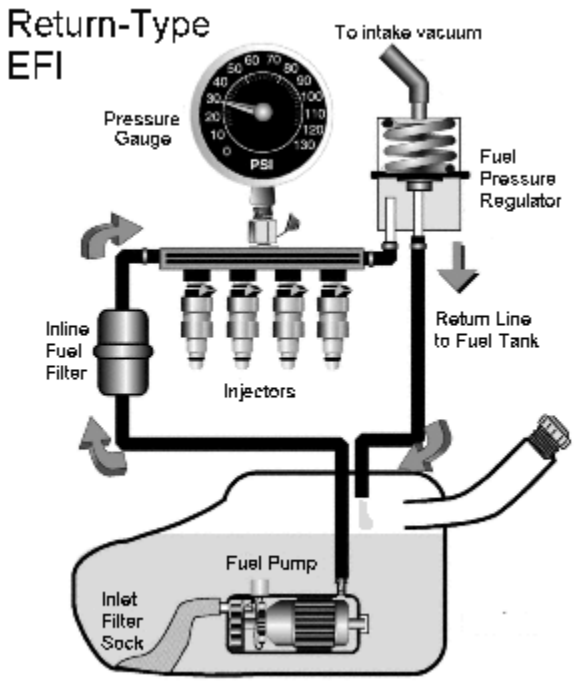
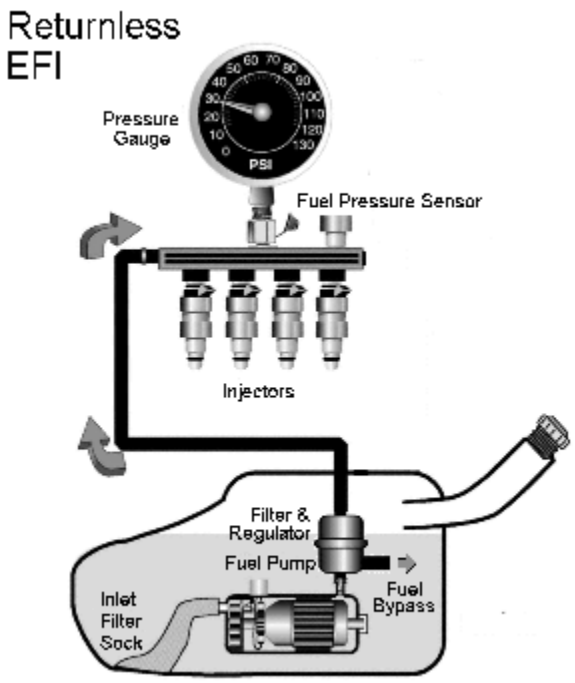
Adjustable Fuel Pressure for the AJ34 Returnless Fuel System

Theory of operation

With the older style return fuel systems increasing the fuel pressure can be as simple as replacing the in line fuel pressure regulator with a different or adjustable one. With the 4.2L AJ34, the fuel system was changed to be a single ended arrangement with a variable speed pump in the tank and an electronic pressure sensor at the fuel rail.





For the singe ended type system the Engine Control Unit (ECU) monitors the pressure reading from the sensor and controls the speed of the pump to match the amount of fuel that the injectors are using. The software tries to maintain a constant pressure at the fuel rail so if you were to increase the pressure, say because you needed a higher pressure to deliver more fuel to the crazy mods you just did, then the ECU would read the sensor and slow down the pump to hold its programmed target PSI. Because of this closed loop control, you either have to change the programming in the ECU to control the pump to a higher pressure or fake out the sensor input so that it *thinks* the higher pressure is the right one.

Reprogramming the software is not so easy but it turns out that the pressure sensor is a simple device that outputs 0-5V depending on the pressure it reads. There is a manifold pressure reference connected to the sensor and the ECU's strategy is to maintain a 55psi differential, so that the fuel on one side of the injector is 55psi *above* the air pressure in the intake runner.

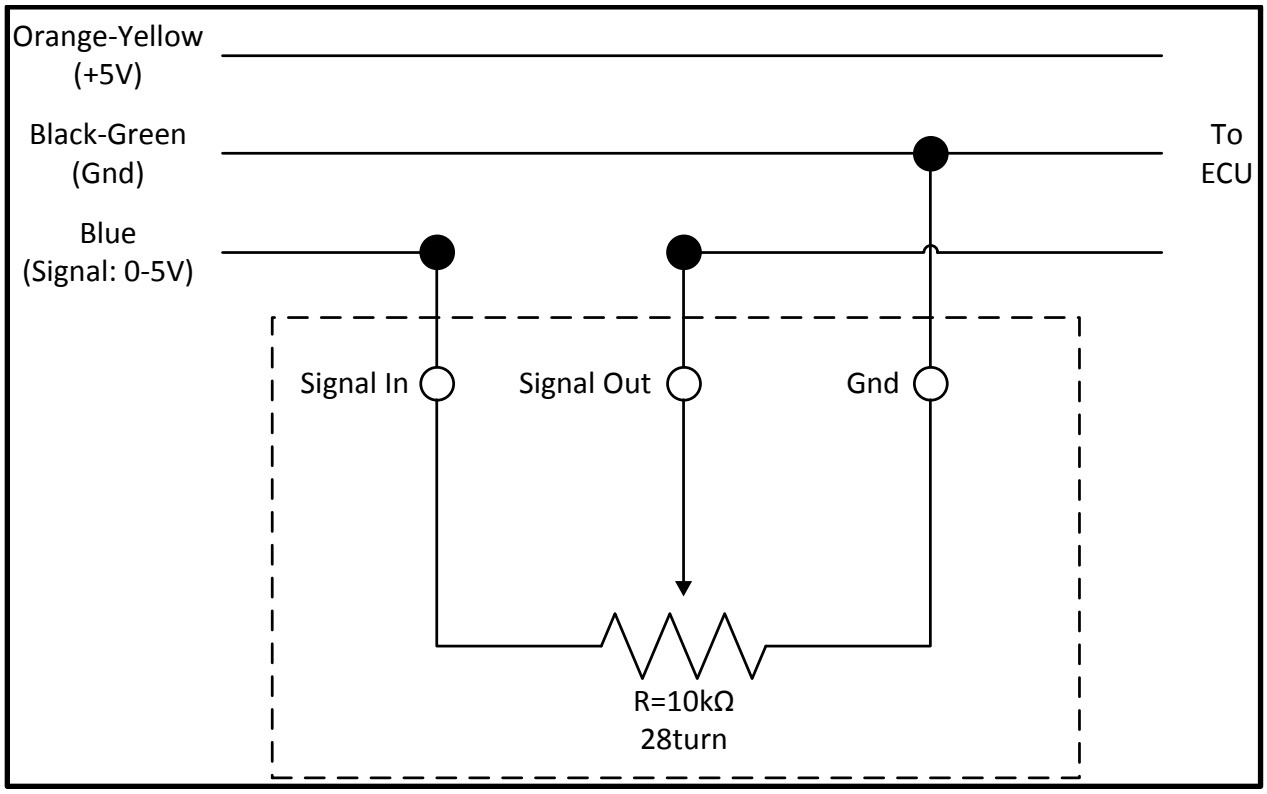
This is important because the convention is to talk about fuel pressure in absolute terms but if you connect an external pressure gauge, one that is measuring against atmospheric pressure in your garage, then you will see something unexpected. In fact, an external pressure gauge will show a pressure that varies depending on throttle position, because

the gauge is measuring against the air pressure and the regulator is adjusting against the manifold vacuum (or boost) pressure.

Making it adjustable

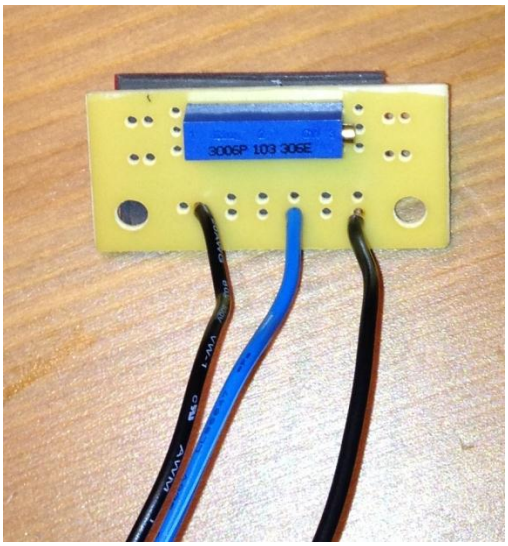
The system tries to hold a constant pressure, which means that the sensor should output a constant voltage at the stock 55psi. Other pressures, whether they be higher or lower, will have a different, but also constant voltage corresponding to them. To fool the ECU into controller to a different pressure, then we need to apply an offset to that sensor voltage that it sees, which can be done with a simple voltage divider circuit. Since we want it to be adjustable, and I really didn't know what was the correct voltage to get any given pressure, I built it with a potentiometer.

The specific resistance is not all that critical, nor is the number of turns from end to end. What you do need is a resistance sufficiently high that the current is small and enough turns that you can get fine grained resolution in the adjustment. I chose a 10k-ohm, 28 turn potentiometer and wired it up like the diagram below.

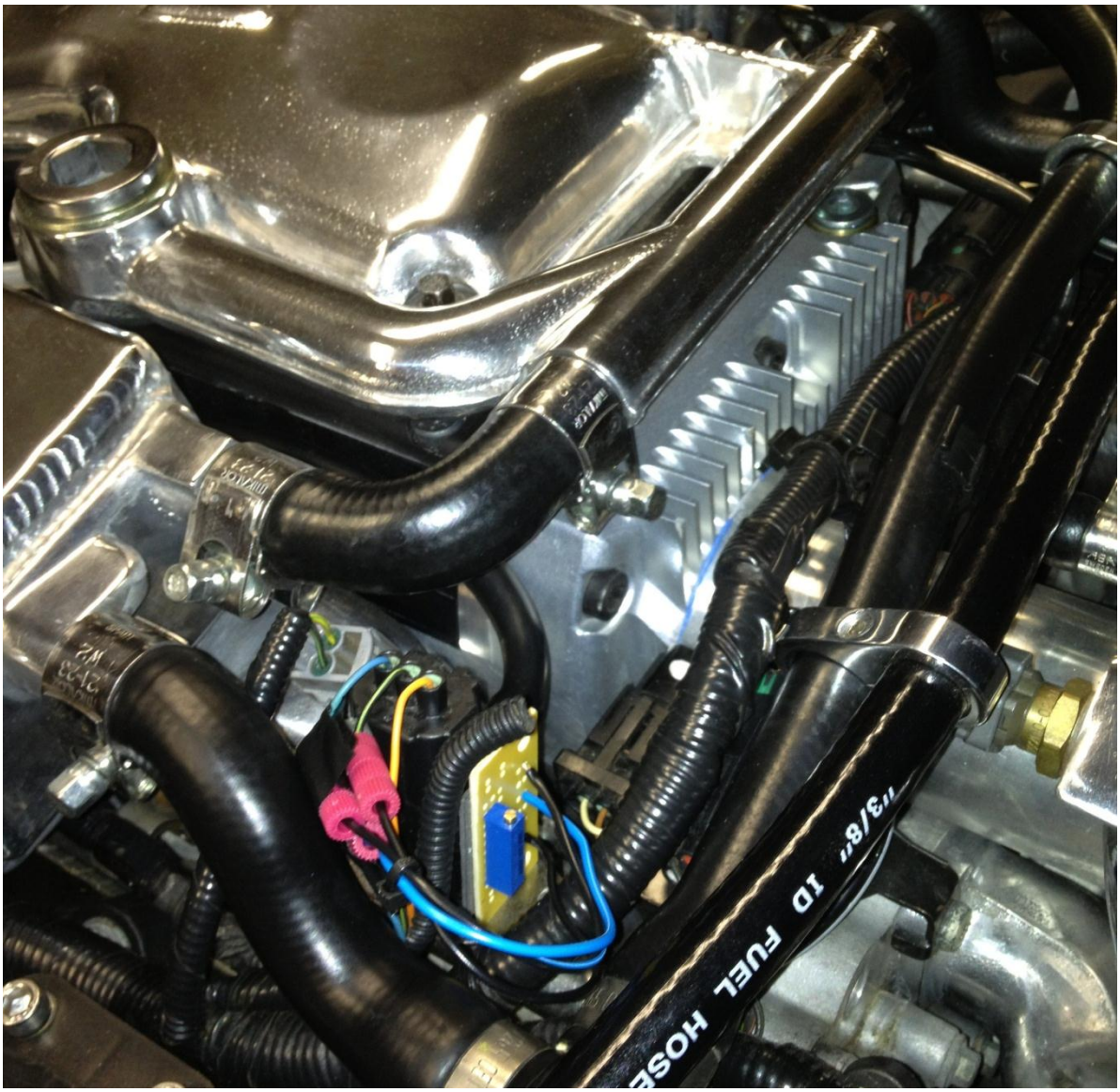


At the sensor there are 3 wires, a +5V for the sensor, a ground and a signal wire. You need to splice into the Black & Green ground and *cut* the Blue signal wire to insert the potentiometer as shown.

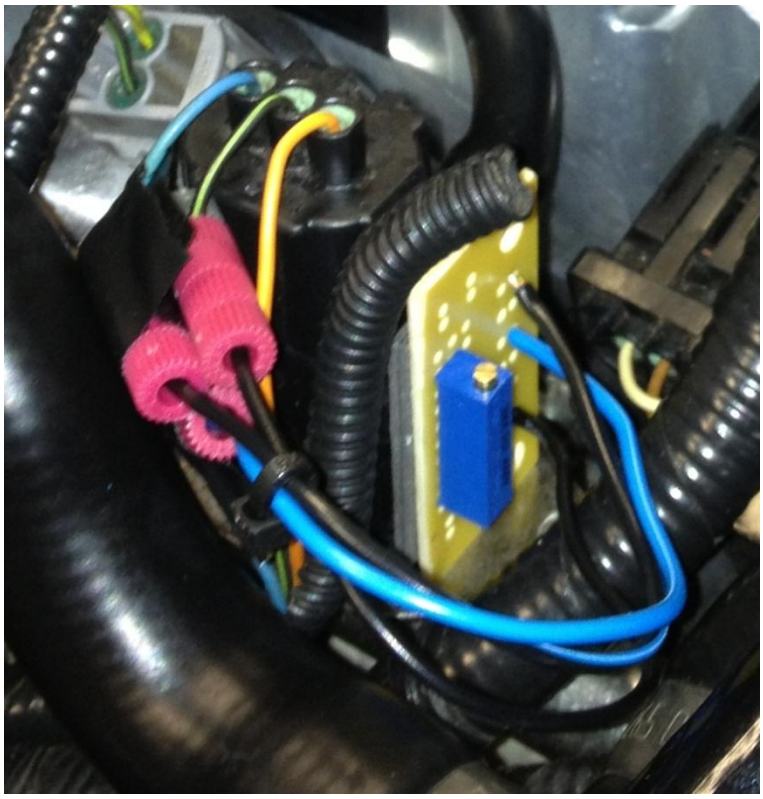
I built the prototype on a rather large (meaning easy to work with) PCB, with just the pot and 3 wires as shown below:



Installed it looks like:



Up close the prototype installation looks like this:



I used Posi-Taps to tie into the wires and taped over the protruding ends for the two on the blue wire to make sure that they won't short to anything. This is not a permanent solution, and it's certainly not weatherproof but it does allow for testing, and the pot being pointed up like that makes for easy adjustments.

When testing is complete I will make a smaller version and encase it in potting compound for weather tightness. I will also permanently solder and weather proof the connections to the vehicle harness.

Testing

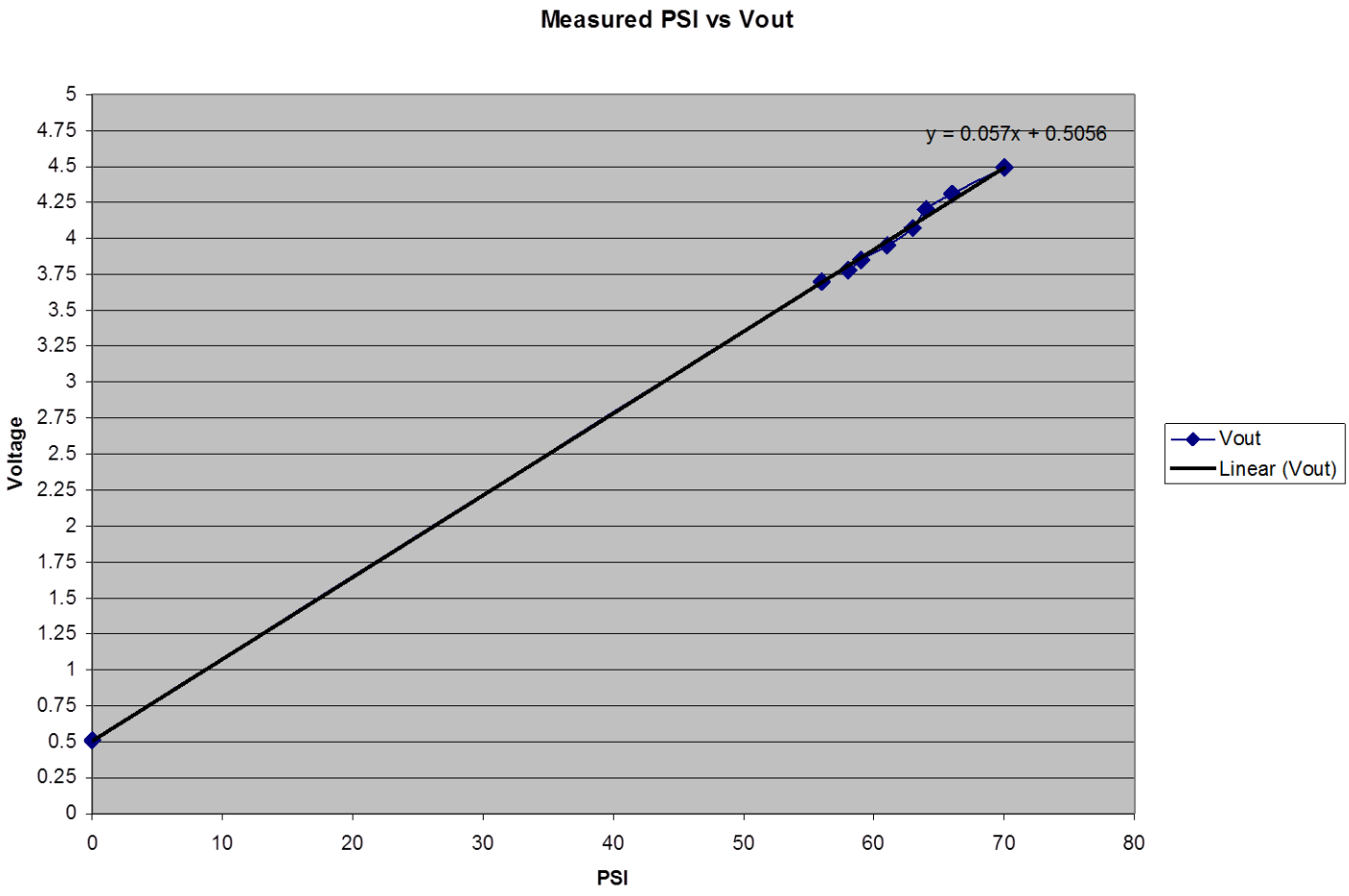
The first step was to get an understanding of how the fuel pressure related to the voltage output of the sensor. As was mentioned before, an external gauge and the pressure sensor have a different reference, one comparing to the atmosphere and the other to the manifold vacuum. There is an easy solution to this though, simply pull the hose off of the pressure regulator (don't forget to plug the vacuum leak in the manifold) and let the regulator see the same atmospheric pressure as the external gauge.

The potentiometer needs to be adjusted so that there is zero resistance between *Signal In* and *Signal Out*. This ensures that the initial reading is the completely stock, unbiased pressure.

Doing that, I was able to plot the gauge pressure vs. the voltage output of the sensor. With the key on and engine off the fuel pump isn't running so the pressure will bleed down to zero. At zero pressure the reading was about 0.5V.

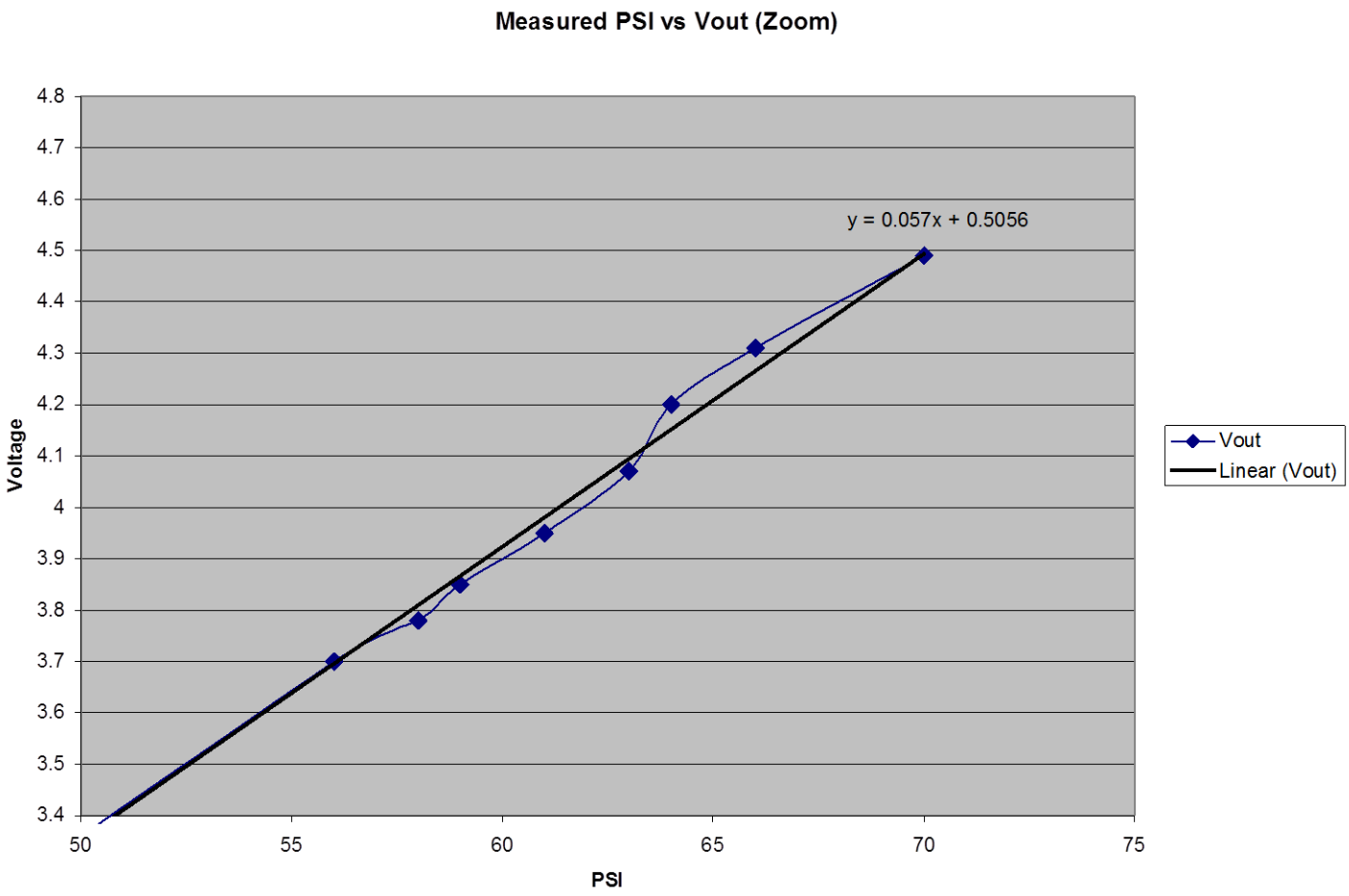
Once the car is started it will control to 55psi and after allowing a little idle time for the pressure to settle, I read the voltage coming out of the sensor. The initial reading was about 3.7V for 55psi and by adjusting the potentiometer I could read out the pressure from the external gauge and the voltage from the sensor.

Plotting the results gives this, including the zero pressure value of 0.5V.

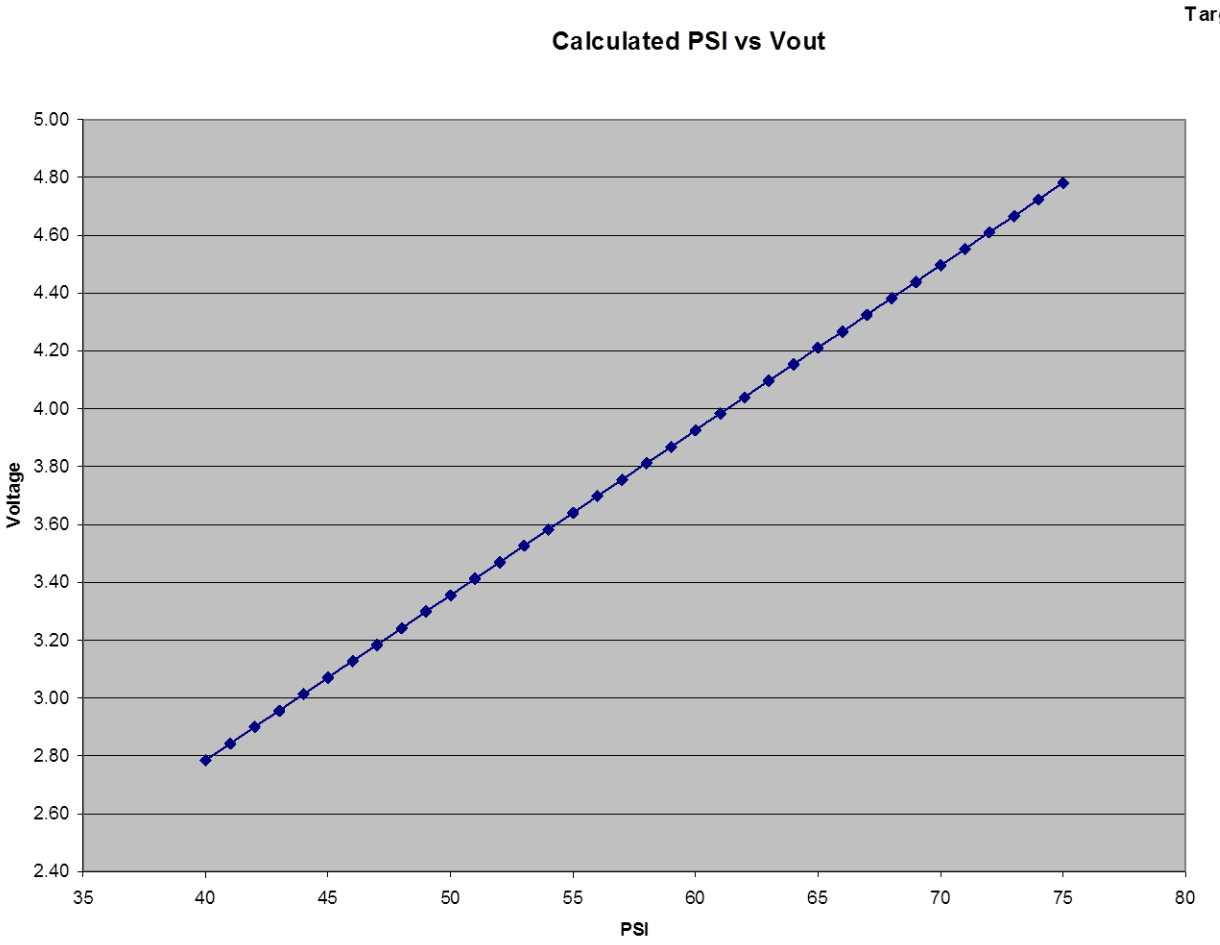


Zooming in a little closer to the pressure range we are interested in, the voltage is pretty linear with pressure. Applying a linear fit to the data we can extrapolate the relationship between fuel pressure and voltage.

Voltage = (0.057 * psi) + 0.5056



Using the linear fit equation, we can calculate the expected voltage from the sensor at the desired pressure, shown below:



Target PSI	Vout
0	0.51
40	2.79
41	2.84
42	2.90
43	2.96
44	3.01
45	3.07
46	3.13
47	3.18
48	3.24
49	3.30
50	3.36
51	3.41
52	3.47
53	3.53
54	3.58
55	3.64
56	3.70
57	3.75
58	3.81
59	3.87
60	3.93
61	3.98
62	4.04
63	4.10
64	4.15
65	4.21
66	4.27
67	4.32
68	4.38
69	4.44
70	4.50
71	4.55
72	4.61
73	4.67
74	4.72
75	4.78

Example: To get 65psi pressure, adjust the potentiometer until the *Signal In* reads 4.21V.

You can't actually use this circuit to get a *lower* pressure but the calculated values are included for completeness. In principle you could do it by connecting the potentiometer between the signal and +5V instead of ground, but I can't think of any reason to lower the fuel pressure from stock.

This pressure is held as a differential between the reference and the fuel rail, so whatever the manifold pressure is, the sensor *Voltage* for a 65psi *differential* will be the same, even if the external gauge with an atmospheric reference reads something very different.

I was not able to get much more than 70psi, so this may be approaching the limits of the stock pump. There is a regulator as part of the pump assembly, although I do not know what its pressure setting is.

Another note is that the OBD pressure reading will still be 55psi, since the ECU doesn't know any better. The reading is still just as precise as before but is offset by the amount set on the potentiometer.

Conclusion

After running the 65psi pressure setting for a few hundred miles, I found that the OBD pressure reading can hold within 2-3psi even at WOT. This suggests that the stock pump is capable to supply the needed flow at 65psi but may be approaching its limits.

As with any modification, care and close monitoring is required.