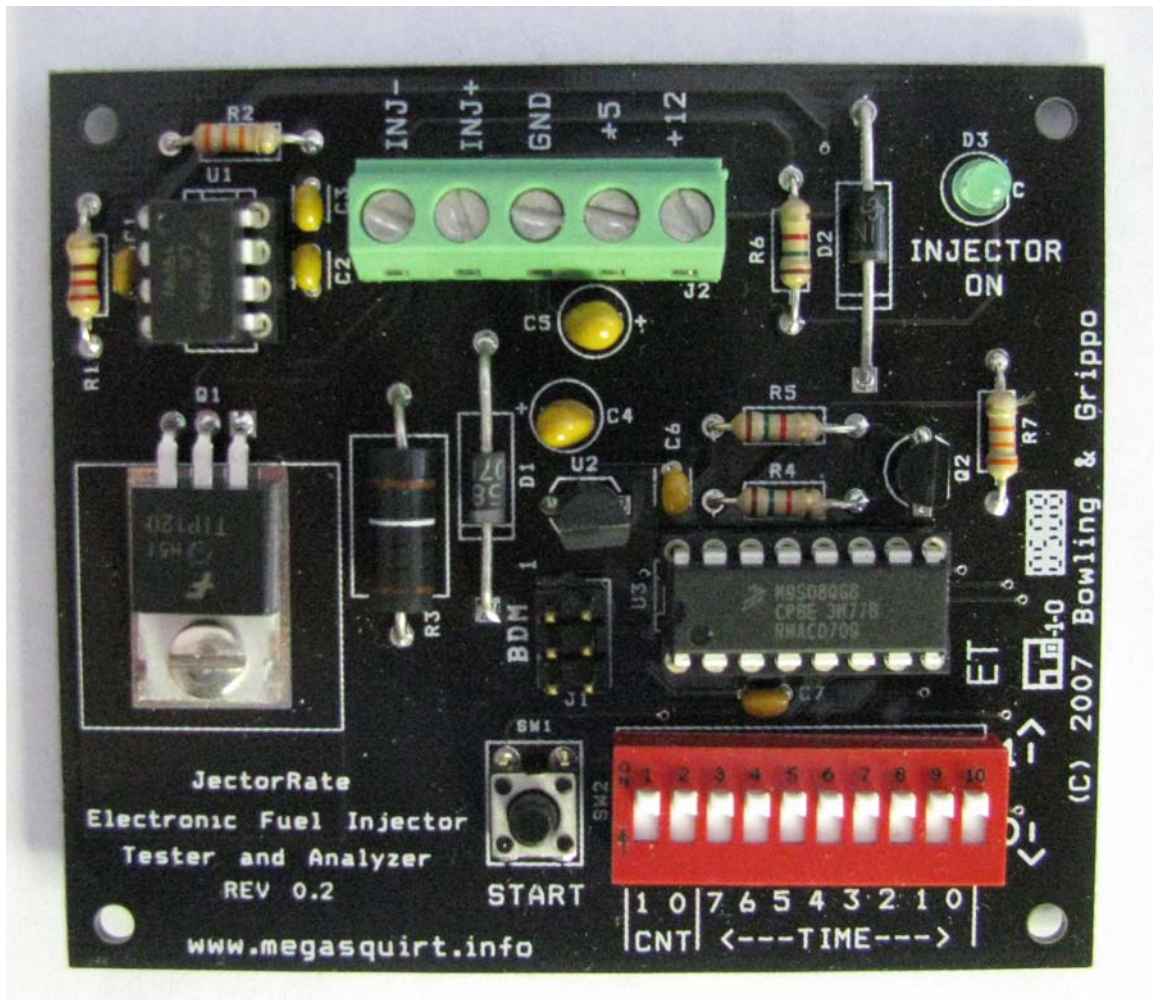


JectorRate
Electronic Fuel Injector Tester
By Bowling and Grippo

Rev. 1.01

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Introduction

This document describes the **JectorRate** Electronic Fuel Injector device tester and quantifier system.

This system is designed to provide a method for one to test electronic fuel injectors for operation, spray quality, and to allow for the cleaning of injectors off of the vehicle. Additionally, software has been developed which allows one to determine fuel rate delivered from the injector for quantitative analysis and comparative studies. Everybody needs one of these – build it now!

The **JectorRate** system is comprised of the following systems:

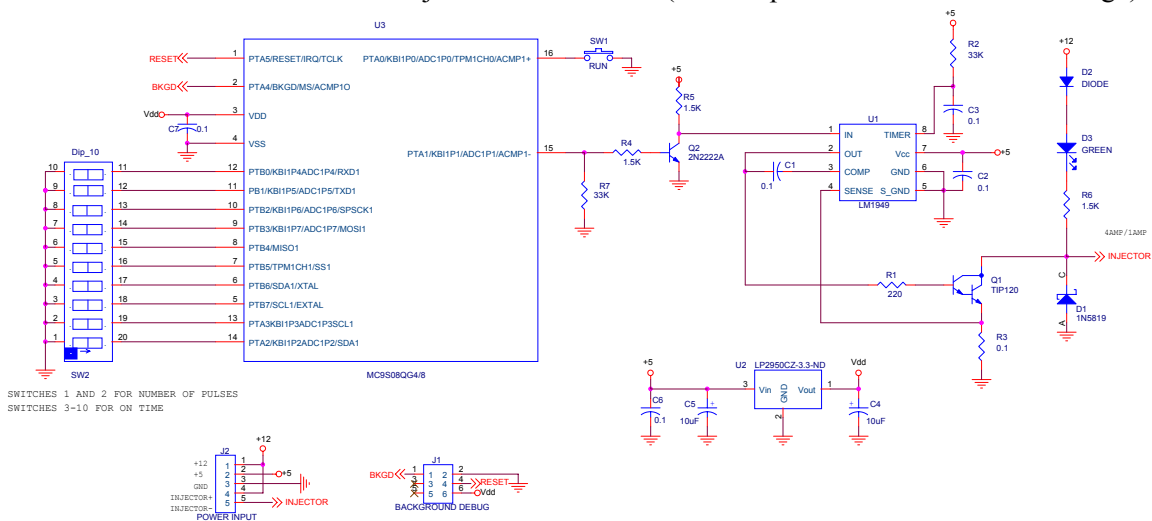
- **Injector Driver Board:** This electronic circuit generates user-defined timing pulses to the injector. Based on the ubiquitous Freescale 9S08QG family Micro-controller, this circuit allows the user to generate pulse widths from 0.1 milliseconds to 25.4 milliseconds, in 0.1 ms increments. The user can also set the number of pulses (1, 50, 100, or 250 pulses) applied to the injector. The circuit will control saturated and peak/hold injectors outputting peak and hold current of 4 amps open and 1 amp hold. These values should suffice for most popular fuel injectors.

- Test Stand/Test Fuel Delivery: Mineral Spirits, Varsol, or similar test/cleaning fluid (not water) is supplied under a controlled and measured pressure to the injector under test. The fluid that has been metered through the itty-bitty tiny injector opening (driven by the Injector Driver Board) is measured using a graduated cylinder – this is used to determine fuel delivery rate. Later on we will show you how to construct the fuel pressure source from either a automotive fuel pump and regulator, or a portable (manually-pumped) metal plant sprayer.
- Analysis Software: A Windows-based (appropriate Bill Gates bashing text here) PC application has been developed to determine the injector flow rate in pounds per hour, based on test stand measured volume vs. pulse width. The user can enter up to five measurement pairs, which are used to determine the flow rate. Additionally, the user can perform the test at one fluid pressure and extrapolate (now there's a term!) the flow at other pressures. Now, where else can you extrapolate your injector flow for such a small amount of money?

If there are questions or comments (no opinions, criticisms or pontifications), feel free to contact Bruce Bowling at bbowling@earthlink.net, or Al Grippo at agrippol@verizon.net.

Circuit Description

Here is the schematic of the Fuel Injector Driver circuit (see the .pdf file for a full-screen image):



This circuit is based on a Freescale 9S08QG4/8 (the 4k or 8k device will work with supplied software) micro-controller which generates pulses to the injector drive controller circuit. The injector drive circuit composed of an injector drive controller IC and a Darlington transistor is used to drive the fuel injector under test. Pulse width (i.e. open time of the injector) is set by 8-positions of a 10-position DIP-switch (SW2), which can generate any injector on pulse width from 0.1 ms to 25.5 ms, in 0.1 ms increments. Injector off time is preset at 10 ms and can not be changed. The actual DIP switch setting conversion is determined by the PC software application, or the table contained in this document The number of injector pulses is set by a 2-positions of the 10-position DIP-switch (SW2). The values for these settings are shown in the following table:

Number of injector pulses	DIP Switch 1 (Bit 1)	DIP Switch 2 (BIT 0)
1 Pulse	0	0
50 Pulses	1	1
100 Pulses	0	0
250 Pulses	1	1

The test process starts when the “**START**” pushbutton, (SW1) is depressed and then released. Not until the “**START**” pushbutton is released will the test sequence start. The microprocessor reads in the value of the DIP switch and proceeds with the test by opening the injector for the specified milliseconds time, and then closing the injector for a fixed time length of 10 milliseconds (this time is non-adjustable). The process is repeated *N* times, with *N* being specified by the user (1, 50, 100, or 250 – see the table above). Drive to the injector is switched by the microcontroller. Injector current is controlled by the injector drive controller, U1 and amplified by Darlington transistor, Q1.

The PC analysis program (described later) allows one to determine the pulse width DIP switch setting easily – one merely enters the desired pulse width (from 0.1 to 25.5 milliseconds) and the program will indicate the required binary setting for 8 positions of the 10-position DIP switch, SW2. More later.

If you don’t want to use the analysis aspects of the PC analysis program, the following is a table showing the setting for the right hand eight switch setting used to obtain injector on pulses from 0.1 millisecond to 25.5 milliseconds. A 0 on the DIP switch indicates the switch position switched toward the bottom of the PC board and a 1 on the DIP switch indicates the switch position switched toward the top of the PC board.

DIP SWITCH BIT 7-0 76543210	TIME in ms.	DIP SWITCH BIT 7-0 76543210	TIME in ms.	DIP SWITCH BIT 7-0 76543210	TIME in ms.	DIP SWITCH BIT 7-0 76543210	TIME in ms.
00000000	0.0	01000000	6.4	10000000	12.8	11000000	19.2
00000001	0.1	01000001	6.5	10000001	12.9	11000001	19.3
00000010	0.2	01000010	6.6	10000010	13.0	11000010	19.4
00000011	0.3	01000011	6.7	10000011	13.1	11000011	19.5
00000100	0.4	01000100	6.8	10000100	13.2	11000100	19.6
00000101	0.5	01000101	6.9	10000101	13.3	11000101	19.7
00000110	0.6	01000110	7.0	10000110	13.4	11000110	19.8
00000111	0.7	01000111	7.1	10000111	13.5	11000111	19.9
00001000	0.8	01001000	7.2	10001000	13.6	11001000	20.0
00001001	0.9	01001001	7.3	10001001	13.7	11001001	20.1
00001010	1.0	01001010	7.4	10001010	13.8	11001010	20.2
00001011	1.1	01001011	7.5	10001011	13.9	11001011	20.3
00001100	1.2	01001100	7.6	10001100	14.0	11001100	20.4
00001101	1.3	01001101	7.7	10001101	14.1	11001101	20.5
00001110	1.4	01001110	7.8	10001110	14.2	11001110	20.6
00001111	1.5	01001111	7.9	10001111	14.3	11001111	20.7
00010000	1.6	01010000	8.0	10010000	14.4	11010000	20.8
00010001	1.7	01010001	8.1	10010001	14.5	11010001	20.9
00010010	1.8	01010010	8.2	10010010	14.6	11010010	21.0
00010011	1.9	01010011	8.3	10010011	14.7	11010011	21.1
00010100	2.0	01010100	8.4	10010100	14.8	11010100	21.2
00010101	2.1	01010101	8.5	10010101	14.9	11010101	21.3
00010110	2.2	01010110	8.6	10010110	15.0	11010110	21.4
00010111	2.3	01010111	8.7	10010111	15.1	11010111	21.5
00011000	2.4	01011000	8.8	10011000	15.2	11011000	21.6
00011001	2.5	01011001	8.9	10011001	15.3	11011001	21.7
00011010	2.6	01011010	9.0	10011010	15.4	11011010	21.8
00011011	2.7	01011011	9.1	10011011	15.5	11011011	21.9
00011100	2.8	01011100	9.2	10011100	15.6	11011100	22.0
00011101	2.9	01011101	9.3	10011101	15.7	11011101	22.1
00011110	3.0	01011110	9.4	10011110	15.8	11011110	22.2
00011111	3.1	01011111	9.5	10011111	15.9	11011111	22.3
00100000	3.2	01100000	9.6	10100000	16.0	11100000	22.4
00100001	3.3	01100001	9.7	10100001	16.1	11100001	22.5
00100010	3.4	01100010	9.8	10100010	16.2	11100010	22.6
00100011	3.5	01100011	9.9	10100011	16.3	11100011	22.7
00100100	3.6	01100100	10.0	10100100	16.4	11100100	22.8
00100101	3.7	01100101	10.1	10100101	16.5	11100101	22.9
00100110	3.8	01100110	10.2	10100110	16.6	11100110	23.0
00100111	3.9	01100111	10.3	10100111	16.7	11100111	23.1
00101000	4.0	01101000	10.4	10101000	16.8	11101000	23.2
00101001	4.1	01101001	10.5	10101001	16.9	11101001	23.3
00101010	4.2	01101010	10.6	10101010	17.0	11101010	23.4
00101011	4.3	01101011	10.7	10101011	17.1	11101011	23.5
00101100	4.4	01101100	10.8	10101100	17.2	11101100	23.6
00101101	4.5	01101101	10.9	10101101	17.3	11101101	23.7
00101110	4.6	01101110	11.0	10101110	17.4	11101110	23.8
00101111	4.7	01101111	11.1	10101111	17.5	11101111	23.9
00110000	4.8	01110000	11.2	10110000	17.6	11110000	24.0
00110001	4.9	01110001	11.3	10110001	17.7	11110001	24.1
00110010	5.0	01110010	11.4	10110010	17.8	11110010	24.2
00110011	5.1	01110011	11.5	10110011	17.9	11110011	24.3
00110100	5.2	01110100	11.6	10110100	18.0	11110100	24.4
00110101	5.3	01110101	11.7	10110101	18.1	11110101	24.5
00110110	5.4	01110110	11.8	10110110	18.2	11110110	24.6
00110111	5.5	01110111	11.9	10110111	18.3	11110111	24.7
00111000	5.6	01111000	12.0	10111000	18.4	11111000	24.8
00111001	5.7	01111001	12.1	10111001	18.5	11111001	24.9
00111010	5.8	01111010	12.2	10111010	18.6	11111010	25.0
00111011	5.9	01111011	12.3	10111011	18.7	11111011	25.1
00111100	6.0	01111100	12.4	10111100	18.8	11111100	25.2
00111101	6.1	01111101	12.5	10111101	18.9	11111101	25.3
00111110	6.2	01111110	12.6	10111110	19.0	11111110	25.4
00111111	6.3	01111111	12.7	10111111	19.1	11111111	25.5

Electronic fuel injectors of the peak and hold variety usually desire an opening current roughly four times greater than that required to keep the injector open. The injector drive controller, U1, determines the value for the open and hold currents. The microcontroller proceeds to drive the injector drive controller / Darlington transistor circuit, producing the desired open current through the injector. After approximately 3.3 milliseconds (if the test pulse width is set by the DIP switch equal or greater than 3.3ms.), the injector drive controller circuit will lower the Darlington transistor's average drive to a value which generates the target holding current. The 3.3 millisecond number works well and the hardware internal to U1 supports that time.

Also, why did we not use a MOSFET or IGBT to drive the injector instead of a Darlington? Because a Darlington transistor is easier to control and they are available everywhere, including Radio Shack.

For you mathematically minded individuals possessing large frontal lobes, the injector's average drive current is given by:

$$\begin{aligned} \text{Injector Peak Drive current} &= 0.386 \text{ volts} / R3 \\ &\text{or} \\ 3.86 \text{ amps (we call it 4 amps)} &= 0.386 \text{ volts} / 0.1 \text{ ohms} \end{aligned}$$

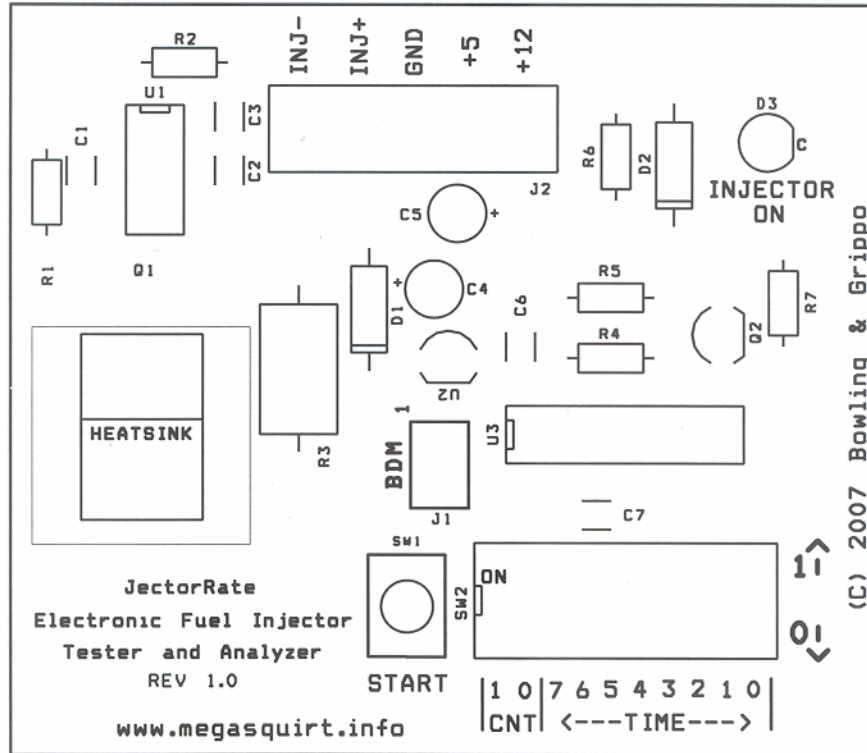
$$\begin{aligned} \text{Injector hold current} &= 0.94 \text{ volts} / R3 \\ &\text{or} \\ .94 \text{ amps (we call it 1 amp)} &= 0.94 \text{ volts} / 0.1 \text{ ohms} \end{aligned}$$

If you desire 2 amps peak current and 0.5 amps hold current, you can replace R3 with a 0.2 ohm, 2 watt resistor.

The five volts portion of the circuit requires less than 60mA. The injector power supply required is 12 volts with at least 6 amps max capacity. A happy, low-cost power-supply solution is to use a switching power supply salvaged from an old PC. One can usually obtain an old PC for next to nothing, often free. [*Tip: steal it from your parents or grandma's computer – they probably have become sick of the Internet by now and never use the thing – they will never know*]. The wires are color-coded – the black wire is ground, the red wire is +5 volts, and the yellow wire is +12 volts. The +12 volt source in a PC supply is well protected, because it has to drive electromechanical items such as hard and floppy drives. If one does use a PC supply, it is advisable to solder a ¼ watt or larger wattage resistor (680 – 1K ohms) between the +5 volts and ground (red and black wire), and another one between the +12 volt yellow wire and ground. These “ballast” resistors allow the internal regulator feedback circuit in the power supply to operate correctly. Otherwise the power supply could potentially act ‘flaky’ and you may be tempted to blame it on the electronics, which is wrong.

Circuit Board Assembly Instructions

The silkscreen view of the printed circuit board is shown here:



The path of least resistance is to purchase an assembled and tested PC board, however assembly of this board is quite easy. All that is required is a fine-tipped soldering iron (25 watts or so) and rosin-core solder – the stuff for soldering electronic components (Radio Shack solder is o.k), not the variety you use on water pipes or sheet metal. Do not use acid based solder. Be sure to keep the soldering iron tip clean and well-tinned – if you do not know what I am talking about then find someone who does and let them show you the correct method of soldering electronic components. This makes a good first kit for learning electronics, but practice soldering/destroying on something else until you get the hang of it – don't screw up this board with globs of solder.

The parts list for the JectorRate PC board follows:

Designators	Qty	Description	Manufacturer	Part Number
C1,C2,C3,C6,C7	5	0.1uF Capacitor	Digi-Key	399-4331-ND or 399-4329-ND
C4,C5	2	10uF Cap@16WV	Digi-Key	399-3563-ND
D1	1	1N5819	Digi-Key	1N5819-E3/54GICT-ND
D2	1	1N4004	Digi-Key	1N4004-E3/73GI-ND
D3	1	Green LED	Digi-Key	160-1712-ND
J1	0/1	2x3 Pin Header (BDM) See Text	Digi-Key	A26569-ND
J2	1	5-Pin Screw Terminal	Digi-Key	277-1239-ND
Q1	1	TIP120	Digi-Key	TIP120-ND
Q2	1	2N2222A	Digi-Key	P2N2222AGOS-ND
R1	1	220 Ohm Resistor	Digi-Key	220QBK-ND
R2,R7	2	33K Ohm Resistor	Digi-Key	33KQBK-ND
R3	1	0.1 Ohm 2 Watt Resistor	Digi-Key	WHCR10FECT-ND
R4,R5,R6	3	1.5 K Ohm Resistor	Digi-Key	1.5KQBK-ND
SW1-SW6	1	Momentary Push Button Switch	Digi-Key	CKN9071-ND
SW2	1	10 Position DIP Switch	Digi-Key	GH7195-ND
U1	1	LM1949 8-Pin DIP	Digi-Key	LM1949N-ND
U2	1	3.3 Volt TO-92 Voltage Regulator	Digi-Key	LP2950CZ-3.3-ND
U3	1	9S08QG8 16-Pin DIP Microcontroller	Digi-Key	MC9S08QG8CPBE-ND
No Designator	1	8-Pin socket for U1	Digi-Key	ED3308-ND
No Designator	1	16-Pin socket for U3	Digi-Key	ED3316-ND
No Designator	1	3/8" 6-32 screw for U1	Any	N/A
No Designator	1	6-32 nut for U1	Any	N/A
No Designator	1	JectorRate bare PC Board	Any	N/A

For JectorRate PC Board Rev. 0.2 and 1.0

Here is a step-by-step assembly guide for the JectorRate PC board. It is a good idea to check off each step, just in case you need a break – you can resume where you have left off, and you will know where that point was.

After you have inserted the components and before soldering, cut the leads, protruding through the bottom of the PC board to approximately 1/8". It is not necessary to cut the leads of J1, J2, SW1, SW2, and the 8 and 16-pin sockets for U1 and U3 as they are short to begin with.

1. Hold the PC circuit board, and familiarize yourself where the components mount – hold it such that the text “www.megasquirt.info” is on the bottom edge. This position matches the silkscreen drawing above.
2. Insert resistor R1 (220 Ohms red-red-brown). It can be installed in either direction. Now solder the resistor.
3. Insert resistor R2 (33K Ohms orange-orange-orange). It can be installed in either direction. Now solder the resistor.
4. Insert resistor R3 (red 0.1 Ohms black-black-brown). It can be installed in either direction. Now solder the resistor.
5. Insert resistor R4 (1.5K Ohms brown-green-red). It can be installed in either direction. Now solder the resistor.
6. Insert resistor R5 (1.5K Ohms brown-green- red). It can be installed in either direction. Now solder the resistor.
7. Insert resistor R6 (1.5K Ohms brown-green- red). It can be installed in either direction. Now solder the resistor.
8. Insert resistor R7 (33K Ohms orange-orange-orange). It can be installed in either direction. Now solder the resistor.
9. Insert capacitor C1 (0.1uF). It can be installed in either direction. Now solder the capacitor. Now solder the capacitor.
10. Insert capacitor C2 (0.1uF). It can be installed in either direction. Now solder the capacitor. Now solder the capacitor.
11. Insert capacitor C3 (0.1uF). It can be installed in either direction. Now solder the capacitor.
12. Insert capacitor C4 (10uF). It must be installed in the correct orientation. On the PC board there is a + sign to the left of the silkscreen for this component. Depending on the manufacturer, the + or – side of the capacitor is marked. If a + sign is along the side of the capacitor, install it such the + on the capacitor is on the same side as the + on the silkscreen. If there is a stripe or – sign on the capacitor, align it with the component designator C4 on the PC board. Now solder the capacitor.
13. Insert capacitor C5 (10uF), It must be installed in the correct orientation. On the PC board there is a + sign to the right of the silkscreen for this component. Depending on the manufacturer,

the + or – side of the capacitor is marked. If a + sign is along the side of the capacitor, install it such the + on the capacitor is on the same side as the + on the silkscreen. If there is a stripe or – sign on the capacitor, align it with the component designator C5 on the PC board. Now solder the capacitor.

14. Insert capacitor C6 (0.1uF). It can be installed in either direction. Now solder the capacitor.

15. Insert capacitor C7 (0.1uF). It can be installed in either direction. Now solder the capacitor.

16. Insert diode D1 (1N5619). There is a band marked on one end of D1. Make sure the band aligns with the line on the silkscreen for the device. Now solder the diode.

17. Insert diode D2, (1N4004). There is a band marked on one end of D2. Make sure the band aligns with the line on the silkscreen for the device. Now solder the diode.

18. Insert LED, D2. The flat edge on the LED must align with the silkscreen. This LED must be installed in the proper orientation or it will not illuminate. Solder the LED, but be sure not to use too much heat, just enough to flow the solder.

19. If you are not assembling a Rev. 0.2 PC board, proceed to step 19A. If you are assembling a Rev. 0.2 PC board, there was a mistake in the orientation of U2 relative to its silkscreen outline on the PC board. For Rev. 0.2 PC boards only, U2 (LP2950) is inserted such that the flat side of the LP2950 is aligned with the arced side of the silkscreen. i.e. inserted backwards from the silkscreen The flat side of U2 should be aligned along the bottom edge of the PC board. Now solder U2. Proceed to step 20.

19A. Insert voltage regulator U2 (LP2950) into the PC board. Make sure the flat side of it aligns with the PC board's silkscreen. Now solder U2.

20. Insert transistor Q2 (2N2222) into the PC board. Make sure the flat side of it aligns with the PC board's silkscreen. Now solder Q2.

21. Insert transistor Q1 (TIP120). There is a metal tab on the PC side of this part. The tab must go against the PC board when the part is installed . This part must be secured to the PC board with a 1/4" 4-40 screw and nut to transfer heat from it to the PC board.

22. Insert the 8-pin socket for U1 into the PC board – make sure the pins go thru each hole. You can mount the socket in either 0 or 180 degrees, it does not matter. Sockets have a pin 1 indicator on one end. Align the pin 1 indicator with the square pad on the PC board. With the socket snug against the circuit board, flip the board over and solder all 8 pins to their respective holes. A little solder is all that is required.

23. Insert the 16-pin socket for U3 into the PC board – make sure the pins go thru each hole. You can mount the socket in either 0 or 180 degrees, it does not matter. Sockets have a pin 1 indicator on one end. Align the pin 1 indicator with the square pad on the PC board. With the socket snug against the circuit board, flip the board over and solder all 16 pins to their respective holes. A little solder is all that is required.

24. Insert the “START” pushbutton (SW1) in the board. You will find it goes in easily when oriented correctly, and this can be mounted either 0 or 180 degrees (but not 90 or 270). The

pins are arranged in a rectangle, not a square, and these pins must go up/down on the board, not left/right. Solder all four pins.

25. Insert the 10-position DIP switch SW2 in the board. You will note on the switch that the word “ON” is imprinted, or there may be a small arrow, on one end, pointing in one direction. This indicates the position of the switch slide when it is “on”. Put the position ON facing upwards and to the left as indicated on the silkscreen, such that moving the switch up turns it on. Solder all 20 pins of the switch.

26. Insert the Power/Injector 5-pin screw connector into the PC board. It is to be positioned such that the five wire holes face the top of the board. Now solder the connector to the PC board.

27. Header J1 is optional and used if you want to program or re-program the microcontroller. Install the 6-pin J1 header into the PC board and solder all six pins. To program or re-program the microcontroller, you must have microcontroller background, a P&E Micro, PKG 68HCS08 software (PKGHC08_USB) with the USB Multilink (USM_ML_12) interface. This software and interface bundle are available from:

http://www.pemicro.com/products/product_processor.cfm

28. Plug the pre-programmed CPU (U3) into its 16-pin socket – make sure that the dot on the CPU package (denoting pin #1) is facing to the left on the PC board. The dot is on the same end as the notch on the left end of the silkscreen for U3.

29. Plug the injector drive controller IC (U1) into its 8-pin socket – make sure that the dot on the injector drive controller IC package (denoting pin #1) is facing to the top on the PC board. The dot is on the same end as the notch on the left end of the silkscreen for U1.

You are done with the PC board assembly! Looks nice? Will it work? Let’s find out...

External wiring from the PC board to the power supply and injector is shown on the illustration below. Connections from the PC board to the power supply connect to screw terminal block J2, located at the top of the PC board. Simply screw the +5V wire from the power supply (red if using a PC supply) to the +5 on the board (use 18-20 gauge wire). Screw the +12 from the power supply (yellow on a PC supply) to the +12 on the board (use 18-20 gauge wire). Finally, screw the ground wire (black on a PC supply) to the **Gnd PC** board’s terminal. If you are using separate power supplies for the +5 and the +12 voltages, be sure to hook all of the ground terminals together, or you will be scratching your head (or other) later.

Not necessary for PC board testing, but indispensable for fuel injector testing is connecting the fuel injector to the PC board. We will connect a fuel injector after initial PC board testing. Fuel injectors are not polarity sensitive, so it doesn’t matter how the two leads are connected to the PC board. The fuel injector is connected to J2 on the INJ+ and INJ- pins as shown in the following illustration. INJ+ is the positive output from the PC board and INJ- is the “switched ground” for the fuel injector.

To test the PC board, perform the following:

1. You don’t need to connect a fuel injector to test the PC board.
2. Connect your power supply to the PC board as per the previous paragraph. Make sure you have the +5 volts, +12 volts and ground connections from the power supply to the

PC board wired correctly. Improper connections will guarantee destroying the components on the PC board.

3. Set all of the switches on the 10-position DIP switch, (SW2) to the up position. This DIP switch setting will set the PC board for 250 injector pulses at 25.5ms. on time pulse. Off time is automatically set at 10ms.
4. Apply power to the PC board.
5. Depress and release the “START” pushbutton (SW1).
6. The “INJECTOR ON” LED will start blinking if all is OK. It will blink for just less than 9 seconds.

If the above test was successful, your PC board was successfully assembled. Good work!

Hopefully, the board works without problems, but don't cry if it does not. None of the parts are expensive, and most will not cause problems unless they are abused, violated, or tortured during assembly. Don't blame the circuit – it works - the problem is elsewhere. You will most likely find that it is a bad solder joint or a mis-wiring of the external board connections. Systematically go over the board and hunt for problems. We have all been frustrated by a nonfunctional assembly – take a break if you need it and re-examine later. You will get it to work.

If the “INJECTOR ON” LED blinks, the PC board works. If it doesn't blink, then you are *temporarily* screwed. If you are the latter we will go through the circuit and attempt to find the fault(S). It is impractical to go through every combination here. When following the following troubleshooting ideas, you must correct one problem before moving to the next one. Check, once again, and make sure all of the semiconductors (D?, Q? and U? devices) are orientated correctly on the PC board. The following tests may find your problem(s):

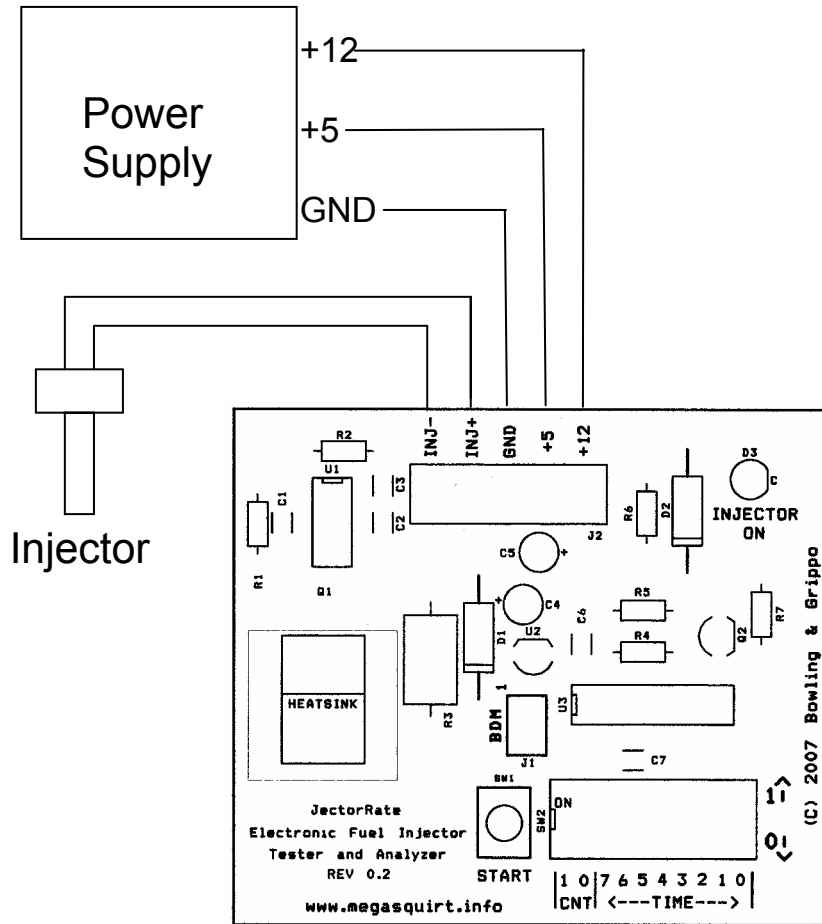
Troubleshooting Ideas:

1. Test the voltage output from your power supply. With a volt meter, check the voltage between GND and +5 and GND and +12 on the power input screw terminal, J2. Those points should read 5 and 12 volts restively. If one of the other voltages are incorrect, disconnect the power supply from the PC board and test it. If it tests good, you probably have a short on the board; possibly a solder bridge where it doesn't belong. Correct the power supply problem.
2. Make sure all of the switches on the DIP switch are in the up position.
3. Check to see you have the proper voltages (+5 and +12), and the board is wired properly and the ground (GND) is connected. If *nothing* is still the result, then check solder joints, improper parts placement, etc. If you have inserted the injector drive controller IC (U1), microcontroller, U3, transistor(s) Q1 or Q2 or voltage regulator U2 incorrectly, then you have likely destroyed it and at this point and you will need to replace that component.
4. If you hooked the +12 volts to the +5 volt pad on the circuit board, most, if not all of the semiconductors with U or Q numbers are destroyed, so do not do this.
5. Check the voltage output from U2. It should be 3.3 volts. First check +5 volts entering the voltage regulator on the left hand lead. Measure it with the black lead of a voltmeter connected to GND and the red lead touching the right hand lead of Q2. If the voltage is not 5 volts, you probably don't have your power supply connected as in test #1. If the voltage is 5 volts, now measure the voltage on the left hand lead of Q2. It should read 3.3 volts. If not, you probably inserted Q2 incorrectly. Obtain a new Q2, remove the old one and replace it per assembly step #19.
6. If you have access to an oscilloscope then check left side lead of R4 for pulses, after depressing and releasing the “START” pushbutton. If you see pulses here, the

- microcontroller is functioning. If not, the microcontroller could be non-programmed or installed backwards. Also, check for bent leads on the microcontroller, U3. Replace U3.
7. With the oscilloscope, test the right side lead of R5 for pulses, after depressing and releasing the “START” pushbutton. If you see pulses here, the pulse from the microcontroller that is passing through Q2 is functioning. If not, replace Q2 in its proper orientation.
 8. With the oscilloscope, test the top lead of R1 for pulses, after depressing and releasing the “START” pushbutton. If you see pulses here, the pulse from the injector drive control IC (U1) is functioning. If not, replace U1 and make sure it is inserted into its socket.
 9. If the “INJECTOR ON” LED is not blinking and the above tests pass, diode D2 may be inserted backwards. If the LED is always on, diode D1 may be inserted backwards. Check for either and correct the direction.

Now that the PC board is hopefully functional, let’s connect a fuel injector and run the test again. You will hear the injector clicking during the, just less than, 9 second test sequence. The system is fully functional at this point.

You will need a connector to plug onto the injector. This is a good junkyard item. You can also get it at places such as Fuel Injection Specialties or Electromotive. Most use the Bosch connector, but GM and Nissan use weird connectors, so you may want to get many different connectors and wire them in parallel. Remember the driver circuit is designed to drive only one fuel injector – don’t go hooking up eight injectors and trying to flow all of them at once.

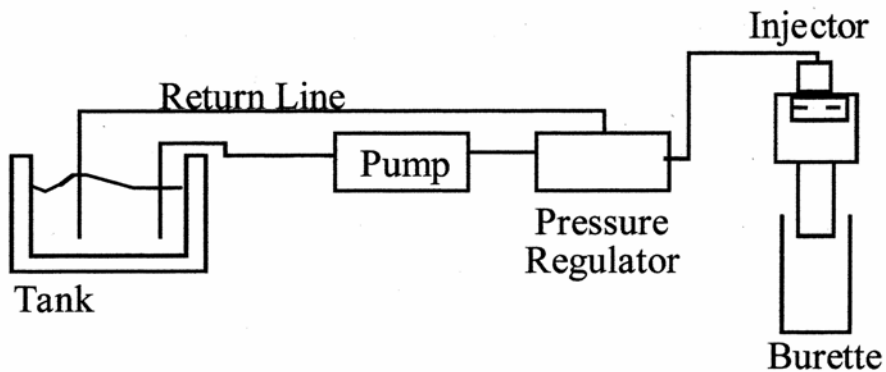


Test Stand Overview

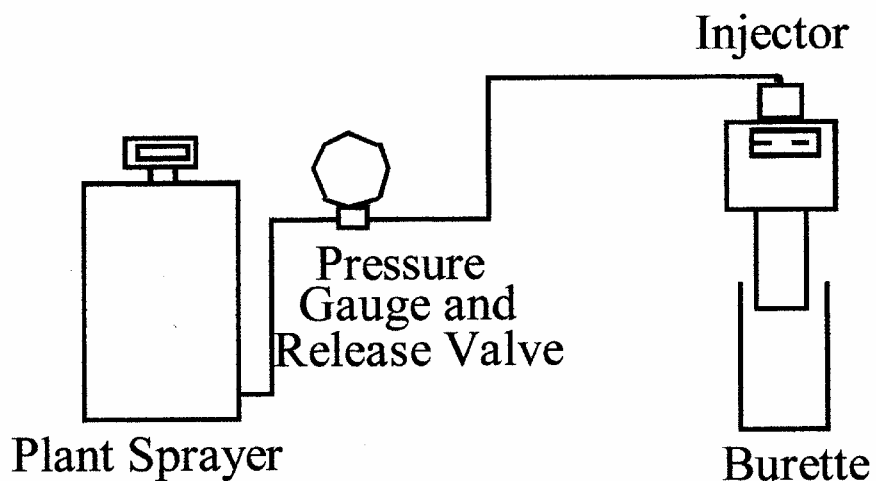
If you are reading this, you have a working board (or are in desire for a working board), and you want to “flow them injectors”. But, before you “go a flowin”, you have to make the mechanical part of the test stand. This is where you can be creative and use what you have at hand. The goal here is to provide the cleaning fluid under a known pressure, and collect and measure the flowed amount.

Delivering the test fluid under pressure is a little tricky. There are several ways to do this, and I will discuss a few of them. Which method you choose will depend on equipment, ease of use, and which seems to be the right one for you.

The first method is to do a “mockup” of an automotive fuel delivery system. This means having a fuel tank or container, a fuel pump, and a pressure regulator. You will have to rig up the fuel line, as well as a fuel return line from the regulator to the tank. Be careful that you do not generate sparks that can ignite the test fluid.

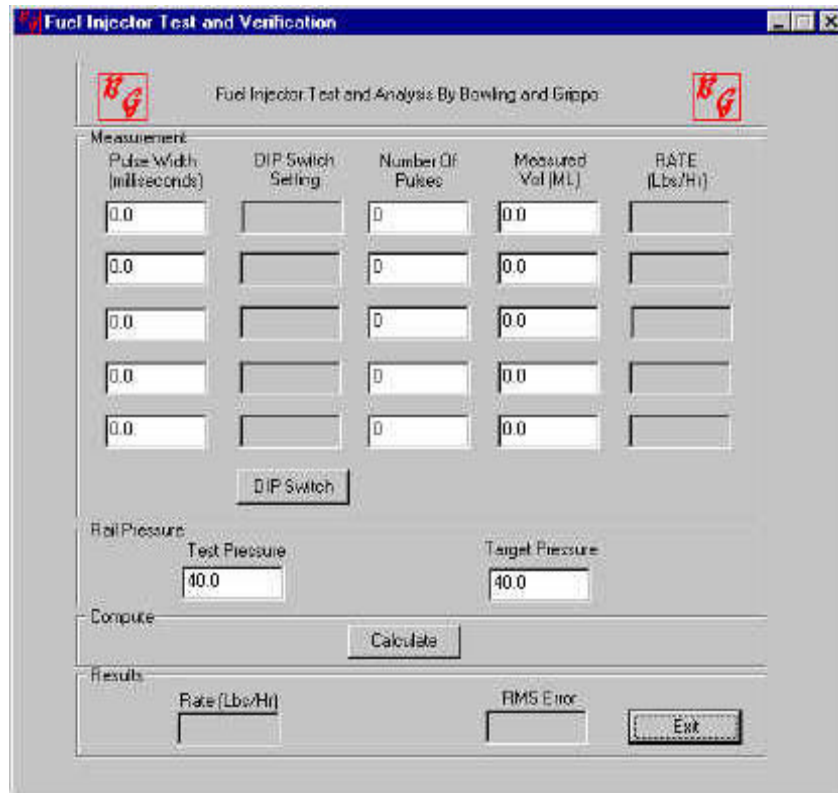


Another test rig is to use a metal plant sprayer, which you can get from any garden shop. Disconnect and chuck the sprayer wand, leaving just the tank. Hook the sprayer hose to a pressure gauge and a valve to relieve built-up pressure after testing. Fill the tank with the test fluid and pump it up. You can easily get 10-15 PSI out of this setup, and the software will convert this test flow to your target pressure rating. Do not pump this over 20 PSI, or “it will blow”. If you kill yourself with this rig by pumping it up to 300 PSI, don’t come whining to me later. This is your deal, and your responsibility to make it safe. These are not “plans”, just guidelines for you to follow in making up your rig.



PC Software

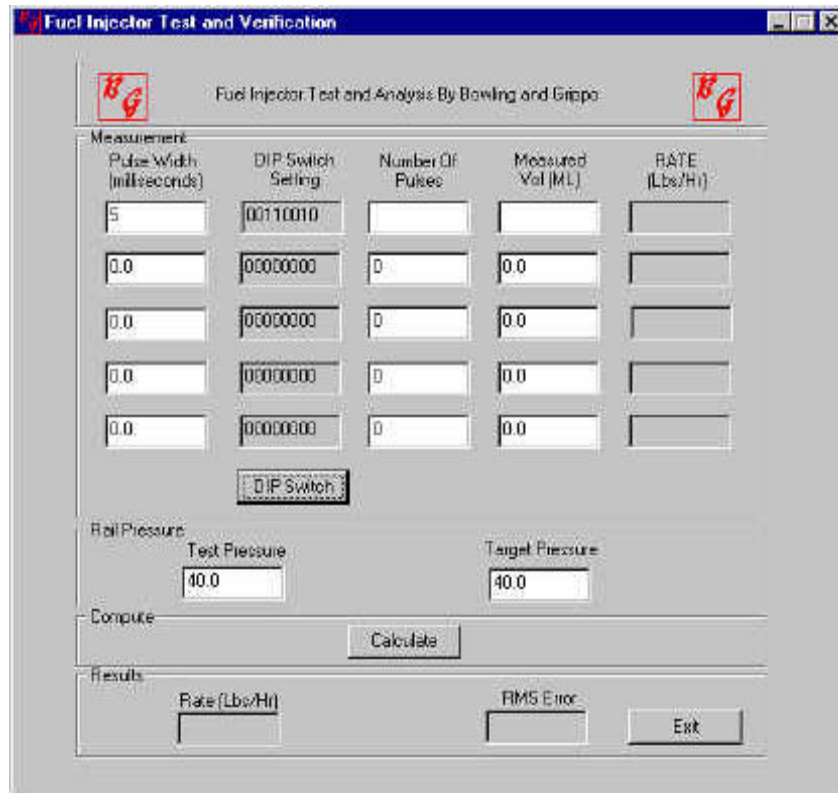
A freeware windows-based program is available which performs the analysis. Here is a screenshot:



This is a Visual C++ application in EXE format. All DLLs are linked in, so that the only thing needed is this application (this is why it is 1.3 MB in size). You can put the application in any directory on your hard drive. It runs under Windows 95/98/2000/XP or Windows NT. Not DOS or Windows 3.1. There is no install script, just copy anywhere and double click to run. To delete just drag to the trash can. Freeware rules!

Looking at the screen, you will see that there 5 rows of input boxes – this is where you place your test results. But, before you run a test, you need to come up with a few test pulse widths to try. Something like 2, 4, 8, 10, and 15 milliseconds is a good start.

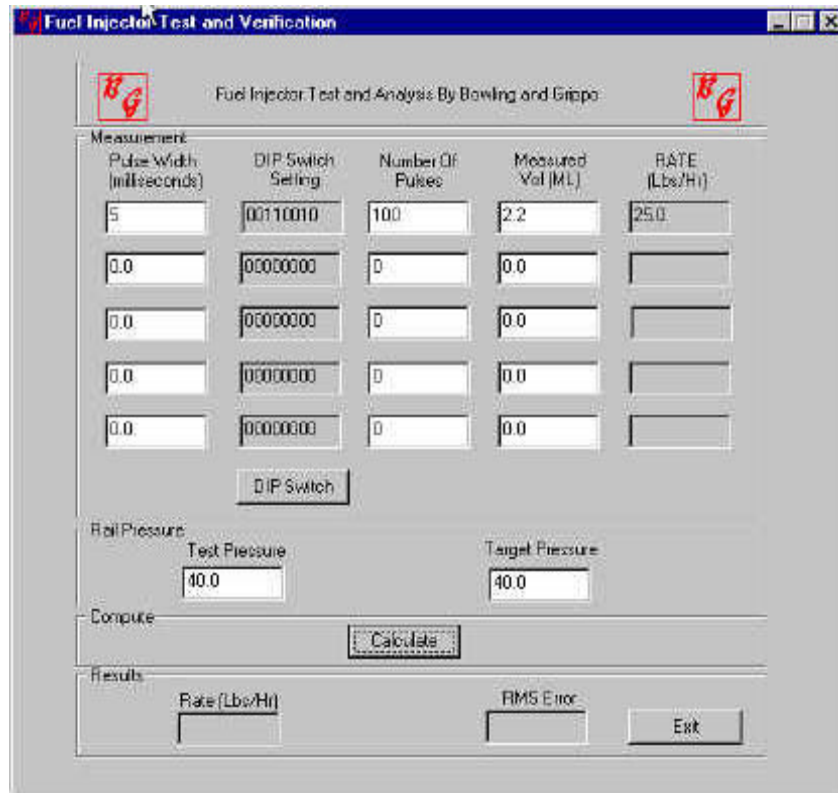
The box just to the right of the milliseconds boxes are the binary DIP switch settings to be entered on the JectorRate board, and it *follows* the number entered in the milliseconds box. When you change the milliseconds box and hit return, this box will automatically update, magic-like. To test this part of the software, place 5 milliseconds in the upper left box and hit return. Your screen will look like this:



Yup, there is a binary number in the DIP switch setting box. This is what gets entered on the board. If you feel so inclined, check the binary number to see if it is correct. The rest of the crowd will blindly trust me!

Now, it's decision time. How many pulses do you use? The only way to find this out is to run a few test runs with different number of shots and see how much fluid collects in the burette. Remember, you have only four choices for the number of pulses on the hardware, but also remember that you can re-fire the injector again (and again). So, play around with your injector under test to see what works.

Now, you have the number of shots determined, you run the test and enter the number of shots and the measured burette reading (in ML) into the software. Then click the *Calculate* button. Do this to get this next screen:

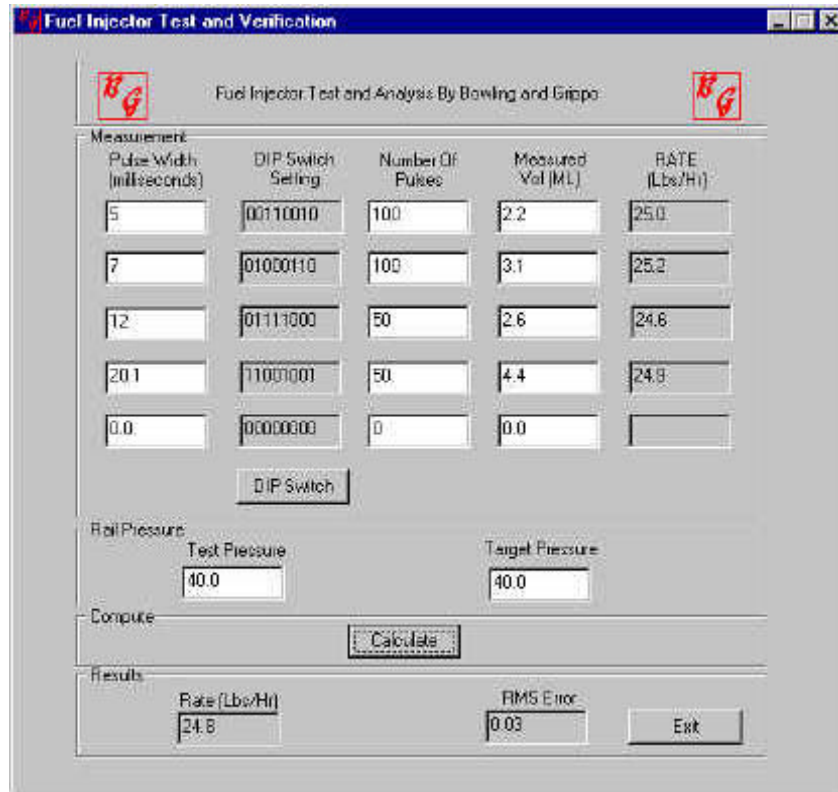


When you enter the data and press *calculate*, you notice that the Rate box is automatically filled in with a pounds-per-hour value. This is just a straight linear computation. This is the flow rate of the injector for this particular test.

You might ask “why didn’t the bottom boxes fill in”? The bottom boxes (grouped under *Results*) are the resultant calculation of a weighted least-squares fit of the test results, and to get them to “fill in” you must enter at least three different test number sets into the software (or four or five). When you click the “Calculate” button, the least-squares test is executed (only if there are three or more data sets), and the least-squares results appear below. Rows with zeros entered for pulse widths or measured volume are excluded from the calculation.

The next screen shot shows the results of a least-squares calculation of four test values. Notice that each test came up with a slightly different flow rate. The least-squares calculation can be considered a fancy averaging of all of these rates into one final number.

One thing to note on the least-squares is that it performs a weighted calculation, based on the injector pulse width. Larger pulse widths (like 10 ms) are weighted more than smaller pulse widths (like 3 ms). Why? Because injectors have a period of time in which they open and close, and during this time a small amount of fuel flows. Nominal injector open times are around 1 – 3 ms. Because of this, small pulse widths have a greater contribution of this open/close fuel flow than larger overall pulse widths. What we are after is the flow of the fully open injector, therefore larger pulse widths are weighted higher in the least-squares calculation.



To the point above – the fuel flow during the injector open/close time can be determined by flowing small pulse widths (1 – 3 ms), and watching the Rate boxes to the right. You will see a trend with the rate dropping off with pulse width. If you keep on increasing the pulse width, there will be a point where the rate number does not increase very much (within measurement error) – this is close to the point where the injector is fully open, and this number is very important to EFI controller calculations.

Now, the final item to ponder is the test pressure. The example above has a test pressure of 40 PSI, and a target pressure of 40 PSI. But, if you measure the injectors (test pressure) at a different pressure than your application fuel rail pressure (target), then you can enter these values into the software. The least-squares fit value at the bottom will be scaled by the difference in pressures. Note that the Rate boxes on the right *are not scaled*, only the least-squares result is scaled. Here is a screenshot of different test and target pressures. Look at the least-squares fit value box – it is now different. This is the target flow rating.

Fuel Injector Test and Verification

Fuel Injector Test and Analysis By Bowling and Grippo

Pulse Width (milliseconds)	DIP Switch Setting	Number Of Pulses	Measured Vol (ML)	RATE (Lbs/Hr)
5	00110010	100	2.2	25.0
7	01000110	100	3.1	25.2
12	01111000	50	2.6	24.6
20.1	11001001	50	4.4	24.8
0.0	00000000	0	0.0	

DIP Switch

Rail Pressure

Test Pressure: 40.0 Target Pressure: 50.0

Compute:

Results

Rate (Lbs/Hr): 30.4 RMS Error: 0.03

This should give you enough information to get you going with testing fuel injectors. Mortgage the house and start a fuel injector re-manufacturing company and become filthy rich!

A few closing points: if you want to clean your injectors, simply hook the injector up in reverse flow and run a bunch of pulses. You can use a cleaning fluid of your choice – I have used carburetor cleaner with good results. Also, the controller can be used to check injectors on the car – just hook up the connector to the injector. Do not try running the car with this hooked up because you do not know what pulse width the car needs.