MegaSquirt\textsuperscript{2.0}

Electronic Fuel Injection Controller

Assembly, Installation, and Tuning Manual

for
MegaSquirt Version 2.2 Hardware/2.00 Software

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

http://groups.yahoo.com/group/megasquirt/

http://members.shaw.ca/megasquirt/MS%20FAQ.htm

February 2003
# MegaSquirt<sup>2.0</sup> Assembly, Installation, and Tuning Manual

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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 unknowingly supplied the information for MegaTweak3000, as has Roger Enns for the EasyTherm and MS Palm material. 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 “Neon” John De Armond, Bill Shurvington, Camden Lindsay, Perry Harrington, Ira Emus, Clare Snyder, Wing Gee, Mike Lough, Guy Hill, and many, many others. This manual has been edited by Lance Gardiner, Patrick Carlier, Richard Lockhurst, and Dan Barnes, with comments from Al, Bruce, and Eric.
Introduction to MegaSquirt

MegaSquirt is an experimental Do-It-Yourself universal programmable electronic fuel injection controller for spark ignition internal combustion engines. MegaSquirt was designed by Bruce Bowling and Al Grippo, and has been offered in two group buys so far. In order to assemble, test, and install and safely use MegaSquirt, you must read, understand and follow this manual.

IMPORTANT: While MegaSquirt has been thoroughly tested and installed in many vehicles, it is an experimental unit, and the user assumes all risks and liabilities for the installation and use of MegaSquirt hardware and software. The MegaSquirt project is intended to provide a learning experience for all participants, so make sure YOU understand the requirements and limitations of the controller, software, and any fuel supply components you add or modify.

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 spec 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) which operate 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. Also, 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 has a retention duration of 20 years.

Commonly available 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 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. Bruce and Al's 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)

- **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 prior to installing it. (Jeff Clarke)

- **Willette programmer** - to program or reprogram the processor. (Jim Willette)

- **Relay kit** - to simplify wiring of the MegaSquirt. (Bowling and Grippo)

- **MegaView** - to provide a dedicated display for the MegaSquirt - planned for 2003. (Bowling and Grippo)

- **MegaJolt** - a companion ignition controller for MegaSquirt - **MegaJolt Light** to be released in early 2003. (Bowling and Grippo)

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: solder it together, install in the vehicle or boat, tune, and use. The complete source code is available on this site for those who want to understand or even modify the control algorithms - one can convert this board to control nitrous, alcohol, methanol, LPG, etc. - there is really no limit.

**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-yourselfers. 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 2-1/2 years ago.

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 (this is to come soon in another system to be called MegaJolt). 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.

A flash-based Motorola microprocessor (MC68HC908GP32) is used for the calculation of fuel and injector control. Additionally, host software has been developed (Windows-based) which allows the run-time adjustment of control parameters. All information for the system is available on the MegaSquirt web site at www.bgsoflex.com/megasquirt.

What you NEED to Know 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:

- the tools and ability to assemble and test an electronic printed circuit board,
- additional parts to suit your installation, including:
  - coolant and air temperature sensors,
  - an oxygen sensor (either narrow-band or wide-band) and bung,
  - wiring and various connectors for the sensors, injectors, etc.,
  - injectors and bungs/manifold,
  - throttle body,
  - high pressure fuel pump and supply/return lines,
  - a fuel pressure regulator,
- the tools and ability to cut the aluminum case end-plates for connectors and LEDs,
- the knowledge and skills to install all of the necessary sensors and wiring,
- the knowledge and experience to be able install or adapt a complete high-pressure fuel system in your vehicle for MegaSquirt,
- a 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], 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..


You won't be dealing with your MegaSquirt alone, however. Nearly a thousand MegaSquirt kits were shipped by the end of the first two group buys. There is a huge amount of collective experience and knowledge related to the assembly and installation of MegaSquirt in various vehicles available on the MegaSquirt Yahoo! site.

**Purchasing a MegaSquirt**

An on-going group buy started in the Spring of 2003. The printed circuit board (PCB), programmed processor, MAP sensor and a few other key parts are available in the group buy, and you order the remaining parts from Digi-Key. A web-site order form has been set up for this purpose. It is at:

http://members.shaw.ca/megasquirt/bom.htm

The Digi-Key parts ordering form does not include the enclosures, which must be ordered separately. See the form for more details. This means that you have to place 3 orders to get a complete kit (PCB and some critical parts, Digi-Key parts, and enclosure). Bruce and Al will maintain an inventory of partial kits and order more when it goes below a certain point. This will make MegaSquirt kits available pretty much at all times, shorten delivery time, and greatly free up Bruce's and Al's time for developing other products. The downside is that it will be slightly more expensive, but still the cheapest thing around by far.

There will be no relay kit, it will be set up the same as the MegaSquirt. You purchase the printed circuit board (PCB) for $15 from the group buy and the rest you get from Digi-Key.

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.

What Bruce and Al do not want individuals selling their own version of the PCB. They cannot maintain any quality control or support for such boards, and every issue become prefaced with “what PCB are you using...”. Having a sole source for the PCBs 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.

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. It 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. We assume you have some basic automotive, computer, and electronics background, or are willing to find this information yourself. If you don’t have such knowledge, 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 solution, one of the commercial controllers might suit your needs better.

A great many advanced topics have been left out, including: assembly language programming, the dual table code, the hi-res code, all of the many useful Tomtek modifications to code and hardware, tuning rotary engines, tuning turbocharged engines, running propane injection, water injection, etc. For information on these and other topics, see the FAQ and the Yahoo! message list.
Assembling Your MegaSquirt

In the group buy, you receive a PCB (just the printed circuit board), plus some essential components, called a partial kit. The partial kit includes:

⇒ printed circuit board (PCB)
⇒ a pre-programmed 68HC908GP32 processor
⇒ MPX4250AP MAP sensor, and the
⇒ 34151 FET driver

Ordering Components from Digi-Key

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

http://members.shaw.ca/megasquirt/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 on the next page of this manual). 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. If you have questions about the specification or appearance of an item, check the part number at the Digi-Key site first. (www.digikey.com). Entering the part number in their search engine will give you access to both the catalog information and the manufacturer’s datasheet. You can also access this information from the ordering form at:

http://members.shaw.ca/msbom.htm

by clicking on the part’s description.

When you get your parts kit from Digi-Key, it will contain the components listed on the following page for a (minus the PCB, U1, U3, and U7). Note that you will have some extra parts. These are the result of Digi-Key’s 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 They are also listed in this document in Appendix I, though in somewhat limited resolution.

Before plugging in your soldering iron, be sure you read and understand the assembly instruction that follow. For all you folks who are first time solderers about to put your MegaSquirt together, read the deployment guide thoroughly. Even if you have gone through NASA’s soldering certification you might learn a thing or two from reading it again. You do not need to use silver solder for MegaSquirt. Regular 60/40 or 63/37 solder is fine.

Assembly Guide for Version V2.2

The following is a step-by-step assembly guide for the V2.2 MegaSquirt partial kit. Read through all of these directions first. Be sure to check off each step as you complete it.
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<td>2 (5)</td>
<td>R12, R17</td>
<td>22 ohm, 5%, 0.25w,axial</td>
<td>22QBK-ND</td>
</tr>
<tr>
<td>1 (5)</td>
<td>R21</td>
<td>100K ohm, 5%, 0.25w,axial</td>
<td>100KQBK-ND</td>
</tr>
<tr>
<td>1 (5)</td>
<td>R22</td>
<td>10M ohm, 5%, 0.25w,axial</td>
<td>10MQBK-ND</td>
</tr>
<tr>
<td>1 (5)</td>
<td>R29</td>
<td>1M ohm, 5%, 0.25w,axial</td>
<td>1.0MQBK-ND</td>
</tr>
<tr>
<td>1 (5)</td>
<td>R32</td>
<td>270 ohms, 5%, 0.5w,axial</td>
<td>270H-ND</td>
</tr>
<tr>
<td>1</td>
<td>U1 - Group Buy (pre-programmed)</td>
<td>68HC908GP32 Processor - 40 Pin DIP</td>
<td>MC68HC908GP32CP</td>
</tr>
<tr>
<td>1</td>
<td>U3 - Group Buy</td>
<td>MPX4250A Pressure Transducer</td>
<td>MPX4250AP</td>
</tr>
<tr>
<td>1</td>
<td>U4</td>
<td>4N25 opto-isolator - 6 Pin DIP</td>
<td>160-1300-5-ND</td>
</tr>
<tr>
<td>1</td>
<td>U5</td>
<td>LM2937ET-5.0 Regulator - 3 Pin T0-220</td>
<td>LM2937ET-5.0-ND</td>
</tr>
<tr>
<td>1</td>
<td>U6</td>
<td>MAX232CPE - 16 Pin DIP</td>
<td>MAX232CPE-ND</td>
</tr>
<tr>
<td>1</td>
<td>U7 - Group Buy</td>
<td>34151 FET driver - 8 Pin DIP</td>
<td>34151</td>
</tr>
<tr>
<td>1</td>
<td>Y1</td>
<td>32.768 KHz Crystal</td>
<td>300-1002-ND</td>
</tr>
<tr>
<td>1</td>
<td>n/a</td>
<td>40 Pin DIP Socket</td>
<td>A9440-ND</td>
</tr>
<tr>
<td>1</td>
<td>n/a</td>
<td>Connector DB-37 Female</td>
<td>237F-ND</td>
</tr>
<tr>
<td>1</td>
<td>n/a</td>
<td>DB-37 Hood</td>
<td>937GM-ND</td>
</tr>
<tr>
<td>1</td>
<td>Printed Circuit Board - Group Buy</td>
<td>Double sided, plated holes, solder mask PCB</td>
<td>n/a</td>
</tr>
</tbody>
</table>
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 group buy 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) - download from [http://www.bgsoflex.com/megasquirtpcdown.html](http://www.bgsoflex.com/megasquirtpcdown.html) and install it on your computer.
- A MegaStimulator will make these checks, and several other tasks, much easier.
- General electronic kit assembly tools (screwdriver, 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% devices, the readings may not be exactly as designated, this is okay.
- 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 1/4” drill bits for cutting the end plates.

Don’t 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, or Willette programmer 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, 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 & Testing (steps 1-19)
- Serial Communications Construction & Testing (steps 20-22)
Clock Circuit Construction & Testing (steps 23-36)

Input Section Construction & Testing (steps 37-56)

Output Section Construction & Testing (steps 57-73)

Power Supply Construction & Testing

1. Get ready for assembling your MegaSquirt. Plan on taking 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.

   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. There is a certain tolerance that the boardhouse uses, 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 can not slide the board in, deburring the box sometimes makes all the difference. The boards bind if the edges are sharp, slip right in when cleaned up. If this still doesn’t work, then before soldering anything to the boards file the sides down a bit. Use a 12” finishing file and slid the board back and forth on both long sides for about 30 seconds. (If you do not have your case yet, yet can proceed and check the sizes later, it will just be a much more delicate job).

Resistor Color Codes

<table>
<thead>
<tr>
<th>Color</th>
<th>Band 1</th>
<th>Band 2</th>
<th>Multiplier (3rd band)</th>
<th>Tolerance (4th band)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>x1</td>
<td>Not used</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>x10</td>
<td>Not used</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>x100</td>
<td>Not used</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>x1000 = 1K</td>
<td>Not used</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>x10000 = 10K</td>
<td>Not used</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>x100000 = 100K</td>
<td>Not used</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>x1000000 = 1M</td>
<td>Not used</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td>Gold</td>
<td>Not used</td>
<td>Not used</td>
<td>divide by 10</td>
<td>= 5%</td>
</tr>
<tr>
<td>Silver</td>
<td>Not used</td>
<td>Not used</td>
<td>divide by 100</td>
<td>= 10%</td>
</tr>
<tr>
<td>None</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>= 20%</td>
</tr>
</tbody>
</table>

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.

So the first capacitor would be 10*10^4 = 10*10,000 = 100,000pF = 0.1µF, since 1,000,000pF=1µF.

The second capacitor would be 15*10^2 = 15*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
2. Install and solder the **DB-37 (P2)** header 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.

Note: you should 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” off of this side, up to 60 seconds on the file. When you are done the board should fit nice and snug.

Then install and solder the **DB-9 (P1)** header.

3. Next, install the **40-pin DIP socket** 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 which makes up the power supply, and then verify operation. The first part to install is capacitor **C14** (0.001 uf, 102K marking).

Note: many of the component leads will have to be bent to go into the holes, use pliers for this. Also, 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, don’t 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** (1N4001) - make sure banded end is installed correctly as per board.

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

7. Install and solder **D13** (1N4001) - make sure banded end is installed correctly as per board.

8. Install and solder **D15** (22 or 24 volt zener, 1N4749 or 1N4748) - make sure banded end is installed correctly as shown on the printed circuit board.

9. Install and solder **C15** (a tantalum capacitor, 33 or 22 microfarads (uf)) - make sure polarity is observed. It has a small + near the positive lead. If your capacitors came in a MegaSquirt group buy kit, then there’s a thick white line with a little ’+’ embedded in it. That’s the positive pin. The longer lead is also always the positive lead.

10. Install and solder **D12** (1N4001) - make sure banded end is installed correctly as per board.

11. Install and solder **C16** (tantalum, 33 or 22 uf) - make sure

---

**Positive is:**

**Capacitors:**  the longer lead on polarized capacitors, sometimes marked with a small +

**LEDs:**  the longer lead on LEDs, and the lead opposite the “flat” on the case.

**Diodes:**  the end with a band (or sometimes a ”k”, "+", "cath", a color dot or , or a raised edge or taper).
polarity is observed. The longer lead is positive on all of the capacitors.

12. Install and solder **C17** (0.1 uf, 104K marking).

13. Install and solder **L1** (inductor, 1uh, small coil of wire with leads).

14. Install and solder **L2** (inductor, 1uh).

15. Install and solder **C18** (0.1 uf capacitor, 104K marking).

16. Install and solder **C22** (0.1 uf capacitor, 104K marking).

17. Install and solder **C21** (4.7 uf electrolytic) - make sure polarity is observed.

18. Install the voltage regulator **U5 (LM2937ET-5.0)**. 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 we go any further, we are going to ensure 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, 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. Unplug the stimulator when finished.

<table>
<thead>
<tr>
<th>Pin</th>
<th>2</th>
<th>19</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 0.1 uf (104K marking) by soldering them in the appropriate locations.

21. Next, solder the **U6 (MAX232CPE)** - 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. 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. [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.]

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 (if you cannot find it, do a "Search - Files and Folders" for "Hypertrm.exe").

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. Click OK.

<table>
<thead>
<tr>
<th>Baud Rate</th>
<th>9600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Bits</td>
<td>8</td>
</tr>
<tr>
<td>Stop Bits</td>
<td>1</td>
</tr>
<tr>
<td>Flow Control</td>
<td>None</td>
</tr>
</tbody>
</table>

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 don't 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.

I. 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 the processor clock circuit and battery voltage read back. First, install \textbf{C1} (0.1 uf, 104K) and solder.

24. Install and solder \textbf{C19} (0.033 uf, 333K marking).

25. Install and solder \textbf{C20} (0.01 uf, 103K).

26. Install and solder \textbf{C23} (50 pf, "50" or "47" marking).

27. Install and solder \textbf{C24} (20 pf, "20" or "22" marking).

28. Install and solder \textbf{R14} and \textbf{R20} (10K, brown-black-orange).

29. Install and solder \textbf{R21} (100K, brown-black-yellow).

30. Install and solder \textbf{R22} (10M, brown-black-blue).

31. Install and solder \textbf{R3} (50K, yellow-white-white-red-brown).

32. Install and solder \textbf{R6} (10K, brown-black-orange).

33. Install and solder \textbf{Y1} (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.

34. Insert the CPU \textbf{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.

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" screen (hit the button) 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 screen).

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 like that, 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 is there, you are running! If not, check the cable, make sure there is power, and check the COM port. The only other value on the screen which is working correctly is the "Batt V" box - it should be displaying the battery voltage (from about 7-8.5 volts, depending on the 9-volt battery
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 (0.1 uf, 104K marking).

39. Install and solder C5, C7, and C9 (0.001uf, 102K marking).

40. Install and solder C11 (0.01 uf, 103K marking).

41. Install and solder C2, C4 and C10 (0.22 uf, 224K marking).

42. Install and solder C6 and C8 (1.0 uf, 105K marking).

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

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

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

46. Install and solder R29 (1M, red-black-black-yellow-red).

47. Install and solder R10 (kit supplied 390 ohm, 1/2 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 (1N4001). This is the infamous Wing Diode - you will want this (reduces tach signal false-triggering).

49. For most installations, diode D8 (John Zener, 5.1V, 1N4733) is not needed. Note: the diode is needed if the 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. 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 (4N25) - observe the proper orientation (notch).

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

52. The MAP sensor, U3 (MPX4250AP), is next. It mounts on the underside of the PCB - see this photo for details. 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.
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 don’t 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. Eric and Bruce have tested this with about 30 feet of 1/8” tubing and they saw 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** (2.49K, 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 resistors, 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. Also, 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).

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Resistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>2.49K (supplied)</td>
</tr>
<tr>
<td>Ford</td>
<td>22K</td>
</tr>
<tr>
<td>Bosch</td>
<td>2.2K to 7K, depending on type</td>
</tr>
</tbody>
</table>

Note: To avoid changing the tables in the controller code, the bias resistor should have a value equivalent to that of the thermistor sensor you will be using when it is at 81° Fahrenheit.

54. Now, it’s 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 of 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.

55. Install and solder D11 (5.1 Zener diode, 1N4733).

Note: diodes D1 to 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. No jumpers, leave these positions open. 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, and the added protection from external diodes is not needed. However, one can put the diodes in if they wish, but they may have had problems with upper ADC readings with the diodes installed. The Zener diodes that are marked at 5.1 volts seem to kick in at voltages like 4.5V or so - we do not know the reason for this. Diodes sourced from Newark, Digi-key, etc, all seem to have a different knee voltage. These tend to screw up the MAP readings at the high end, and they are not needed on the MAP because it is an active device, mounted on the PCB, so incorrect hookup is not a problem. For the temp sensors, the diodes limit how cold you can go - without them you can get to - 40 degrees F, and with them installed the lower limit is right around - 20 degrees. However, the holes are there in the PCB for those who want to install the diodes.

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 - old hat to you by now. Now, you should be able to see action when you move the knobs on the stimulator. First, look at the RPM - it should increase when you move the RPM pot on the stimulator. The same for the air temperature, coolant, and oxygen sensor - all sensors should react to the stimulator. To get the O2 sensor to respond on the PC Configurator or MegaTune, you must set the CLT and TPS knobs on the MegaStimulator such that: the throttle is closed or near closed (not WOT), the coolant is above the threshold (default is 160 degrees), and the ECU must be powered up for at least 30 seconds. Look at the tuning screen - the O2 voltage should move once these conditions are met.

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 unplug the processor again, like before.
Output Section Construction & Testing

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

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

59. Install and solder D7, D9, D20, D22, and D23 (1N4001) - observe the proper polarity.

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

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

62. Install and solder the transistors Q3, Q5, Q9, Q10, and Q11 (PN2222A).

Note: Digi-Key parts kits use PN2222A 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, 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. Also, it is very important to space the transistors 1/8" to 1/4" off of the surface of the PCB, to prevent shorting of the traces below.

63. Install C29 (0.1 uf, 104K) - and solder.

64. Install and solder C30 (4.7 uf - marked 4.7 uf), observe polarity. Recall that the longer lead on the capacitor is the positive lead.

65. Install and solder D21 (36V Zener, 1N4753). Mount this one 1/8 - 1/4 off of the surface of the board. This Zener diode sets the flyback breakdown voltage.

66. Install/solder Q1 (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 (270 ohm, 1/2 watt). This resistor is mounted 1/4" to 1/2" 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 (IXDI404PI/33151) FET driver.

We now have everything installed, other than the FETs and the LEDs - these mount on the case ends. So, we need to cut these out before we can proceed with the assembly. To cut the end plates for the MegaSquirt, do the following:

a. Print out the template on the next page, and use it as a cutting guide (Please Note: *.PDF files do not maintain size integrity. Verify printed sizes before cutting!). Use a Dremel or a jigsaw to cut out the slots, or drill several smaller connected holes and file them out to a rectangle. Clean off any burrs and rough edges with a file - especially around the FET mounting holes. The template assumes the board is inserted in the second slot, not the bottom one.

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 (1/4”) 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.

(At the very least steps 1-4 to be 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 together with each other to make the complete case, 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 - oriented the other way, the groove may put stress on the side of the FET.
MegaSquirt End-Panel Cut-Out Templates

Be sure to verify the template size against your end-plates, as .pdf files do not necessarily maintain size integrity.

Front Panel Cut-out Template
LED Hole Size = 1/4”

Back Panel Cut-out Template
MOSFET Mounting Hole Size = 1/8”
70. Next, mount the LEDs (D17, D18, D19) 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. Next, 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 on the preceding pages. Then solder the LEDs to the PCB from the top of the
71. Now, finally, its time to mount the two FETs (Q2, Q7). 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 insulating set-up to prevent the tab from touching the metal case back. Use the illustration above 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, then bent down to enter the holes. Here is a drawing:

73. 73 steps to success! It s time to test it all. Plug in the processor, DB-9 cable, and

MOSFET mounting details

Use heat sink compound between the FET, mica, and back panel.

Note with the plastic insulated FETs supplied by Digi-Key, you can mount the FET directly to the back panel, no insulator or mica is needed. Do use heat sink compound.

stimulator. Now, you should see the injector LEDs on the stimulator board 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 160 degree coolant temperature (adjust on the stimulator), the fast-idle LED should also glow.

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 can not 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’re going to be working the board, “Krylon Krystal” clear spray works very well. Several coatings, preferably baked at 175-200 deg in between. This should slow down or prevent “solder bloom” and other deterioration of the PCB. Condensation is a fact of life 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’ve got the DB9 to go to your laptop (~2”).

You cannot install the MegaSquirt box underhood. 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 airstream 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.

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

1) verify that each component is the correct item for each location. Start with the assembly guide and check each step to make sure you have not missed a component. Also check all solder joints visually,

2) verify that all components that have a particular orientation are installed correctly - this includes all ICs, all polarized capacitors, all diodes and LEDs, the MAP sensor, the voltage regulator, and the transistors. 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) which should be replaced if installed incorrectly.

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

4) note which (if any) of the LEDs light on the Stimulator, and under what conditions.

5) 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,

6) finally, if none of this helps to discover and solve your problem, send a message with the above information to the MegaSquirt Yahoo! list.

Feel free to ask for help, that’s 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. And, following the assembly steps, you will discover problems and correct them as you go along.

If you discover odd behaviour from your MegaSquirt 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" 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.

**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 [firing].
- **Injector #2** - lights when the second injector bank is grounded [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 the **either** injector bank is instructed 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 temp., 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].

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. 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.
For the “MegaWheels” stickers for your MegaSquirt, contact Mike Lough at:

http://www.locustom.com/ms_ordering.htm

They are just the right size for the MegaSquirt case. They look like this:
Wiring and Sensors

In order to install your MegaSquirt in your vehicle, you will need to have several functioning sensors. These are:

- coolant (CTS) and intake air temperature sensors (IAT),
- an oxygen sensor (EGO), either narrow-band or wide-band, and threaded bung, and
- wiring and various connectors for the sensors, injectors, etc.,

In these section we will cover the requirements for these components.

Schematic

There is a schematic of the external wiring needed for MegaSquirt on the next page.

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 lots of 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 cheap, but they may have items you can not get from Waytek.

General Guidelines for Automotive Wiring

1) Load on a wire in amps is:

\[
\text{wattage of the device divided by 12 = Amps (volts x amps = watts),}
\]

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

3) Use DIFFERENT color wires - you haven’t lived until you’ve tried to troubleshoot a car done in all black wires five years after the fact.

4) Use a battery charger as a power source as you work things out - if you use the car battery, a dead short will draw 60 jillion amps from the battery in a tenth of a second, and your vehicle will fail the smoke test spectacularly. The battery charger has a circuit breaker - if you goof and provide the same dead short, all you get is "click!" instead of burning the car to the ground.

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

6) 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.

7) Work in a well-lighted area - this is hard enough to do correctly even when you CAN see what you are doing.
8) 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).

9) 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.

10) 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'll have to do that part of the job over to use what you CAN get at the time.

**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 tubing from the sensor to the engine intake manifold. You can use a port on the throttle body if it has full-time engine vacuum (i.e. NOT ported vacuum). The source you choose should have a high vacuum at idle, if it doesn't, 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 won't 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.

One, three and four wire narrow band O2 sensors [NB], and the wide band sensor [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 sensor 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.

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 temp 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 temp will be much greater than 400 degrees C. and the 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.

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 don’t have exhaust gas temperature [EGT] monitoring then you can’t 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’s 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 limited 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 the next page 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 will take the WB characteristics into account. However, you won’t be able to set individual target air/fuel (A/F) ratios for various MAP values. MSTweak3000 may have this feature in the near future.

If your car didn’t come with an oxygen sensor, you can add one. The thread for all oxygen sensors [including wide-band] is: 18mm x 1.5mm, the same as 18mm sparkplugs. So 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 downpipe. 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’ll cut you a deal on a nice machined O2 sensor bung. And 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 4 wire narrow band sensor, you will need to wire the heater in the sensor. The heating element in a heated narrow band O2 sensor (3 or 4 wire) is self-regulating, just connect one heater wire into ignition-switched 12v, the other heater wire goes to ground. The heater wires are the often thicker than the signal and ground wires, and are
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 can’t 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’s 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 doesn’t 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.

### Coolant temperature sensor

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>stoichiometric</th>
<th>best-power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow Band O2</td>
<td>0.45 volts</td>
<td>???</td>
</tr>
<tr>
<td>Wide Band O2</td>
<td>2.50 volts</td>
<td>2.08 volts</td>
</tr>
</tbody>
</table>

### Air temperature sensor

<table>
<thead>
<tr>
<th>Degrees F</th>
<th>Degrees C</th>
<th>Ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>-40</td>
<td>100,700</td>
</tr>
<tr>
<td>0</td>
<td>-18</td>
<td>25,000</td>
</tr>
<tr>
<td>20</td>
<td>-7</td>
<td>13,500</td>
</tr>
<tr>
<td>40</td>
<td>4</td>
<td>7,500</td>
</tr>
<tr>
<td>70</td>
<td>21</td>
<td>3,400</td>
</tr>
<tr>
<td>100</td>
<td>38</td>
<td>1,800</td>
</tr>
<tr>
<td>160</td>
<td>71</td>
<td>450</td>
</tr>
<tr>
<td>210</td>
<td>99</td>
<td>185</td>
</tr>
</tbody>
</table>
sometimes white. O2 sensor heaters typically are about 18 Watts (1.5 Amps), so use an appropriate wire gauge and fuse.

_Temperature Sensors_

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.

Naturally aspirated engines using MegaSquirt can use the same sensors for coolant and air temperature. These coolant and air-temperature sensors are inexpensive (roughly US$9.00) GM units readily available from any parts store (GM #12146312). Turbocharged or supercharged engines should use an open-element air temperature sensor for a faster response time.

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 back to the PCB. You can use a one common wire to do this for all of the sensors.

Or you can try www.carparts.com. Type in part number AX1 (air sensor) - you get the replacement part for GM 12146312, (not cheap though at 25$). The coolant sensor can be found under TX3.

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

The thread for the recommended General Motors 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...)

These sensors were 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.

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 don’t need to mess with Hyperterminal.
Don’t 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 warmup enrichment, you want something that responds fairly 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 drivable while it is warming up. Once the cylinder head is up to temp, 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 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 real TPSs. Real TPSs give 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 setup.
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 really 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.

**Wire Sizes**

For the wires from the DB37 connector to the sensors, injectors, etc., use 18 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.

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.

**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 a 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 uni-polar, others use PWM proportional control, etc., etc.) to manage with a simple solution. Also, the control of all of the different types of IAC motors out there would be a support nightmare.

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

<table>
<thead>
<tr>
<th>Wire Size for Runs up to 15 Feet</th>
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<tbody>
<tr>
<td>Gauge</td>
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<td>8</td>
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<td>20</td>
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<td>22</td>
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(capacity depends on wire quality & length of run)
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:

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-2307</td>
<td>EGR Solenoid</td>
<td>(91-93 Buick, 88-93 Chevy) $28.19</td>
</tr>
<tr>
<td>2-2109</td>
<td>Bowl Vent Solenoid</td>
<td>(78-86 Ford 2bbl) $47.89 (Ford CX-239)</td>
</tr>
<tr>
<td>2-778</td>
<td>Air Control Valve Bypass</td>
<td>(Ford 80-84) $34.89</td>
</tr>
</tbody>
</table>

These all have separate inlet/outlet that looked usable 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 back the spring and turned the tip of the IAC till 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’s tip in this manner.

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

**Ignition Triggering**

Usually, 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.

First, try the suggestions on the MegaSquirt tach signal interfacing page.

Next, check the archives for early messages to see some of the various solutions.

If you are running a VR 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.

Here is how to wire it up. The four HEI module terminals are labelled W,G,B, and C. "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 0.001 uf).

This trick works for pretty much any VR ignition system - it does not have to be a GM, pretty much any VR sensor will drive the HEI module. And 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 of 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.

Now, with that said, almost all of the people here experiencing tach problems have worked them out by experimentation with different components or alternative trigger methods. Does not seem to be the most direct method, but with *so* many different setups out there, it is the only thing that can be done. Things to try *if* you experience tach noise:

1) Change the value of the Ed capacitor - from 0.001 uf to 0.1 uf. The higher value capacitors will average more noise, but may inhibit higher RPM trigger due to too much averaging.

2) 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 isn’t possible to predict in advance what value will work with which ignition.

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

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

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

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 of the VR sensor itself, will work. 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 here with experience on how to do this.

If you cannot get any of the above 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’s 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 cdı’s primary voltage is around 400V. Either use 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 and supply/return lines,
- and a fuel pressure regulator.

Note that if you start by installing MegaSquirt with a throttle body injection 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 carbureted. If you choose a TBI unit, you won’t 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’ll get a rough estimate of injector size:

$$\text{InjectorSize} = \frac{\text{HorsePower} \times \text{BSFC}}{\text{(#Cylinders \times \text{DutyCycle})}}$$

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

$$\frac{(135 \text{ HP} \times 0.55 \text{ lb/hr/HP})}{(2 \times 0.85)} = \sim 43.7 \text{ lb/hr}$$

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

*BSFC is usually between 0.42 and 0.58 at maximum power. 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].

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

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].

Injectors seem to be rated in either lbs/hour and 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 is that:

\[ 1 \text{ lb/hr} = 10.5 \text{ cc/min} \]

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

Injectors should not be used at much more than 80-85% duty cycle. Are injectors rated at this rate. 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.

When using low-impedance injectors, which are also called peak and hold injectors (P&H), you wire them in parallel. It’s the same for P&H or saturated [high-impedance]. How many injectors you can wire into each of the MegaSquirt’s banks depends on the impedance of the injectors. You can approximate the current drain using the direct current (DC) resistance [as measured using a digital multi-meter] of the injector and limit total current per driver. The datasheet for the IRFIZ34N, specifies a 21 Amp, 55 Volts rating.

There a lower bound to the pulse width, below which a low impedance injector cannot be expected to reliably function. There are two problems with running the very lower pulse widths that result from large injectors. There is 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 control 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 as 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. The 25-watt Dale resistors (www.digi-key) work good for this. Depending on injector, pick 2 ohms or so. Be sure to use one resistor in series with each injector, then you can parallel these into the two banks. Do not share two or more injectors per resistor, use a resistor per injector.

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 sensors, injectors, etc. Before you head off to the local parts store or salvage yard, check with Mike Lough and see if he has anything you need in his inventory.

On the web, Waytek has lots of 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 can’t 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.

**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 ’89 era 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."

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 doesn’t 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 doesn’t 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.

If you need a simple way to get to a barbed fitting to connect up 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 TBI’ s. For a complete listing of various fittings with part numbers, etc. try **http://www.ag.auburn.edu/users/gparmer/efi/fittings.txt**.

**IMPORTANT**: Keep the 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.

**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 embedded software which will perform a short priming pulse, then shut down the pump if the engine isn’t running after 2 seconds.

For safety reasons, an inertial safety shut off switch should be installed and used to kill power to the pump upon significant impact to vehicle. Note switch mounting orientation probably matters. ’80/90’s Ford Taurus has switch apparently mounted on driver side of the trunk wall.

If you would like a fail-safe back-up for wiring the fuel pump in case the fuel pump relay fails, you can use a Corvette oil pressure switch. Wire it as shown below (this is a schematic for a 1984 Corvette L83/350 CID). Note that the switch is NOT there to shut off the fuel pump in the case of zero oil pressure. It is there to provide an alternate to the fuel pump relay. It turns on the fuel pump when oil pressure reaches 3-4 psi. As a result, in the event of a fuel pump relay failure you may have slightly longer cranking times, but the engine should run normally otherwise.
Fast Idle Solenoid

- DB-37 Pin 30
- Main Relay
- Ignition Switch
- Battery
- Throttle Body
- Manifold Plenum

Restriction to get desired ‘fast idle’ speed
Understanding how MegaSquirt control the fuel injectors will help you to safely tune your engine for best performance. The amount of fuel injected by MegaSquirt depends on several factors:

- **sensor values**: manifold pressure, engine and intake air temperature, rpm, etc.
- **assumed values**: volumetric efficiency, injector open time, etc.
- **calculated values**: REQ_FUEL, EGO correction, etc.

To understand these, we will start with the REQ_FUEL value.

**REQ_FUEL**

REQ_FUEL is the length of time in milliseconds [ms] that MegaSquirt should “squirt” to give the stoichiometric amount of fuel (14.7 Air/Fuel ratio) at 100% VE, a manifold absolute pressure (MAP) of 100kPa, and an air temp of 70 degrees Fahrenheit for a complete stroke cycle. For a 4-stroke, this is 720 degrees of crankshaft rotation; 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 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. Same with alternate and two squirts. If you put in simultaneous and two squirts, then REQ_FUEL is divided in half - because you squirt twice, you need to inject 1/2 the fuel on each shot.

**Fuelling Equation**

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

\[
PW = \text{REQ}\_\text{FUEL} \times \text{VE} \times \text{MAP} \times E + \text{accel} + \text{Injector\_open\_time}.
\]

The "E" above is the multiplied result of all enrichments, like warm-up, afterstart, barometer and air 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 temp, there are the lookup tables the values are run through (ie. airdenfactor, etc).

To further understand the equations, take a look at the VE Tuner document. This document describes a *future* 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:

\[
PW = \text{Req	extunderscore Fuel} \times \frac{\text{MAP}}{100} \times \frac{\text{VE}}{100} \times \frac{\text{GammaE}}{100} + \text{Inj Open Time}
\]

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:

- 1 Req_Fuel: 10 ms
- 2 Batt. Correction: .1 ms/v
- 3 Inj Open Time: 1.3 ms

so: \[
PW = 10 \times 40/100 \times 74/100 \times 97/100 + 1.3 = 4.17 \text{ ms}
\] in this case.

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

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), the SCI transmit ISR may transmit the PW before it has been calculated for this iteration. In fact, the main event loop will execute over and over again 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, running on the stimulator, 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.

<table>
<thead>
<tr>
<th>RPM</th>
<th>MAP</th>
<th>VE</th>
<th>GammaE</th>
<th>PW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2200</td>
<td>40 kPa</td>
<td>74%</td>
<td>97</td>
<td>4.0 ms</td>
</tr>
</tbody>
</table>
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 MAP as your reference pressure to compute cylinder filling like MegaSquirt does, then a turbo motor is usually worse than a naturally aspirated (NA) motor, because of the added back pressure from the crummy untuned exhaust manifold and the turbine. If you are referencing 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.
Tuning Your MegaSquirt

Now that you have assembled, tested, and installed your MegaSquirt, you need to get your the 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 doesn’t need a pile of tune-up/rebuild parts.

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.

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’re 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.

A wide-band oxygen sensor makes setting up the fuel table even easier and safer, as you can read the air/fuel ratio directly.

One thing you should consider essential for a proper engineered installation is the MegaStimulator. Without this, you can not verify anything at all if the car does not start right away. With the stimulator you’ll know the MegaSquirt unit works or doesn’t work, and you’ll know how to run the software, etc. It narrows problems down to the wiring or engine. For $40 it is a diagnostic/instructional bargain.

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 it’s original fuel system. This allow you to start the engine and verify that the temp sensors, TPS sensor, the O2 sensor, fuel pump, etc., etc., work as expected. It will ease your mind when you proceed to running on MegaSquirt. If you have a running engine, it’s something you might consider.

Once you get the engine started and idling, you proceed to tuning it.

Tuning Software

There are a few software applications to help you tune 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 the substitution of non-standard temperature sensors and to