immediate Value (Signed) to Index Register

AND = Logical AND

ASL = Arithmetic Shift Left

ASR = Arithmetic Shift Right

BCC = Branch if Carry Bit Clear

BCLR n = Clear Bit n in Memory

BCS = Branch if Carry Bit Set

BEQ = Branch if Equal

BGE = Branch if Greater Than or Equal To

BGT = Branch if Greater Than

BHCC = Branch if Half Carry Bit Clear

BHCS = Branch if Half Carry Bit Set

BHI = Branch if Higher

BHS = Branch if Higher or Same

BIH = Branch if IRQ Pin High

BIL = Branch if IRQ Pin Low

BIT = Bit Test

BLE = Branch if Less Than or Equal To

BLO = Branch if Lower

BLS = Branch if Lower or Same

BLT = Branch if Less Than

BMC = Branch if Interrupt Mask Clear

BMI = Branch if Minus

BMS = Branch if Interrupt Mask Set

BNE = Branch if Not Equal

BPL = Branch if Plus

BRA = Branch Always

BRA = Branch Always

BRCLR n = Branch if Bit n in Memory Clear

BRN = Branch Never

BRSET n = Branch if Bit n in Memory Set

BSET n = Set Bit n in Memory

BSR = Branch to Subroutine

CBEQ = Compare and Branch if Equal

CLC = Clear Carry Bit

CLI = Clear Interrupt Mask Bit

CLR = Clear

CMP = Compare Accumulator with Memory

COM = Complement (Ones Complement)

CPHX = Compare Index Register with Memory

CPX = Compare X (Index Register Low) with Memory

DAA = Decimal Adjust Accumulator

DBNZ = Decrement and Branch if Not Zero

DEC = Decrement

DIV = Divide

EOR = Exclusive-OR Memory with Accumulator

INC = Increment

JMP = Jump

JSR = Jump to Subroutine

LDA = Load Accumulator from Memory

LDHX = Load Index Register from Memory

LDX = Load X (Index Register Low) from Memory

LSL = Logical Shift Left

LSR = Logical Shift Right

MOV = Move

MUL = Unsigned Multiply

NEG = Negate (Twos Complement)

NOP = No Operation

NSA = Nibble Swap Accumulator

ORA = Inclusive-OR Accumulator and Memory

PSHA = Push Accumulator onto Stack

PSHH = Push H (Index Register High) onto Stack

PSHX = Push X (Index Register Low) onto Stack

PULA = Pull Accumulator from Stack

PULH = Pull H (Index Register High) from Stack

PULX = Pull X (Index Register Low) from Stack

ROL = Rotate Left through Carry

ROR = Rotate Right through Carry

RSP = Reset Stack Pointer

RTI = Return from Interrupt

RTS = Return from Subroutine

SBC = Subtract with Carry

SEC = Set Carry Bit

SEI = Set Interrupt Mask Bit

STA = Store Accumulator in Memory

STHX = Store Index Register

STOP = Enable IRQ Pin, Stop Oscillator

STX = Store X (Index Register Low) in Memory

SUB = Subtract

SWI = Software Interrupt

TAP = Transfer Accumulator to Processor Status Byte

TAX = Transfer Accumulator to X (Index Register Low)

TPA = Transfer Processor Status Byte to Accumulator

TST = Test for Negative or Zero

TSX = Transfer Stack Pointer to Index Register

TXA = Transfer X (Index Register Low) to Accumulator

TXS = Transfer Index Register to Stack Pointer

WAIT = Enable Interrupts; Stop Processor