How to modify the Megasquirt MS2 V3 for sequential operation

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Background:

There is new firmware available to allow the MS2 V3 Megasquirt ECU to operate as a sequential fuel injection controller in addition to all the other functions it has. To use the MS2 this way you have to do a rather simple modification to the daughter board and add four new injector drive FETs. The only thing I didn't like about the original modification method is that it wasn't set up to use the original two injector drivers. You have to provide four FET drivers and whatever protection circuitry is required.

The original modification is posted here. This modification works very well and is simple to do.

After studying the original MS schematics I have come up with a new, simple modification that allows you to use the original injector FET drive circuitry for two of the injectors. My aim in doing this sequential modification was to tailor the MS2 for my engine with Hi-Z injectors using as much of the original circuitry as possible. I've also came up with an easy way to add the two additional FET drivers that are required onto the MS2 heatsink. Low_Z injectors requiring PWM can not be used in this modification.

This article describes how to do my modification. (Disclaimer: I haven't installed the modified unit on my car yet.)

Warning!

If you don't have good soldering skills or can't read a schematic then I STRONGLY suggest you find a friend who can do these things to modify your Megasquirt. While either modification isn't hard for someone experienced in soldering it is possible to end up doing it incorrectly and/or even damaging your Megasquirt!.

While I don't remember ever destroying a solid state device by soldering directly to the leads, any soldering to solid state devices should be done quickly using the least amount of heat as necessary to do the job. (No 200 watt American Beauties allowed!)

Naming of injector leads:

Some people on the Megasquirt forums have expressed some confusion in connecting which cylinder's injector to which FET drain. The following naming procedure has been suggested,.

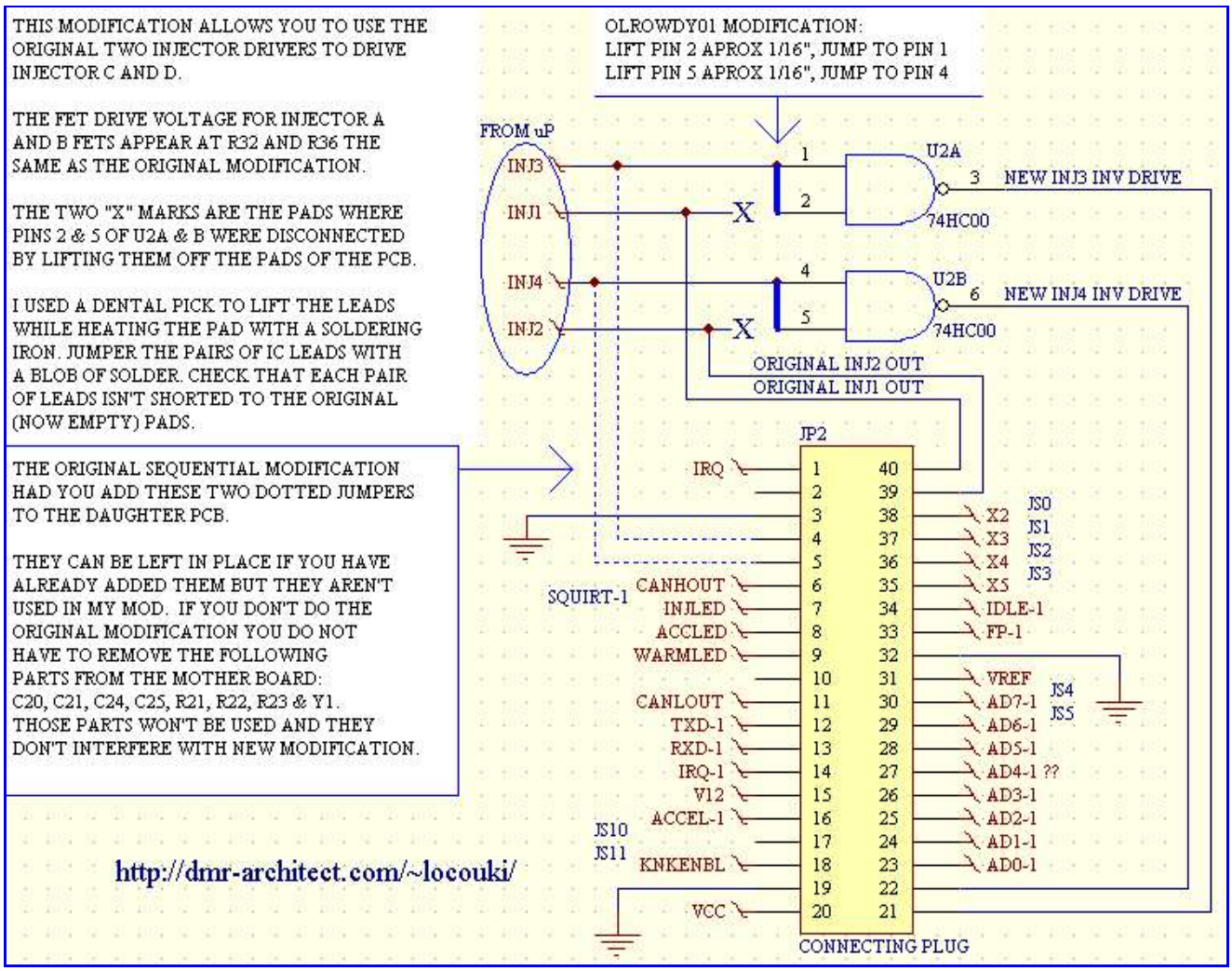
Instead of calling the injector output drive leads numbers 1 thru 4 (which some people have taken to mean that is the cylinder number to connect the wire to) the drive leads should be called "A", "B", "C" and "D". Either way you name the leads the output sequence is from 1 to 4 or A to D. You then connect the leads to the injectors in the order of the FIRING ORDER of your engine. I will use the "A" to "D" naming pattern from now on.

The GSXR-1000 engine I am using has the following firing order, 1, 2, 4, 3. So I will connect the drive leads in this order,

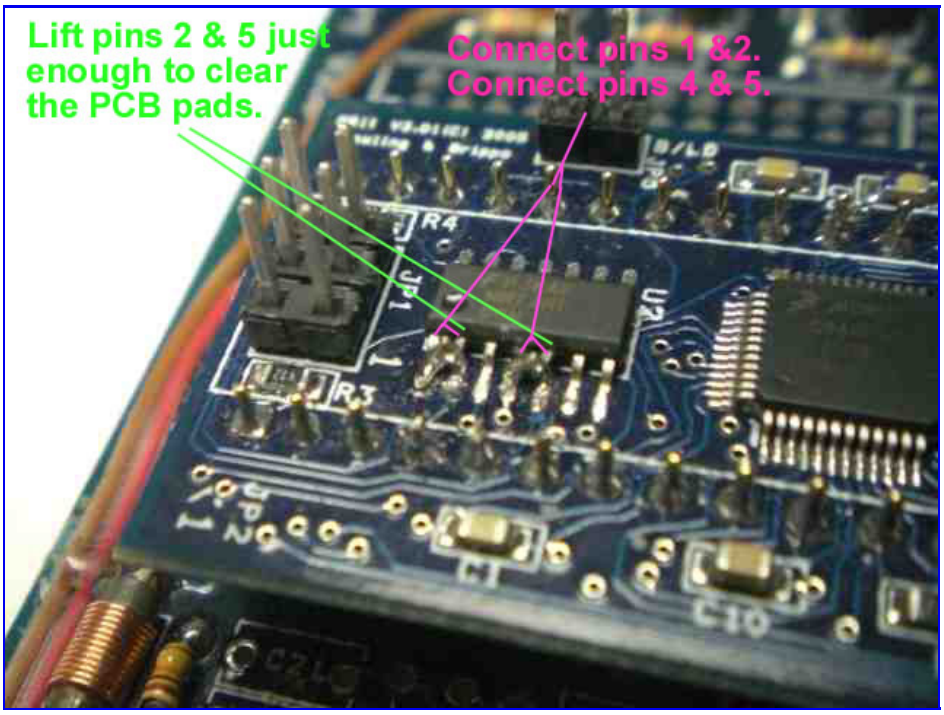
Lead designator	Injector number
A	1
B	2
C	4
D	3

To see an enlarged view of these pictures, left click on a picture or right click and select "View Image".

How to modify the MS2 V3 daughter board.



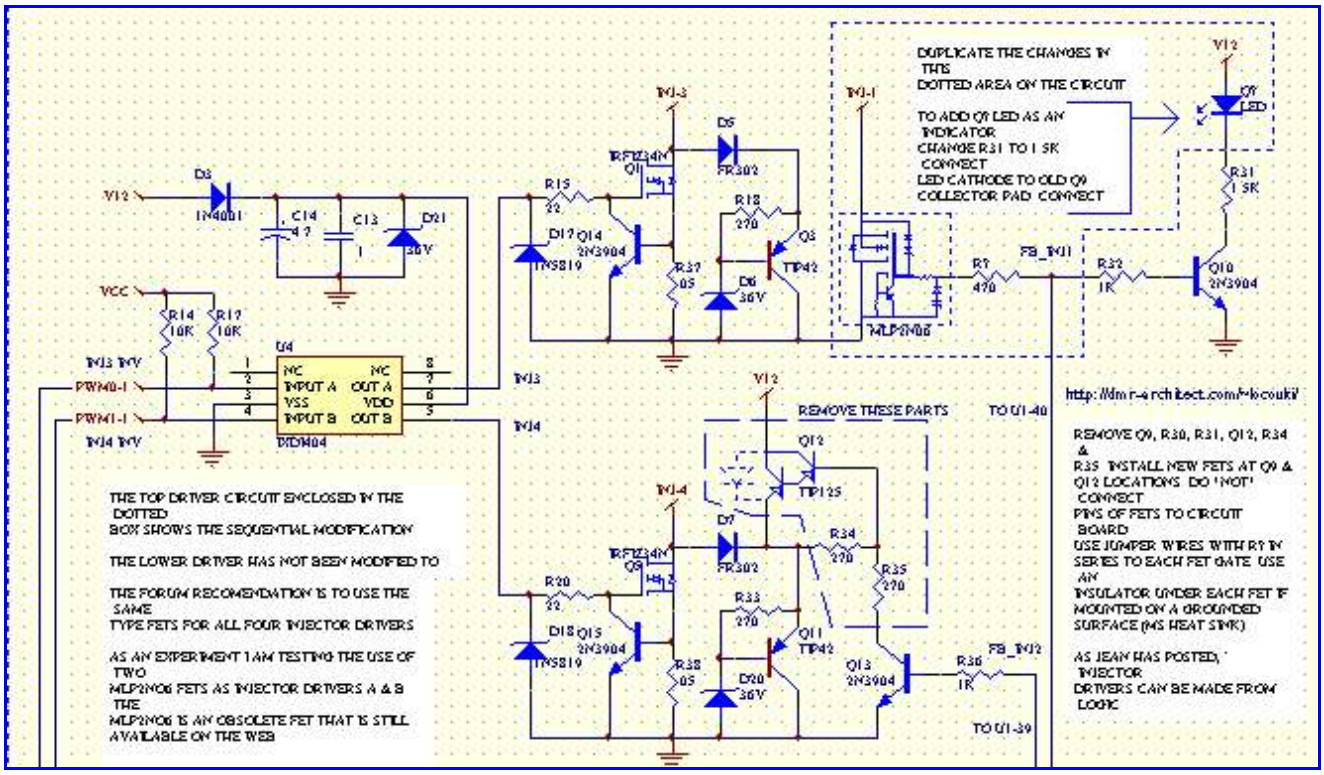
Here is a close up of the modification shown in the above schematic. Lift the pins ~1/16" above the pads, then jumper 1 to 2 and 4 to 5.



Hint:

It might help to prevent the lifted IC leads from reattaching themselves to the pads if you slip a narrow piece of paper under the disconnected lead while jumpering it to the adjacent lead. Try not to apply too much heat to the leads. Start by placing the soldering iron tip to the pin that is still attached to the PCB. This lead will absorb more heat from the iron so it needs to be heated first.

How to modify the MS2 main board.



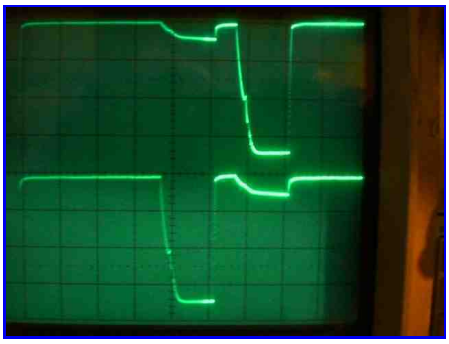
NOTE:

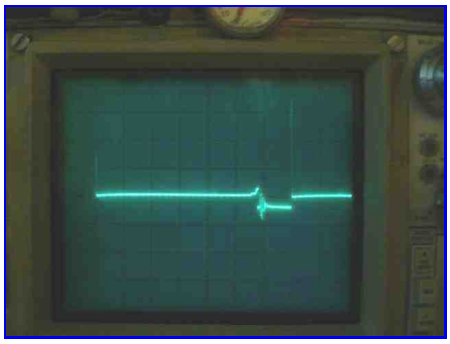
I am testing the use of two different type pairs of FET drivers. The common opinion on the Megasquirt forum where I've posted a link to this article is that all four of the FETs should be the same type though. Until I prove to myself one way or the other I would suggest that you DO use four identical injector FET drivers.

The following is the result of the first test I've done to prove this out.

Setup for test:
I connected the 13.8 Vdc supply through a .22 ohm resistor in series with each supply lead to the injectors. The scope leads were connected at the junction of the the resistor and the injector. The waveforms are showing the voltage drop (hence current) that each injector is experiencing. I had a 50,000 mfd cap connected between the bat lead and ground at the time.

Comparison of waveforms of two different type of FETs driving injectors.





Here is a picture I took off my Tek 365 dual trace scope. It shows a comparison of the fall/rise time of two different type FET injector drivers running with my mod. Two identical Hi-Z injectors are being driven. The upper trace is the stock MS2 Z34 FET. The lower trace is a MPL2N06 FET with no external spike suppression.

The vertical scale is 5 V/div. The horizontal scale is 5 ms/div. The smaller negative going voltage pulse on each trace is the supply voltage dropping slightly when the other injector is firing.

I attached a pizo-electric transducer to the injector to check the glitches on the falling waveform. The glitch corresponds to the start of the mechanical noise the injector makes.

I believe the glitch is caused when the injector movable plunger mechanically hits the stop after ~1.56 mS. Of course fuel would already be spraying for some amount of time before the glitch.

In this picture I have inverted the lower trace and added the two traces together. The resulting (single) trace will be a flat line if the individual traces are exactly the same.

The vertical scale is now 1/10 V/div. The horizontal scale is 5 ms/div. As you can see there is some variation from a flat trace. There is a sharp spike to the right of the pulse that is clearly seen if you click on the picture.

The negative going square area indicates that the Z34 is able to draw more current (227 ma) through the injector. This is probably due to the fact that the Z34 has a lower Rds. (Z34 = .04 + .05 ohms, MPL = .4 ohm.) The left side of the pulse shows the difference between the fall times of the two drivers.

Based on the similarity of the waveforms I will try running the two different types of FETs when I first install the MS2 on the car. I can always replace the Z34s with MPLs if necessary.

General information about the injector drive FETs etc:

Whatever n-channel FETs you choose to use, check that they are rated for logic level (5 volt) gate drive and are avalanche rated (i.e. have a built in zener diode that limits the back emf from the injector winding) and have a low Rds rating. IRFIZ34N FETs are avalanche rated but require more than 5 volt gate drive.

Please note that the two FETs used as Q1 & Q5 will be driven with near battery voltage on the gate. Make sure that your FETs can tolerate that voltage (Vg = more than 15 Vdc). The additional two FETs will be driven by logic level signals.

If you plan to use logic level FETs at Q1 & Q5 you could try lifting pin 6 of the IXDI404 and connect it to the 5V buss to lower the output drive voltage to ~5 volts. I haven't tested this out but the data sheets

indicate that it should work. If you try this please let me know how it works so I can post the results here (or remove this hint).

The MS2 FET protection circuitry is necessary for low-Z injectors running in pulse mode. Hi-Z injectors are run in continuous ON mode during the time they are injecting fuel and don't need that protection. If you are using Hi-Z injectors you can disconnect one lead or remove D5 & D7 to disable the on board protection circuitry.

If the additional FETs don't have an avalanche rating then you will have to provide an external circuit (see the next schematic) to limit the back emf voltage seen by the FETs.

Disconnecting D5 & D7 would allow the Z34s to fly up to the avalanche limit. I've found in my experiments that if I place a 1N4004 diode across my Hi-Z injectors to eliminate the fly back voltage the injector gets very erratic at speeds above ~10,000 RPM. So it seems that it is better to let the voltage spike fairly high as long as it doesn't cause interference.

The MLP2N06CL FETs that I am using have all the protection circuitry build right into the TO-220 header. The MLP includes avalanche, current limiting and other protection circuitry. Unfortunately they are obsolete now but are available at inflated prices ($18 each!) on the web. I don't know if there is a modern equivalent available.

When wiring the extra two FETs source and drain, use wire no smaller than AWG#26. The wires have to be able to handle ~1.5 amps peak current. I ran the FET ground leads to the nearby ground leads of R37 & R38. I plan on installing a DB-9 or DB-25 male connector to bring the injector drive (FET drain) leads out of the MS2 case. I will use two pins for -each- drive wire. I will present my connector wiring schematic when I get to that part of the project.

The gate wire can be smaller as the current is very low. I wired the two R? resistors in series with the jumper wires that connect the FET gates to FB_INJ1 & FB_INJ2. Use a piece of heat shrink tubing to cover the resistors. I use hot melt to hold the wires in place so they don't suffer vibration failure.

I also added two small indicator LEDs at the old PCB thru holes where the Q9 & Q11 gate and source leads were located. Connect the ground lead of the LEDs to the source pad on the board. The LEDs help in bench testing the Megasquirt.

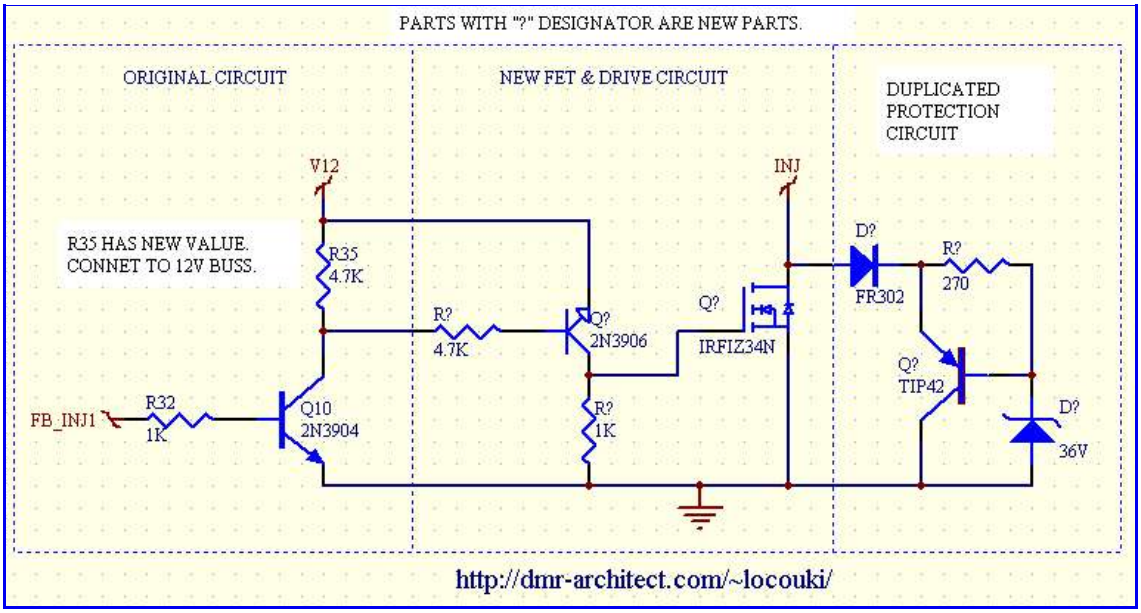
Not shown on the schematics: I connected a 10K resistor between each FET drain and the 12 V buss. This helps when bench testing the MS2 by allowing the injector drive voltage to be seen on an oscilloscope. When the voltage is 0 volts the injector will be spraying fuel into the engine. The voltage will remain at 0 volts for ~5 to 10 milliseconds.

If you want to use four IRFIZ34N FETs:

1. Modify the main PCB as per the above schematic titled "**How to modify the MS2 main board."**
2. Do not install R? the 470 ohm resistors that drive the additional FET gates.
3. You can install your additional IRFIZ34N FETs at Q2 & Q9 locations.
4. The FB_INJ1 & FB_INJ2 drive signals are 5 volts. You will have to provide a higher gate drive voltage since the IFRIZ34 FET isn't logic drive level (5V) rated. The following schematic is one way to create the higher gate drive voltage. Two of these circuits might fit on the prototype area.

Again, remember that the IRFIZ34N FETs are avalanche rated and really don't need the "DUPLICATED PROTECTION CIRCUIT". But if you want to be doubly safe you should also duplicate the flyback circuitry (similar to D3, D6, R18, & Q3) for each of the additional two FETs. The choice here is do you want the FET to provide it's own protection (which they are rated to do) or provide an external circuit to to the same job at a lower limited voltage.

Circuit to drive non-logic level FETs with a battery level signal



I've bench tested this circuit without the duplicated protection circuit and no heat sink. The FET didn't heat up while driving a Hi-Z injector running on the equivalent of a 4 cylinder, 4 cycle engine running at 18,000 RPM for 20 minutes.

If you want to try bank mode injection:

If you want to experiment with bank mode injection (with Hi-Z injectors) all you have to do is connect two of the injectors to FET drain "A" and the other two injectors to FET drain "C". Or use "B" & "D". The unused FETs will still receive gate drive but the drains wouldn't be connected to any injectors.

If the car was already tuned for sequential that tune should be fairly close to work for bank injection since each injector would still be pulsed for the same amount of time. Only the order that they will be firing is different (two at a time).

You will still have the job of selecting which injector to connect in parallel with another one and the point in the engine cycle to inject fuel.

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