ARCC UPDATE

January 2011

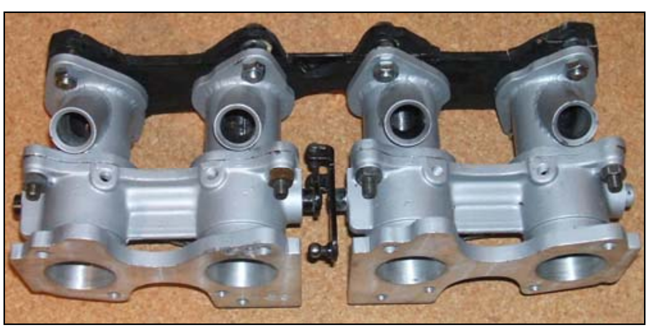
EFI Conversion Progress

by George Beston, Cobourg

The good news is that I have more or less completed the conversion of the 1750 engine in my Spider Jr. from Weber carburetors to an electronic fuel injection system. The motor now starts and runs well, even though some of the small details still need work.

In the beginning, this project was undertaken to optimize the performance and fuel economy of my Spider in everyday driving, to facilitate tuning for future engine upgrades such as intake runners and high-lift cams, and as a hands-on way to develop my knowledge and understanding of how EFI systems work. Along the way, I also wanted to maintain the vintage look of the engine compartment.

The project began with consideration of throttle bodies that could be used to physically replace the Webers, providing both throttle plates and mounting bosses for the individual fuel injectors. Aftermarket units are out there, but they seemed to be pretty expensive. I never even considered motorcycle throttle bodies, not realizing how similar some of them can be in size to automotive units. My familiarity with Spica injection led me to the path of using Spica throttles and fabricating some injector bosses so that both throttles and bosses would fit in the space previously occupied by the Webers.



Starting with flanges scalped from used rubber carburetor mounts, then using custom made parts to build up the injector bosses and finally making adapter plates to bolt to the original die-cast air cleaner plenum, throttle bodies finally came into being as seen here.

Of course, this was only the end of the beginning. In considering what all the needs of the system are, additional ports were added downstream of the throttles to provide for both a MAP signal and idle air. Naturally a fuel rail was needed, and that was built starting with some injector fittings from MSD that are built to utilize 0.5 inch steel tubing to form a fuel rail. When all the pieces are fitted and aligned they are tacked together, and then finish welded on the bench. The last step involves drilling through the tubing to open the rail to the injectors.

And yes, there's more. A throttle position sensor was adapted to the firewall end of the throttle shaft.

Finally, air distribution blocks were taken from two Spica systems for idle air and MAP (Manifold Absolute Pressure) signal purposes. A needle valve was included on the MAP side to damp out signal spikes. An adjustable throttle stop was required to establish a base idle, and a throttle return spring

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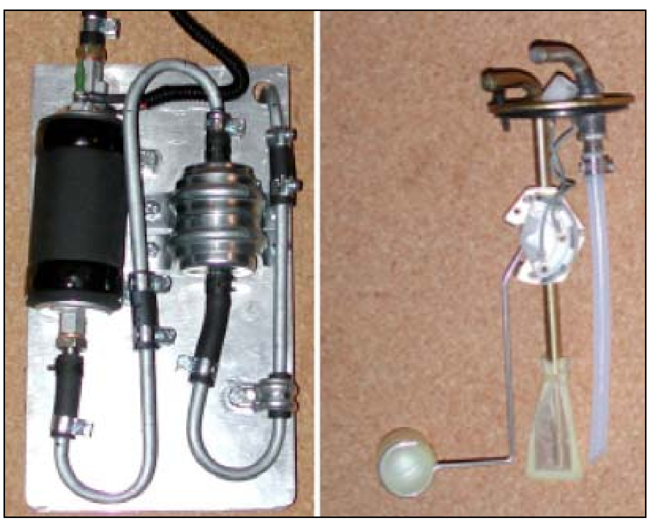
was added on to ensure that the throttles will close immediately if the throttle linkage comes adrift.

Finished throttle bodies as seen from above …

… and below.

To feed gasoline to the injector rail, a recirculating fuel system was devised that included a continuous flow fuel pump, two filters, a pressure regulator and a return line. The sending unit assembly was modified by the addition of a return line fitting.



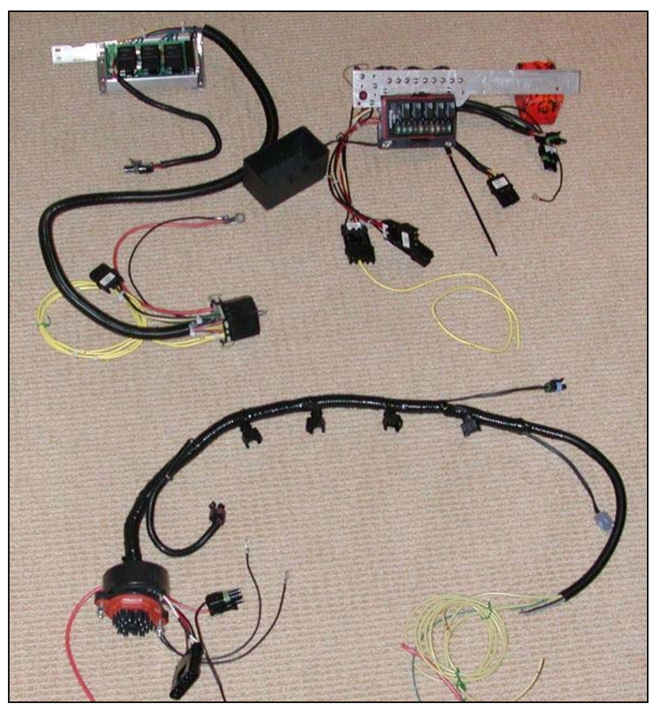
Above left: Fuel pump, primary filter and mounting plate.
Above right: Modified sending unit with return line fitting.

Every fuel injection system considered required the use of an oxygen sensor in the exhaust system. A wide-band sensor from Innovate Motorsports was installed just behind the front muffler. A location closer to the engine is preferable, but space limitations and the design of the 4:2:1 exhaust system more or less forced this location.

Many different EFI systems are available at this time. It's difficult for a beginner to choose because of the range of capability and cost of the various systems. MegaSquirt was chosen for a number of reasons. I liked the grass roots history of Bowling and Grippo, the guys who started the company, and the fact that the software to run MegaSquirt systems is mostly freeware. Another big attraction was price. For what they offer, MegaSquirt systems are very economical. The simplest and lowest-cost system that fit the goals of the project was chosen. It's the basic MegaSquirt computer upgraded slightly to enable it to run both fuel and spark functions. If anyone wants to look it up, it's officially called MS1-Extra or MegaSquirt'nSpark Extra.

Once the computer was purchased, the realities of power and wiring requirements settled in. For a power source, I upgraded my Spider's generator to an Alfetta alternator because I thought the power demands of a fuel injection system would be too much for a generator to handle.

To distribute the current to the new elements being added to my Spider, an auxiliary fuse panel was installed which has ten fuses and five relays. Because I was planning to use a MegaSquirt relay board, I hooked up the new panel to provide five circuits with constant power and five switched circuits.



Clockwise from top left: Relay board and interior harness; auxiliary fuse/relay box; engine compartment harness.

A number of harnesses were constructed using Weather Pack connectors. The main harnesses were from the relay board to the firewall, and from the firewall to the injectors, the throttle position sensor and the air and coolant temperature sensors.

A 22-pin bulkhead connector was used at the firewall. Minor harnesses were built for the fuel pump, oxygen sensor and interior accessories unrelated to the engine management system.

Another wiring change required by the electronics was the replacement of the OE style wire core ignition wires with a set of interference suppressing wires which was sourced from Magnecor.

Early in the project a decision was made to install the ECU behind the radio opening in the dashboard in order to utilize that space and to allow access to the ECU's serial port by removing the radio cover plate. The MegaSquirt relay board was located behind and below the ECU for accessibility.

Once the throttle bodies, computer and wiring were installed, the next step was hooking up all the input signals to the ECU. In this system, the most important interface between the ECU and the engine is at the distributor. My Spider was already equipped with a Crane XR 300 ignition system with an optical trigger. With MegaSquirt, the only part of the Crane system that could be used was the optical trigger located in the base of the distributor. Because MegaSquirt batch fires the injectors, there is no need for the ECU to know which cylinder is firing at a given point in time. It just fires every injector once for every four ignition events. For spark, a big transistor in the ECU grounds the primary winding of the coil every time the trigger system sends a signal, and the distributor rotor takes care of directing the spark to the correct cylinder.

Initial attempts to run the engine on the Mega Squirt system were pretty frustrating. The engine barely ran and was obviously far too rich. After much consternation, it became apparent that the source of the problem was vacuum leaks in the throttle bodies. With the throttle bodies back on the bench, the fittings for idle air and vacuum were identified as the culprits. A touch of Permatex "form-a-gasket" sealer on the threads of all 18 fittings resolved the leak issues.

At that point, the engine started and ran pretty well, but had a tendency to foul spark plugs. Ultimately, a new 40,000 volt coil and a fresh set of plugs resolved the issue. It turned out that the Crane system boosts spark by running a high voltage on the primary side of a coil. Without that boost, the old coil wasn't up to delivering the spark intensity required.

In hindsight, programming the ECU wasn't very difficult. These procedures involve working with MegaTune software files on a laptop and then downloading the files to the ECU via its serial port.

I decided to run the engine on a speed-density algorithm. To do that, three major inputs are programmed into the ECU via the MegaTune software provided.

The first is a calculated value, "Required Fuel", i.e. the pulse width required from an injector to deliver enough fuel to create a stoichiometric 14.7:1 mixture of air and fuel given a cylinder full of air at atmospheric pressure.

The second major input is VE or volumetric efficiency. Roughly defined, VE is a measure of the amount of air that enters a cylinder, expressed as a percentage of cylinder displacement. There are many reasons why it doesn't often reach 100%, but in normal driving conditions the biggest factor is the use of part throttle. VE values were entered into the computer as a 12 by 12 table with axes of engine speed and MAP. The values in the cells represent the percentage of air fill of the cylinders at each combination of MAP and engine speed.

The third and final major input is the AFR (air: fuel ratio) table. Axes of this 8 by 8 table are MAP and engine speed. The desired AFR is entered in each cell. Even though 14.7:1 is ideal, optimized idle characteristics and maximum power are usually achieved richer than that, and fuel economy can be improved by running a bit leaner under cruise conditions of moderate engine speed and low MAP readings.

Basically, the ECU calculates the injector pulse width by multiplying the Required Fuel by the Volumetric Efficiency in the table and by "lambda", the targeted AFR divided into 14.7.

While the engine is running, actual AFR is monitored by the exhaust gas oxygen sensor. If the detected AFR is different than the targeted AFR, a closed loop correction is done by the ECU, making appropriate adjustments to pulse width until the AFR target is achieved.

To optimize the VE table, data from the ECU can be logged during a test drive and analyzed by some additional software called MegaLog Viewer. Based on the extent of correction required to achieve desired AFR values, The VE analyzer feature of this software will recommend and facilitate VE table changes.

Once an accurate VE table is established, some acceleration enrichment can be programmed into the ECU. In setting this I was fooled by the fact that the symptoms of rich and lean conditions on acceleration aren't much different – a bit of a stumble. At first, it was left too rich until observers pointed out that there was a noticeable amount of black smoke out of the Spider's exhaust pipe during acceleration. It took no time at all to cut the acceleration enrichment back to the point of no visible soot, but there was no opportunity to fully sort this out before the end of the season.

At this point, I've achieved most of my initial objectives: the engine starts and runs well and feels very strong right up to the programmed rev limit of 5900 r.p.m.; the fuel consumption has been reduced by about 10%; and the engine compartment looks very original at first glance.

As far as learning a thing or two about electronic fuel injection and how it works, I've made a great deal of progress. I feel highly confident about making tuning adjustments around any engine improvement project in the future.

There are still a number of next steps. To date, the ECU and distributor are not set up to run a spark table. That's this winter's project. There are still some minor issues to sort out with idle airflow, and I need to document this entire conversion so that anyone who wants to can service this EFI system in the future.

Alfa Canadese, June 17-24, 2012

The 2012 National Convention for the Alfa Romeo clubs of Canada and the USA.

Early details: http://alfacanadese.ca

Volunteers wanted: info@alfacanadese.ca

Buon Natale e Felice Anno Nuovo from Zagato.

Upcoming ARCC Events

We're still getting organized for 2011. Watch this space!

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ARCC Update

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