Installing a *MegaJolt Lite Jr.* All-Electronic Ignition System in a Triumph Spitfire

by Paul Geithner

What Is Spark Timing and Why Is It Important?

Ignition timing is critical to Otto cycle engine performance. Why? For proper operation, maximum pressure developed by the burning air and fuel mixture in a cylinder should occur a little after the piston has passed top dead center (TDC) and is on its way back down the cylinder, to take advantage of the mechanical leverage of the position of the piston connecting rods and the crankshaft and optimally develop torque. Developing pressure too early or too late wastes performance potential, and in the extreme can keep the engine from running or cause damage. However, it takes a finite amount of time for the combustion, initiated by the spark, to propagate throughout the mixture in the cylinder. Pressure, temperature, motion of the mixture and fuel grade all affect combustion speed, but pressure is the most important factor. To account for the time it takes combustion to occur and ensure that maximum pressure of combustion is reached at the optimum position of the piston, the spark needs to be "advanced," typically to occur some number of degrees before the piston reaches TDC. As engine speed increases, the speed of combustion does not keep pace and so progressively more spark advance is needed as RPMs go up. This is true to first order, up to a point, because as engine speed increases, pre-combustion cylinder pressure (up to the limits of the engine's induction system to flow mixture), mixture motion and fuel atomization increase too, and these things speed-up combustion. Beyond peak volumetric efficiency and peak torque, which in most street engines is around 3000 to 4000 RPM, combustion speed keeps up with engine speed so that no further advance is needed. Also, the amount of load on the engine affects optimum spark timing. Less advance is needed accelerating, when the throttle is wide-open and lots of air is cramming into the engine and raising absolute pressures inside it, as opposed to cruising or decelerating and pressures are reduced. Therefore, at a given engine speed, more spark advance is needed at low engine loads (i.e., low absolute manifold pressures).

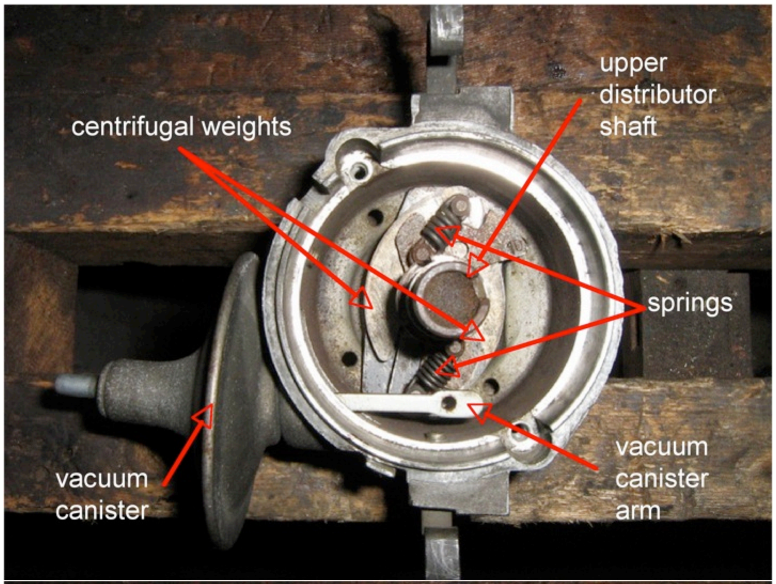
As you progress with engine modifications, the best amount of total ignition advance at a given engine speed and load changes, so to fully reap the benefits of engine performance modifications, it pays to revisit your ignition timing. For example, as you raise an engine's compression ratio, less advance is needed at a given engine speed, and you want to be careful and not have so much advance that you encourage detonation (a.k.a., knock, pinging, pinking). If you go with a "bigger" cam, volumetric efficiency and dynamic compression are reduced at low RPM but increased at high RPM, thereby reducing combustion speed at low RPM but increasing it at high RPM and so requiring an ignition map with more advance at low RPM but less advance at high RPM. So to get the most out of a given camshaft and overall intake setup and preserve low RPM behavior and maximize high RPM performance, tailored ignition timing is crucial. The following table lists these and other engine parameters and their spark advance needs:

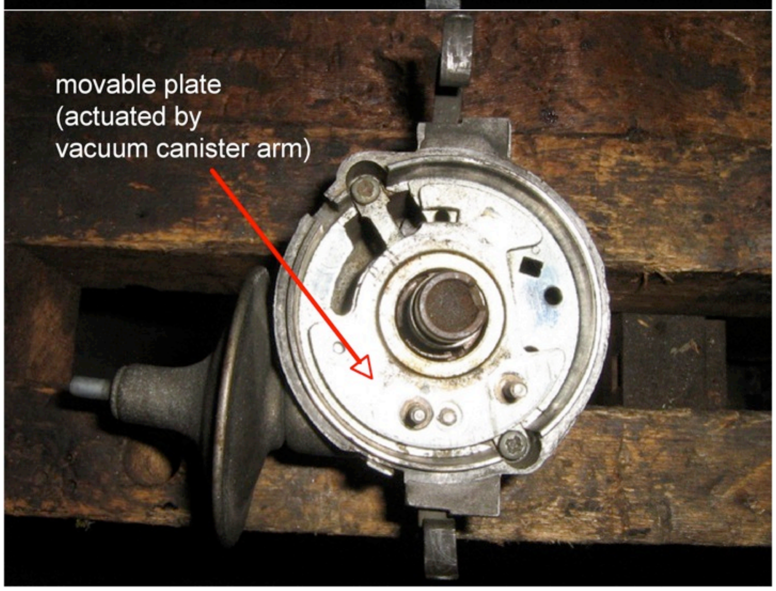
Parameter	Advance Requirements
Higher compression	Less advance
Higher intake efficiency	Less advance
"Bigger" cam (more duration, more overlap)	More advance at low RPM, Less advance at high RPM
Better fuel atomization	Less advance
Higher fuel octane rating	More advance (and higher knock limit)
Air/fuel ratio	More advance for rich mixtures
Higher air temperature	Less advance
Higher humidity	More advance
More efficient combustion chambers (more squish and swirl)	Less advance
Better exhaust scavenging	Less advance (where exhaust is tuned and most efficient)

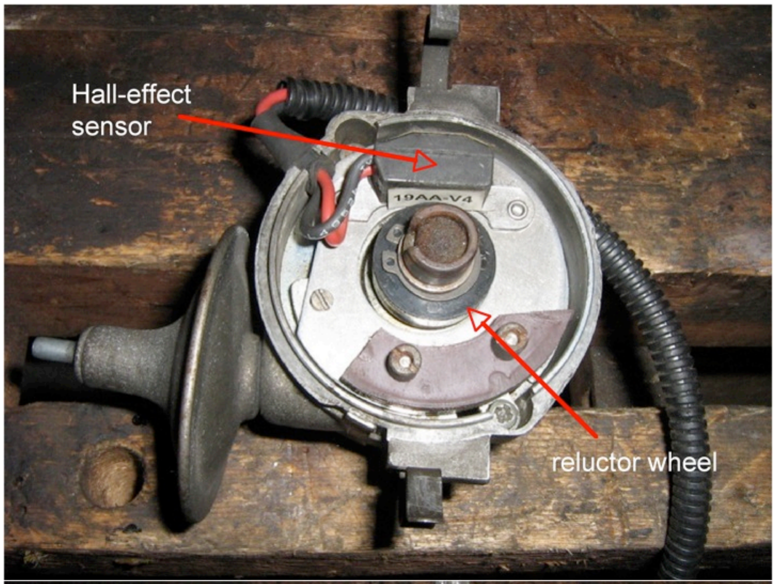
"More" is not "better" when it comes to advance, as indicated by the table. Do not be fooled by ignition maps with big advance numbers everywhere. Proper spark timing is about optimizing performance for a given engine configuration.

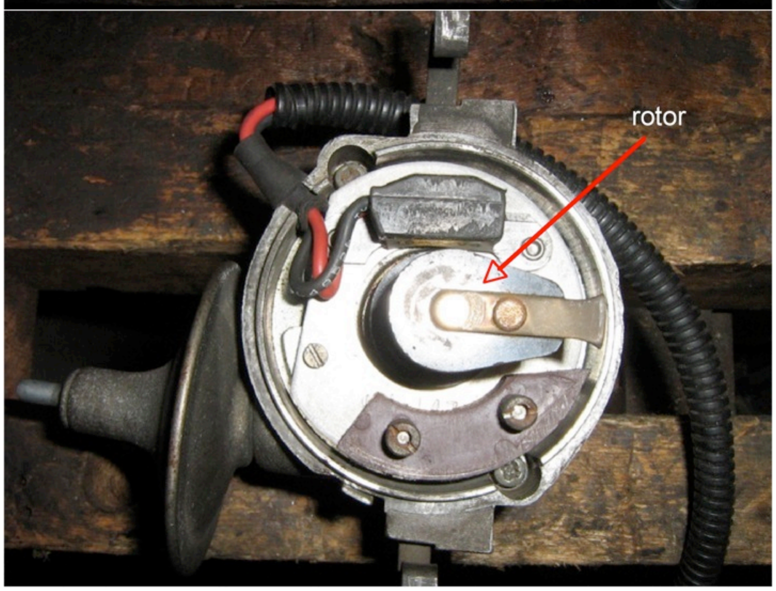
Distributor or No Distributor? That Is The Question

Until recently and prior to the advent of electronics, spark timing on most Otto cycle engines was determined and controlled mechanically by the distributor. Static advance is set by the position of the distributor such that the rotor and plug wire electrodes in the distributor cap are aligned as desired relative to piston position at rest (e.g., to set timing at idle). Dynamic advance with a distributor is accomplished via two mechanisms--centrifugal and vacuum. Centrifugal advance adjusts spark timing as a function of engine speed and works this way: little weights constrained by little springs inside the distributor fling outwards more and more as the distributor spins faster and faster with increasing engine speed, up to a limit imposed by a pin or some other hard stop. The mass of the weights and the stiffness of the springs control the rate of advance, and the location of the hard stop determines the maximum amount of advance. The outward motion of the little weights rotates the upper part of the distributor shaft that holds part of the spark triggering mechanism, e.g., a cam actuating contact points, or a multi-pole magnet or a reluctor wheel interacting with a Hall effect sensor, or a chopper wheel interrupting the light path between a light source and an optical sensor. All of these triggers function as switches to interrupt current flowing in the primary winding of the coil, resulting in magnetic field collapse and induction of high voltage in the secondary winding of the coil, and thus spark. Vacuum advance (or sometimes retard) adjusts spark timing as a function of engine load, where pressure in the intake system is used as a measure of engine load. Manifold vacuum can be sensed via a tap or multiple taps on the intake manifold, or a port near the throttle plate. A vacuum line goes from the tap to a vacuum canister on the distributor containing a diaphragm, which is attached to a link that is attached to the plate holding other parts of the spark trigger mechanism (e.g., the points, the Hall sensor or the light source and detector), so motion of the diaphragm, in response to intake vacuum, can advance (or on some distributors, retard) the spark.


upper
distributor
shaft
centrifugal weights
springs
vacuum
canister
vacuum
canister
arm


movable plate
(actuated by
vacuum canister arm)





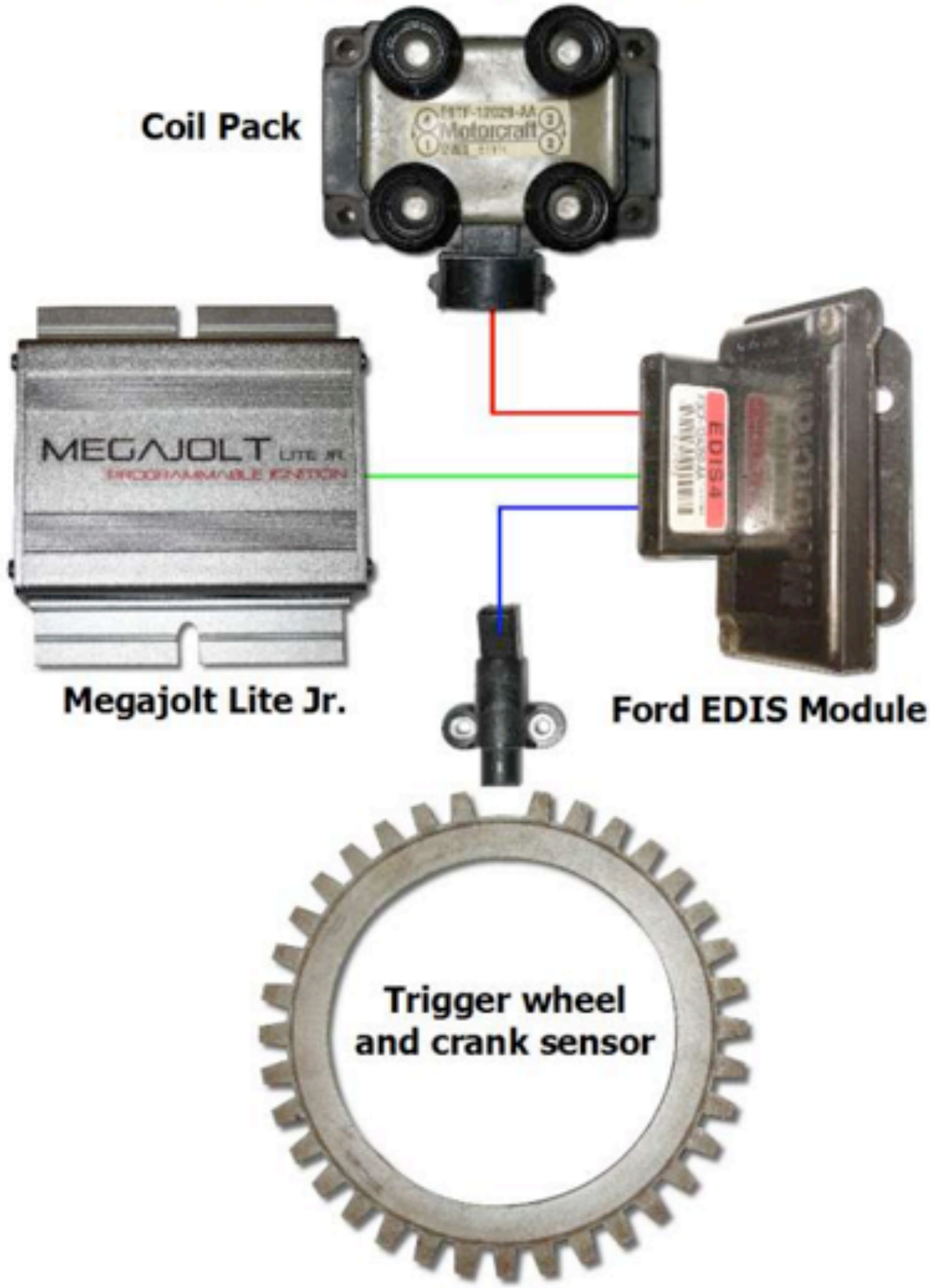
A worthwhile thing to consider, especially if you make engine modifications and want to take full advantage of the performance potential they offer, is to eliminate the distributor and replace its function with a fully electronic ignition control system like MegaJolt or the ignition portion of the MegaSquirt system. These systems sense engine position using a toothed "trigger" wheel attached to the crankshaft pulley rather than the shaft of the distributor and enable precise and fully programmable ignition advance settings versus engine speed and load.

There are two main advantages of distributorless ignition. First, changing the advance map on a distributor is very difficult, time consuming and not really deterministic. It involves adding (welding on) or subtracting (grinding off) mass from the centrifugal weights, changing the centrifugal weight springs, and changing the range of motion that the advance mechanisms make or impart to the distributor. Being able to simply change spark timing incrementally at the click of a mouse, as with MegaJolt or MegaSquirt, is completely deterministic, much faster and allows results to be assessed immediately before environmental conditions change that can affect interpretation of results (like air temperature, humidity, etc.). Moreover, ignition timing maps can be implemented that simply are not physically possible to create with a mechanical system (if such a thing is warranted). Second, fully electronic systems like MegaJolt and MegaSquirt eliminate several mechanical interfaces involved in communicating piston position and delivering the spark that add uncertainty and reduce accuracy. In a traditional distributor-equipped engine, the crankshaft turns the camshaft through a chain or belt, and the camshaft incorporates a gear that engages and turns the distributor shaft, which spins the centrifugal advance weights (constrained by the weight springs) and rotates a mechanism for interrupting primary current to the coil, as well as turns a rotor that spins past contacts in the distributor cap to distribute spark to each spark plug. In the case of many fully-electronic ignition schemes, piston position is sensed directly off the crankshaft by the variable reluctance sensor "looking at" a toothed wheel, and all spark triggering, switching and distributing is done purely electronically, and so the timing "slop" contributed by the rest of the mechanical interfaces in a conventional distributor-based ignition system is eliminated, thereby resulting in much more accurate and precise timing. Other benefits include the fact that all-electronic ignition systems can control timing as a function of load more accurately than a vacuum diaphragm attached to a distributor plate with spark triggering components. Also, systems like MegaJolt and MegaSquirt allow display and recording of running performance data.

<u>"MegaJolting" a Spitfire</u>

MegaJolt is a simple and easy approach to all-electronic ignition. The way it works is that a Variable Reluctance (VR) sensor senses the motion of a toothed wheel attached to the crankshaft and sends pulses corresponding to teeth and gaps to an Electronic Distributorless Ignition System (EDIS) module. A missing tooth in the wheel serves as a reference so that the EDIS module "knows" where TDC is on piston #1. The EDIS module periodically "talks" to the MegaJolt box, which contains a lookup table of spark timing values that are arrayed versus engine speed and engine load (the lookup table or "ignition map" is stored in flash memory). The MegaJolt box gets engine *speed* from the EDIS module and itself interprets engine *load*, either by sensing intake manifold pressure or the position of the carburetor throttle, looks up the corresponding timing value in the ignition map and provides it to the EDIS module. The coil pack, triggered by the EDIS module, fires the appropriate spark plug at the appropriate time.

Crank fired Ignition System Diagram



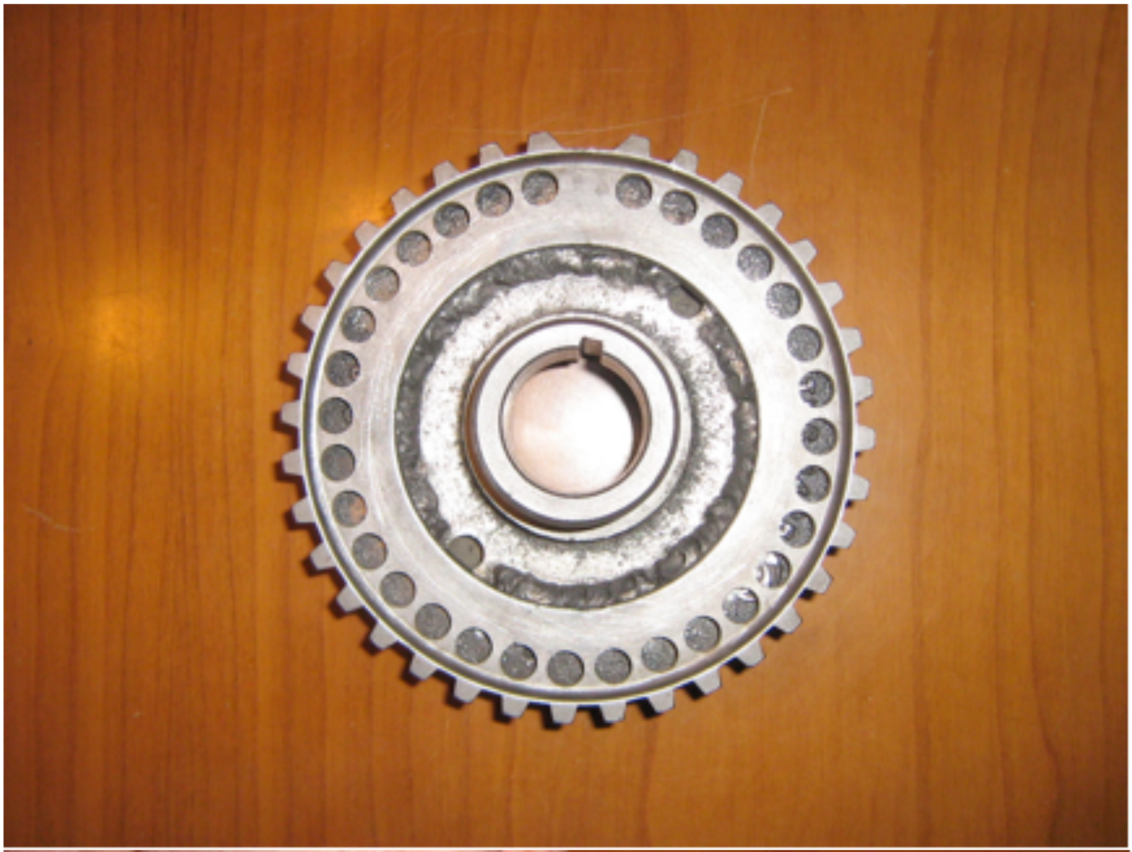
Here are the necessary components to convert a Spitfire or GT6 to MegaJolt:

- MegaJolt ignition controller (MAP or TPS configuration) – available pre-assembled or as a do-it-yourself kit
- Ford Motorcraft EDIS module
- Variable Reluctance (VR) sensor
- "36 minus 1" Trigger Wheel
- Coil Pack (4-terminal pack for a 4-cylinder engine, 6-terminal pack for a 6-cylinder engine)

Before you purchase your MegaJolt unit (as an assembled and tested box or as a do-it-yourself kit), you must determine how you will assess engine load—either via intake manifold pressure (MAP) or throttle position sensing (TPS)—because they come in either the MAP or TPS configuration. Also, it is important when procuring the EDIS, VR sensor and coil pack (be it at a salvage yard, a friend, eBay or wherever) to get the connectors with some wire pigtails so you can easily connect everything together.

Perhaps the trickiest part of the installation is attaching the trigger wheel to the crankshaft pulley. First, the pulley nut is torqued to 150 foot-pounds, so getting the pulley off takes the right tools and right application of force (refer to a shop manual for details). Once you have the pulley off, the toothed trigger wheel can be attached to it with fasteners or by welding. The critical aspects of joining the two are to make sure the trigger wheel is precisely centered on the crank pulley (for balance and for positioning relative to the VR sensor), and that the missing tooth is oriented so that wherever you plan to mount the VR sensor, the missing tooth is in the right place relative to piston #1 compression TDC so that the EDIS module correctly interprets its position. On my 1978 Spitfire, I welded the wheel to the backside of the crankshaft pulley. I centered the wheel by measuring the distance between the inner rim of the trigger wheel and the machined surface of the shaft of the crankshaft pulley.

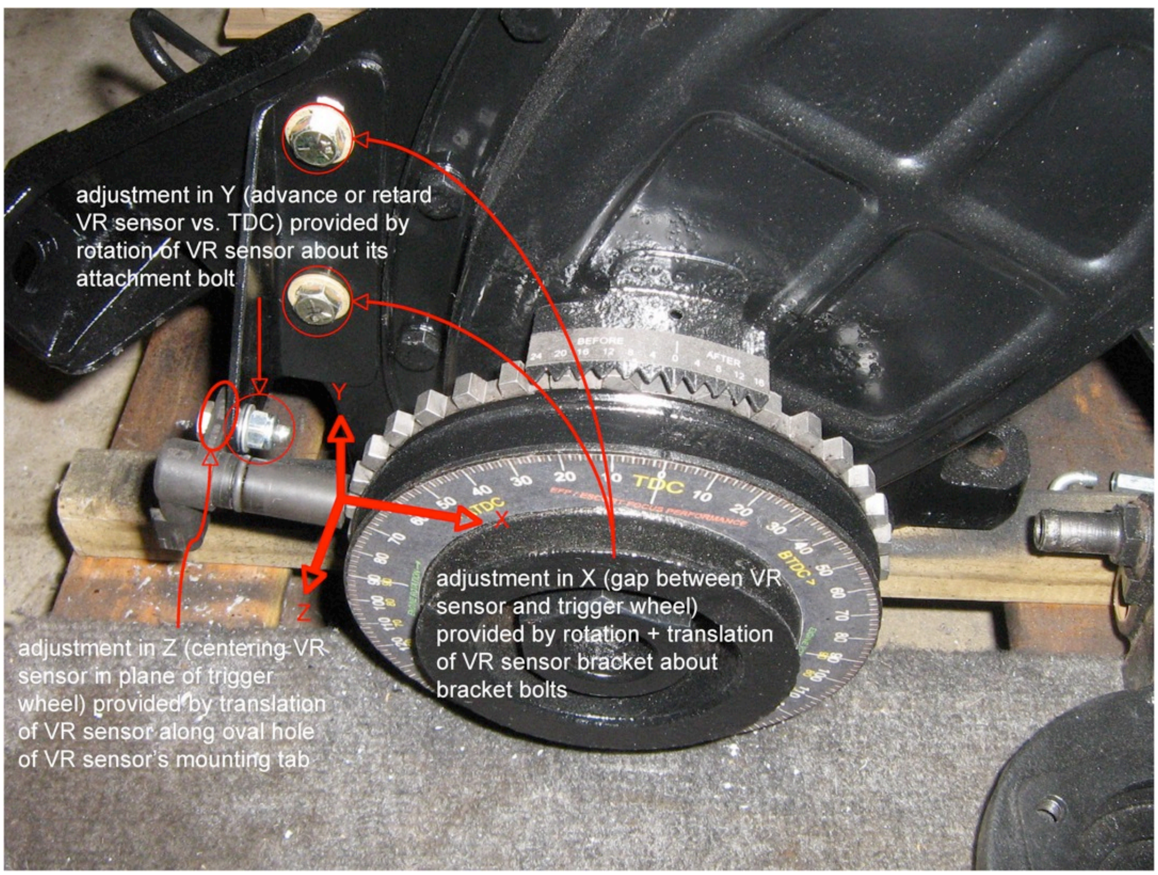
Because I planned to mount the VR sensor 90 degrees counter-clockwise from the TDC mark, I centered the missing tooth gap on the pulley's TDC mark. With the trigger wheel lightly clamped to the crank pulley with two vise grip pliers, I took dozens and dozens of measurements at six points of the circle around the pulley using a digital caliper. I adjusted the trigger wheel until all measurements were the same to one thousandth of an inch, then tack welded the assembly, then re-measured, then performed final welding in alternate beads, each about 1 inch long, until the entire inner rim of the trigger wheel had an even weld bead around it.

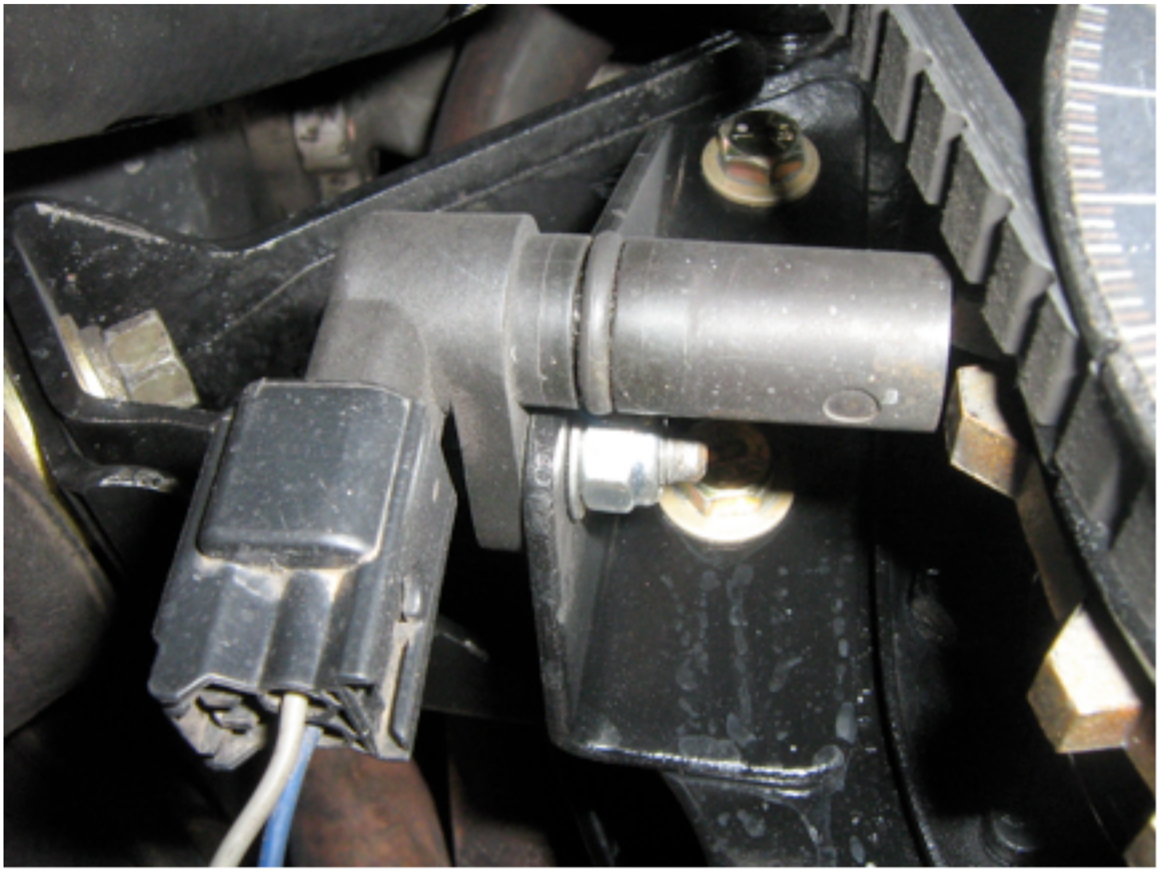


If you don't want to tackle this part of the job yourself, a competent machine shop near you should be perfectly capable of doing it quickly at modest cost.

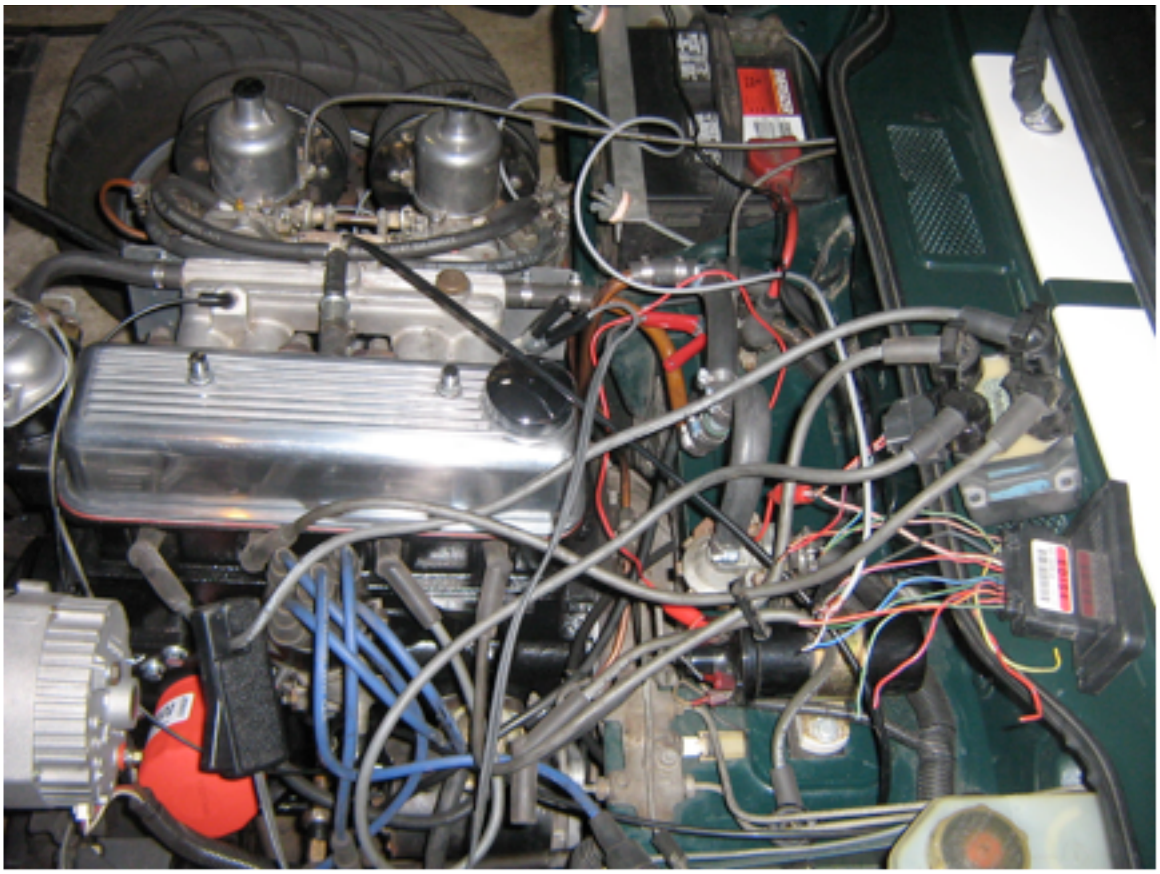
The next step was to mount the VR sensor. There are three measures that are critical to locating the VR sensor correctly: the gap between the VR sensor and the teeth of the trigger wheel, the clocking position of the VR sensor relative to the missing tooth and to the TDC mark on the pulley, and the centering of the VR sensor in the plane of the trigger wheel. The gap is most important because it has to be less than 1mm (0.040") to ensure proper function. Clocking can be corrected within several degrees using an offset function in MegaJolt, and centering the VR sensor in-plane with the trigger wheel has an unspecified but fairly forgiving tolerance (a few mm), so these are less challenging.

I have seen many VR sensor mounting variations, often taking advantage of fasteners that hold the cam timing chain cover in place. I chose to mount my VR sensor on a simple L-bracket mounted directly to the front engine plate. The only modification I had to make was to drill two holes into the front plate for mounting the bracket. I fabricated the bracket from a short piece of 2-inch angle iron. With this configuration, I have adjustability in three critical degrees of freedom to properly position the VR sensor, as shown and described here:



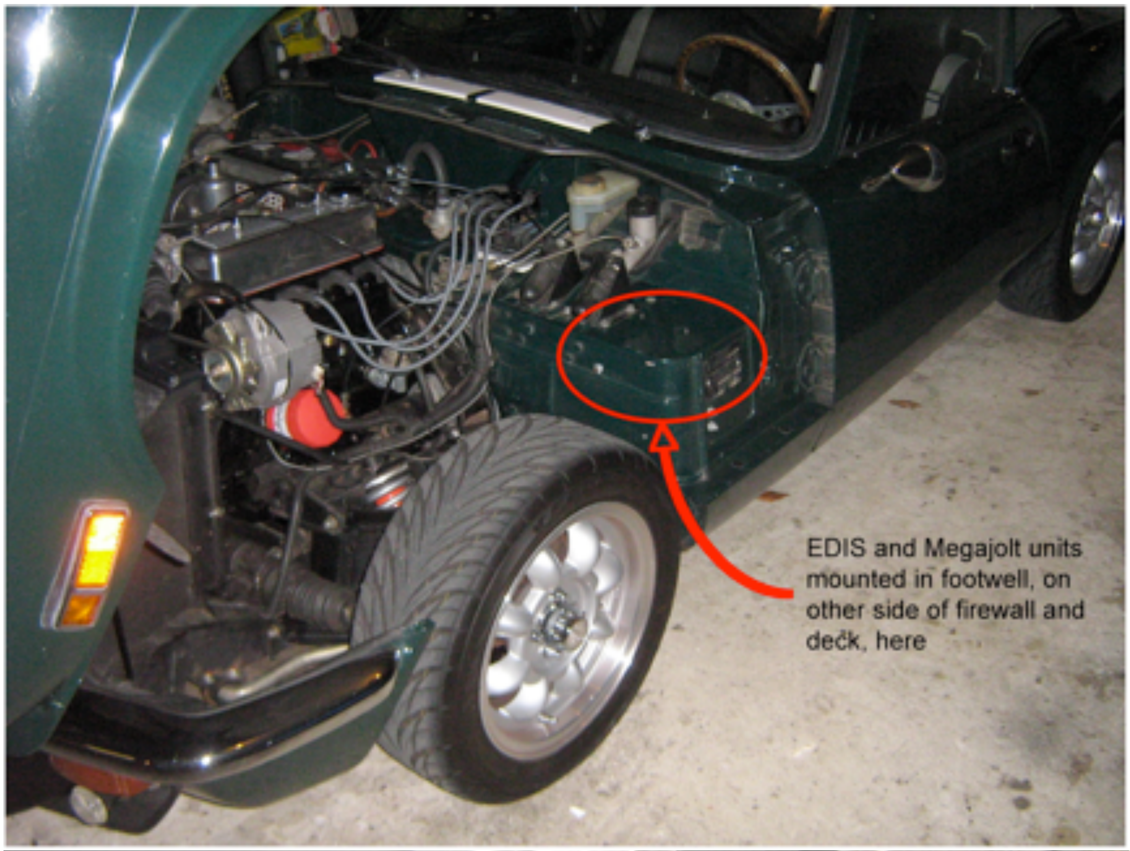


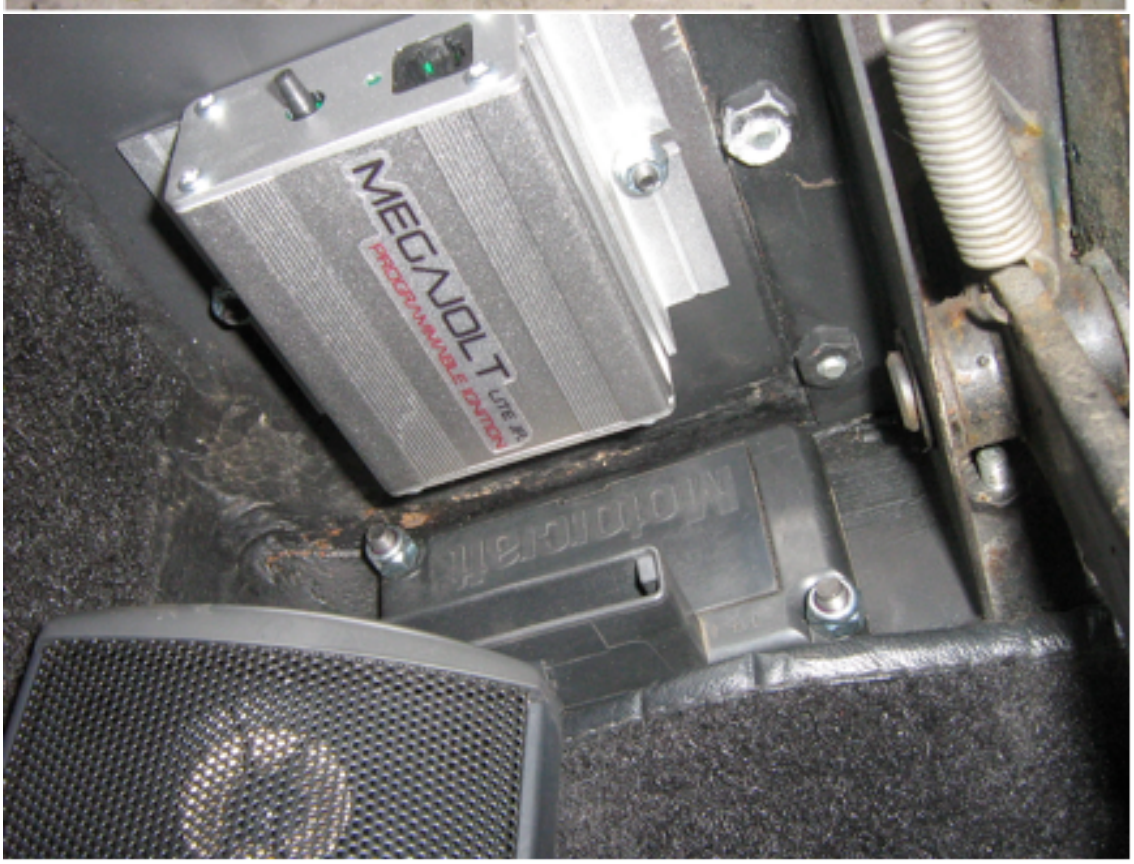
With the toothed wheel and VR sensor in place, I temporarily wired-up the EDIS module and coil pack to verify operation and confirm the polarity of the VR sensor wires. Based on the colors of the wires from the VR sensor and the EDIS module, you may have to guess at the VR sensor polarity. If you guess wrong, you simply will not get any spark and nothing will be damaged, so the remedy is to simply swap VR sensor connections if there is no spark. I guessed correctly and the engine started right up and ran without any incident at a constant 10 degrees BTDC—the "limp-home" mode of the EDIS module without a spark timing controller (the MegaJolt box) present. Observing it with a timing light for the first time, I was struck by how steady the TDC mark was, exhibiting no jitter whatsoever, appearing precisely at 10 degrees before TDC (BTDC).



Next, I added the MegaJolt box itself to the arrangement and verified its operation. The MegaJolt box flash memory comes pre-programmed with a default spark advance map, so it can be used safely right away without the user having to create and load one first. To be able to see the function of the MegaJolt box and change the timing table, I downloaded the MegaJolt configuration software from the Autosport Labs website, installed it on a laptop PC running Windows XP, and connected it to the PC via a serial RS232 connection. With the stock coil missing, my electric tachometer needed a signal to register. The MegaJolt box has a "tach out" signal that I tied to my stock Smiths RVC tach, and it functioned just fine.

With the basic system operation verified and the connections understood, what remained to accomplish was to mount the EDIS module, MegaJolt box and coil pack and make a wiring harness to connect all the components permanently. I decided to mount the EDIS module and MegaJolt box in the driver's foot well area, as indicated in the following photos:

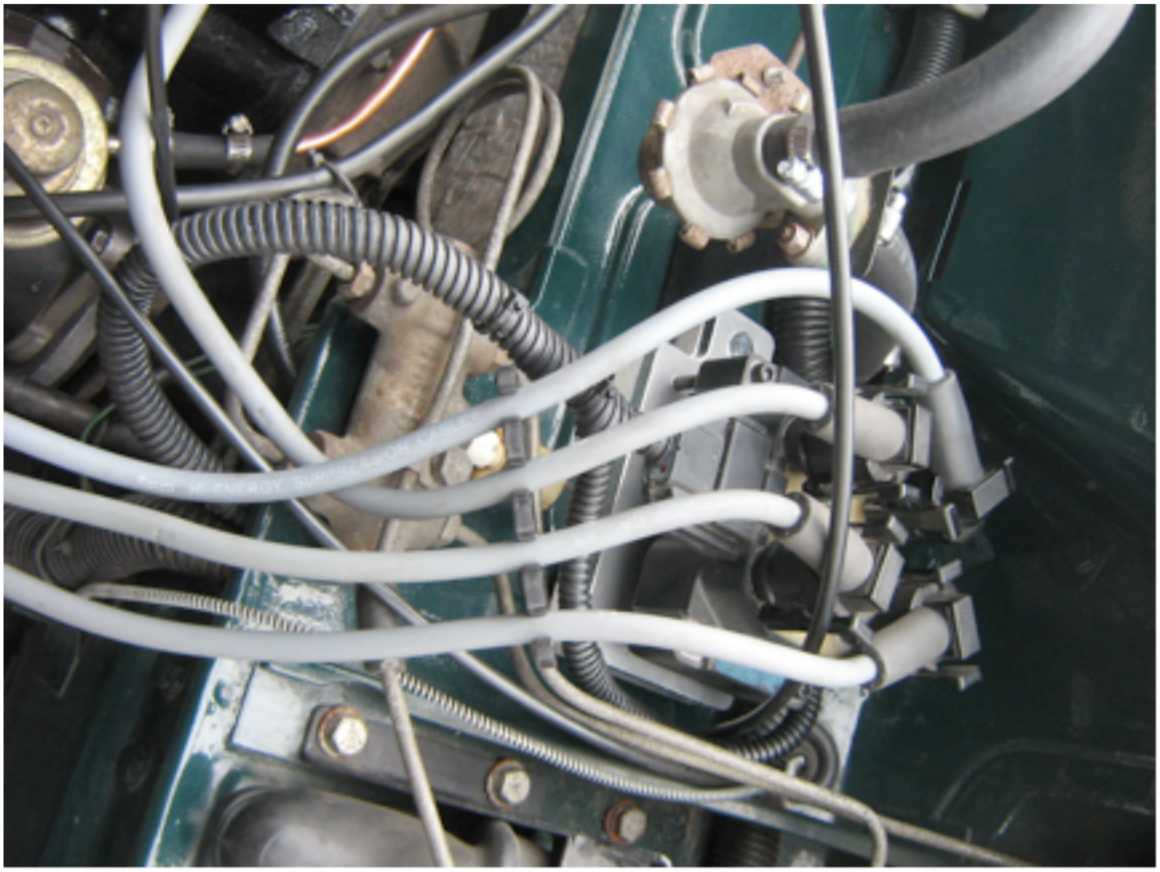

EDIS and Megajolt units mounted in footwell, on other side of firewall and deck, here


MEGAJOLT LITE JR.
PROGRAMMABLE IGNITION

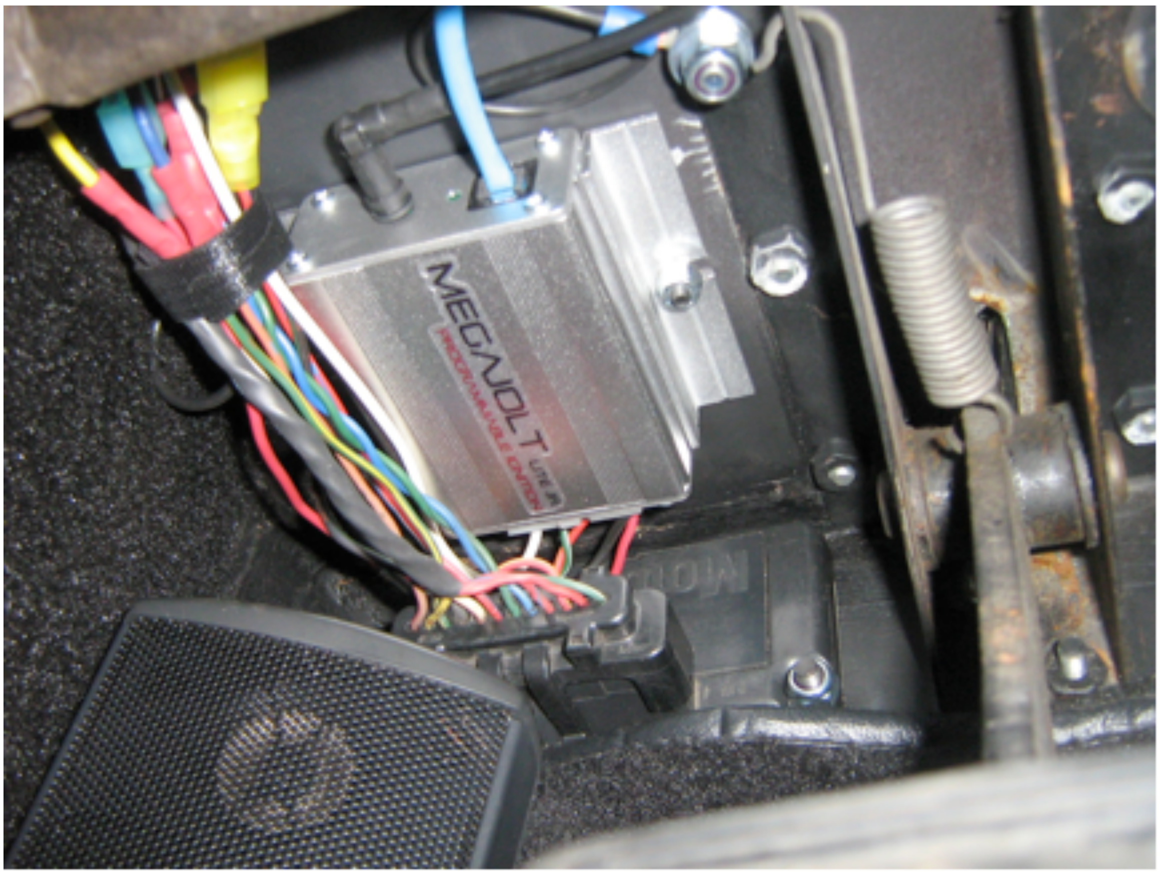
The MegaJolt box needs to be mounted in a protected environment, and locating it and the EDIS module close together reduces wire lengths and minimizes the chances for interference on the signals between them.

I decided to mount the coil pack where the original coil used to be. To accommodate the coil pack, I fabricated a two piece interface plate that mounts to the car with 1 ½ inch long 5/16 flat head machine screws and nuts utilizing the same holes that used to hold down the original coil clamp and the heater valve bracket. The coil pack in turn mounts to this interface plate. The plate is a sandwich of ½ inch thick "Starboard" marine polymer and ¼ inch thick aluminum (both scrap pieces lying around my garage). The Starboard is notched to accommodate the heater valve bracket and the aluminum is tapped with screw threads to receive the four 2-inch long #10-24 Allen head machine screws that secure the coil pack to the plate.

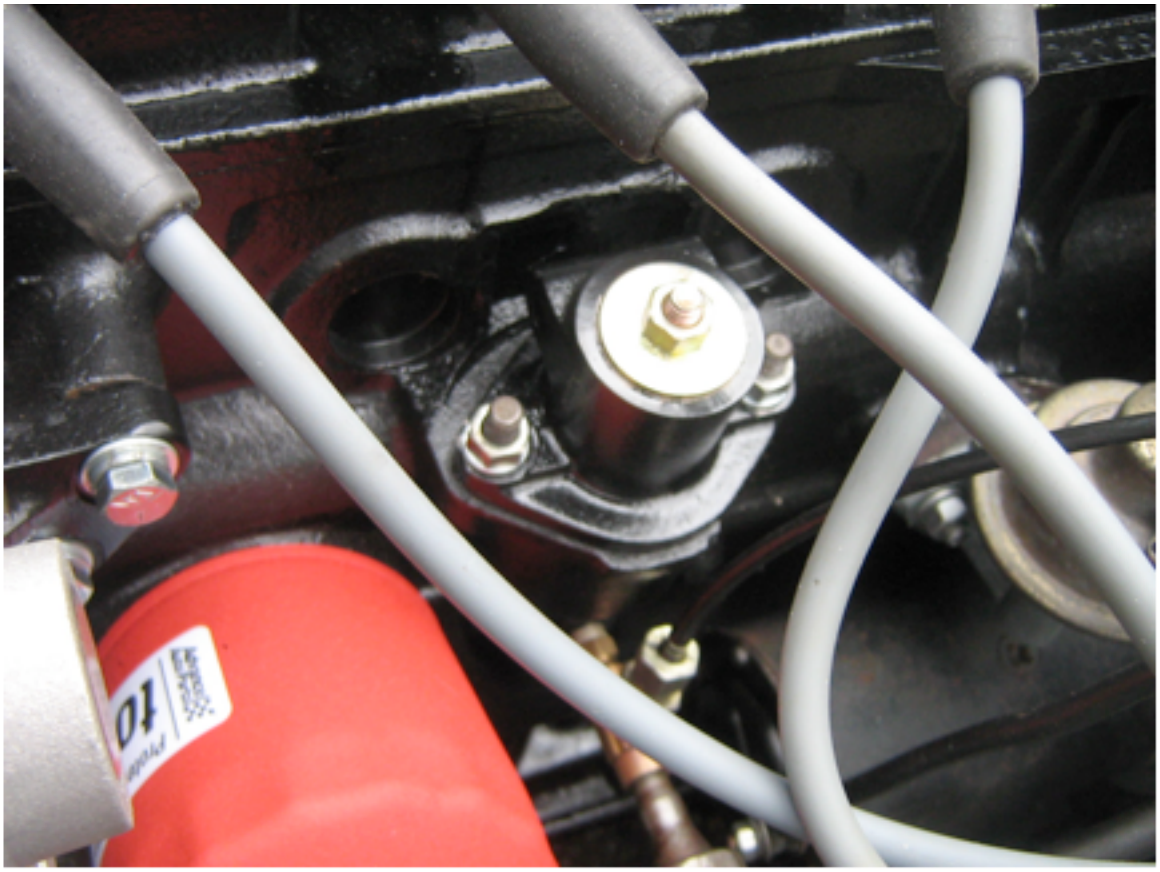
A set of 1991-96 Ford Escort spark plug wires work perfectly well to connect the coil pack to the spark plugs.



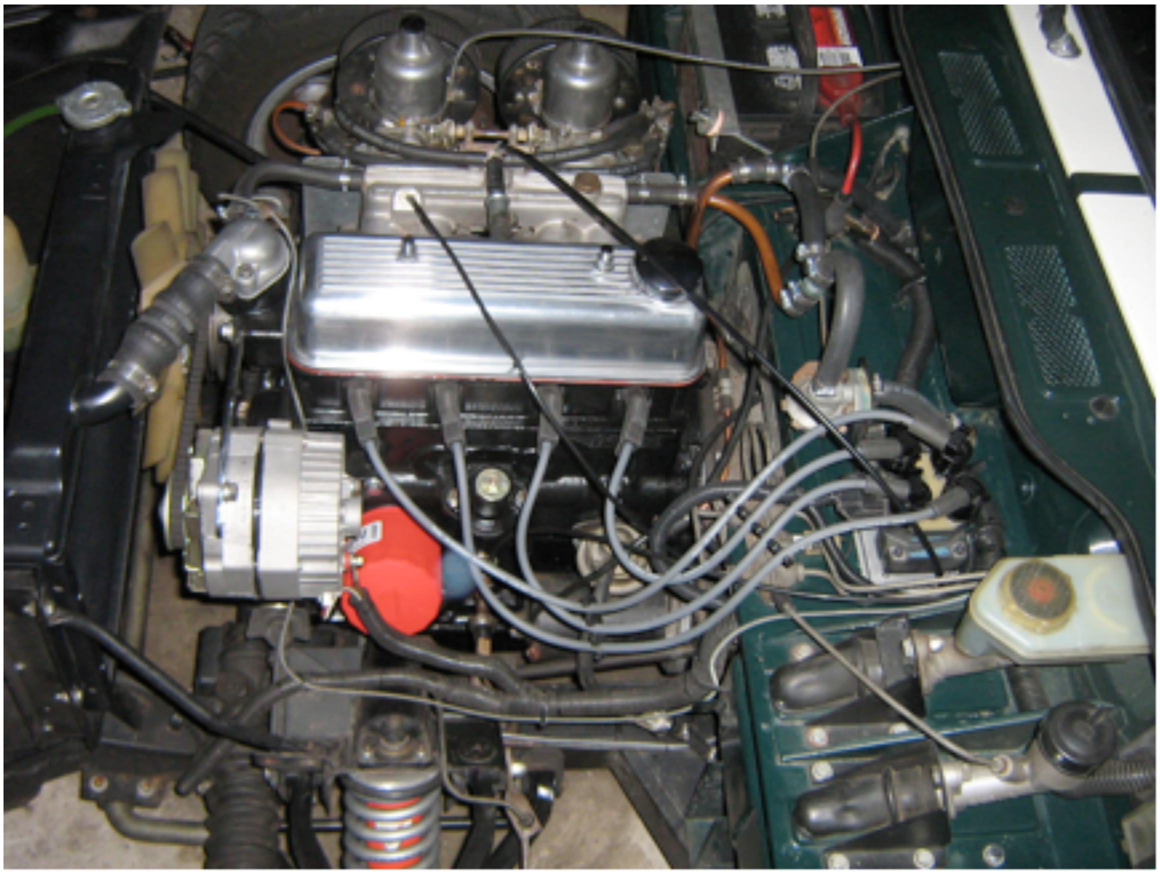
To connect the VR sensor to the EDIS module, I used 24 gauge shielded pair audio cable (from Radio Shack), and to connect the MegaJolt, EDIS and coil pack together and tie them into ignition switched power, ground and the tachometer, I fabricated a harness from 14 and 18 gauge stranded insulated wire. I chose the manifold absolute pressure (MAP) method of assessing engine load rather than the throttle position sensing (TPS) method, so I plumbed some 1/8 inch hard vacuum line from a 1/8 inch NPT fitting on the intake manifold to the MegaJolt box. I ran some cable from the MegaJolt box to the passenger's glove box for handy connection to a laptop PC for tuning and monitoring.



Lastly, with the distributor gone, I needed to keep the distributor drive gear because it also drives the oil pump. So I left the distributor pedestal in place, shimmed appropriately to set the correct drive gear clearance, and plugged the distributor shaft hole with a rubber expandable freeze plug:



Overall, I was pleasantly surprised with the ease of installation and operation, and I am very happy with the performance of the MegaJolt system. The software interface on the PC is intuitive and easy to use, provides useful display options, logs data for analysis later and has several input and output options I have not mentioned here. Given the non-stock state of preparation of my Spitfire's current engine, the MegaJolt system has enabled me to tap more of the engine's performance potential. Besides, it's fun!



More information about my '78 Spitfire can be found here:

http://www.auskellian.com/paul/78.html

For more information about MegaJolt, visit Autosport Labs on the web at:

http://www.autosportlabs.com and http://www.autosportlabs.org

If you would like to implement closed-loop control over fuel injection or are thinking about doing it some day, then the big brother of MegaJolt, called MegaSquirt, is for you. You can use just its ignition control function now, akin to MegaJolt, and utilize its other features later. For more information about MegaSquirt, visit:

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