An Injected Future

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I have just completed converting my 190 SL to a modern engine management system that will fully manage the ignition and fuel delivery process. It totally modernizes the car and changes the driving experience.

Several months ago, there was a thread on the Forum discussing the newer fuel injection systems being installed in classic cars. That caught my interest since twenty years ago; I had installed a primitive fuel injection system in a track car that I was building. After thoroughly reading the Classic Fuel Injection UK web site, I was very impressed with its modern sophistication and use of adaptive routines to improve the engine tune while driving. After viewing an image of the Jenvey throttle body, I was impressed with how closely it resembles a Weber DCOE carburetor. By using the Jenvey throttle body, I could maintain the original appearance of the 190 SL engine compartment by retaining the original air log and air filter. Some may say that this conversion is too expensive but it costs less than the cost of rebuilding a pair of Solex carburetors.

An overall view of the final installation. The Jenvey throttle bodies look very much like Weber DCOE carburetor. Note the fuel rail connects the two throttle bodies and then head to the fuel pressure regulator under the intake hose.

My objective with the installation of the engine management system was to provide easier starting; smoother acceleration and a consistent idle. I wanted to install the system without drilling any holes in the chassis or doing anything that could not be easily returned to original.

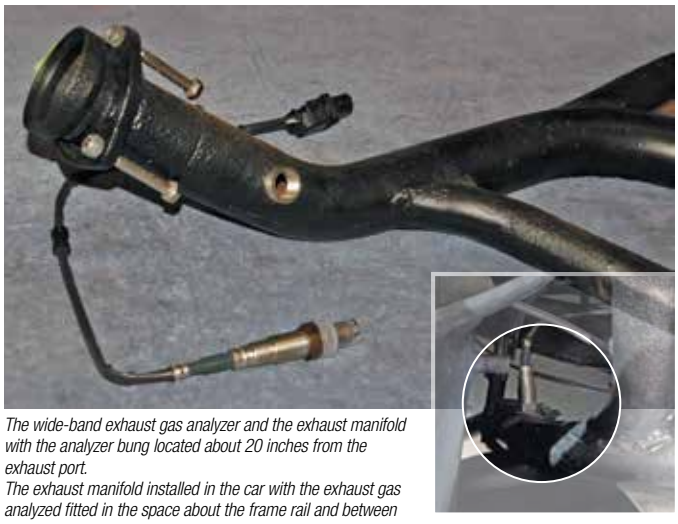
The fuel injection kit from Classic Fuel Injection arrived from the United Kingdom in a large box. Opening the box was like Christmas; I continued discovering new boxes with more components, fittings and wires. The kit included a 13 page installation manual and another 13 page introduction to the software tuning program for the Maxx Engine Control Unit (ECU). A USB memory drive contained addition documentation and the tuning software for the ECU. The kit was very complete; attention had been taken to include everything needed to install the engine management system. Quality was foremost, the connectors were waterproof, the wiring harness was wrapped with a chemical and abrasion resistant wiring harness tape and all generic terminals were clearly labeled.

The Jenvey throttle body. It contains two 350cc fuel injectors and a throttle position sensor.

All of the engine management system laid out on the floor

My first task was to layout the kit on the floor and connect all of the components to the wiring harness so that I could get an overall understanding of the system and to begin planning on how to install all of these items into the engine compartment and make it look organized. There were lots of components: exhaust gas sensor, exhaust gas amplifier, water temperature sensor, intake air sensor, high pressure fuel pump, fuel pressure regulator, idle speed valve, idle speed controller, injection amplifier, engine control unit, distributor pickup, throttle position sensor, fuel injectors, power center with fuses and relays and finally, the wiring harness that connected all of these components together. The kit also contained ample fuel hose, vacuum hose, fittings and clamps. It is interesting to note that the kit only connects to the existing electrical system in three locations, a 12V positive connection, a ground connection and the ignition switched positive connection on the coil. Like all big projects, I focused on it one component at a time.

Exhaust Gas Sensor



The wide-band exhaust gas analyzer and the exhaust manifold with the analyzer bung located about 20 inches from the exhaust port.
The exhaust manifold installed in the car with the exhaust gas analyzed fitted in the space about the frame rail and between the fender and the starter motor.

All engine management systems measure the oxygen in the exhaust gases to determine the fuel requirements of the engine. The instructions recommended that the Bosch wide band exhaust gas analyzer be installed about 20 inches from the exhaust port. I had a spare exhaust manifold and located a good location for the sensor about six inches from the end of the header. This would locate the sensor above the frame rail between the inner fender and the starter where there is ample room. I drilled and ground a hole in the manifold for the sensor bung and had it welded in place.

Engine Temperature Sensor

The 190 SL engine has one access to the engine coolant in the head. I first tried sharing the location with both the engine temperature gauge and the new water temperature sensor but the new sensor indicated a temperature about 20 below the actual head temperature. Since the engine temperature parameter is used in almost all of the ECU calculations, it needed to be accurate. So, I made a M12 to M14 adapter that would mount the new temperature sensor in contact with the engine head coolant. I then mounted the temperature gauge sensor in the coolant drain hole using a M14 to M14 spacer to account for the length of the sensor bulb. The gauge reads very low but it is more important for the ECU to receive the accurate temperature than the driver.

Air Intake Temperature Sensor

Vacuum (or Manifold Absolute Pressure, MAP) is an important parameter used by the ECU (under the air cleaner), fuel pressure regularter (lower center) and idle air step valve (at left with the small air cleaner).

After considering several locations for the air intake temperature sensor, I chose to locate it on the bottom of the air filter snout. I need to make a 14mm hole in the snout to secure the sensor with a nut. This was the second hole that I made but since I have a spare air cleaner, I felt that it was reversible.

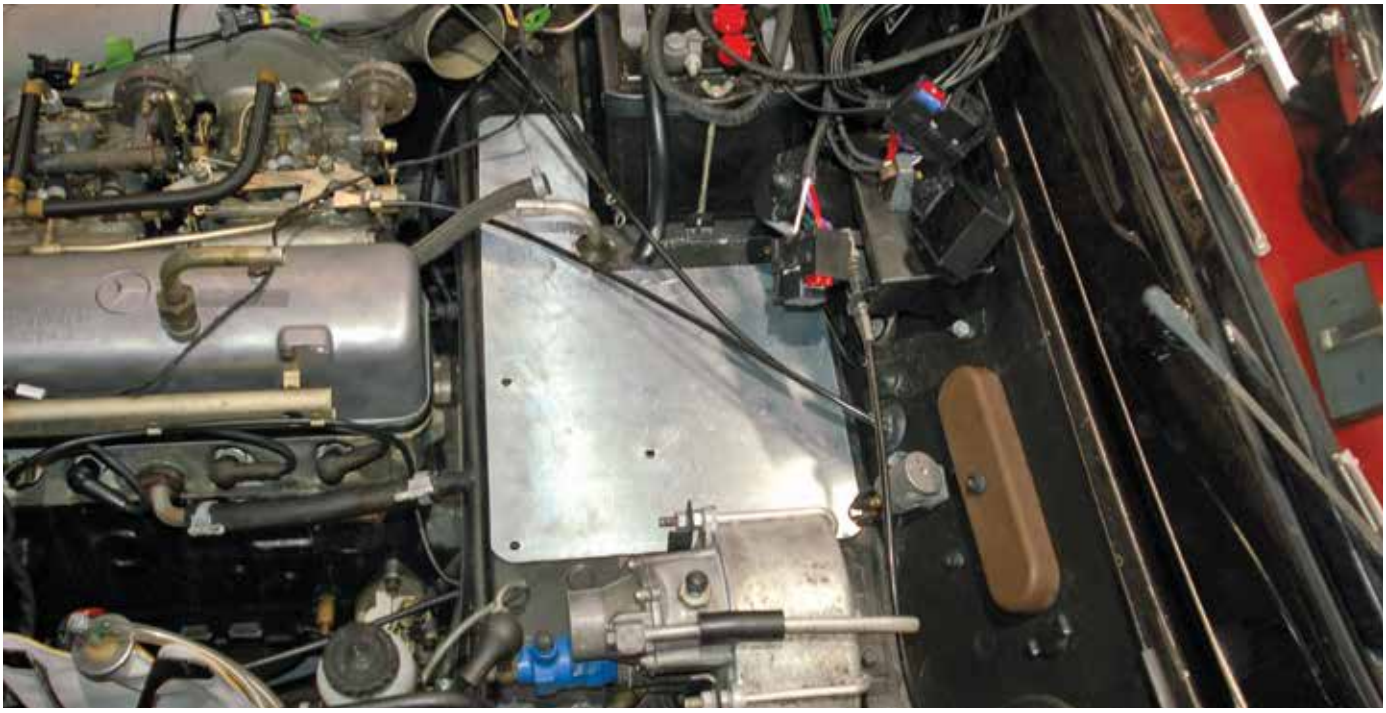
Distributor Pickup

The distributor centripetal advance weights wired in place to inactivate the mechanical distributor advance. The ignition trigger is static at 10 degrees before top dead center.

This system utilized my Pertronix distributor pickup to provide an ignition trigger. The system, however, requires that the centrifugal advance to be frozen so that the distributor provides a consistent crank position trigger since the ECU will control the ignition advance. I used wire to tie the centrifugal weights within the distributor firmly in place. The distributor was then installed, set to ten degrees before top dead center (BTDC) and locked into place. Before changing the carburetors or making any other changes to the ignition system, I started the engine and verified the distributor adjustment with a timing light.

Installing the Components

My next task was to figure out how to position and install all of the components within the engine compartment. I decided to locate them on the shelf between the battery and the brake booster and wrapped around the air filter. I removed the air cleaner and made a cardboard template of the area, extending under the vacuum line to the booster. I converted this template to a 25 gauge steel plate into which I could drill holes and fasten the components. The key to getting all of the components to fit on the plate was to elevate the fuse relay component above the idle controller.



The metal foundation plate for mounting engine management components. It has been cut to fit the available space including the area beyond the brake booster vacuum pipe. Note the holes where the air filter base can be bolted to the chassis and secure the plate.

All of the components mounted on the foundation plate. Note that the fuse and relay component is mounted above the idle speed controller.

The location for the idle speed stepper valve was dictated by its need to share the brake booster vacuum hose.

Likewise, the fuel pressure regulator needed to be located with access to the fuel rail hose and the return fuel hose to the tank. I needed to flatten the regulator bracket so that the regulator would fit under the air cleaner rubber hose. The next challenge was to get the wiring harness to fit within the space and to reach all of the components.

Wiring Harness Adjustments

The air and water sensor wires needed to be split out from the injector wiring harness to become independent wires. These wires and the injection wiring harness were then wrapped with wiring harness tape. I also looped a couple of wires and wrapped them with the wiring harness tape so the loop seemed to disappear. One of the advantages of using a universal engine management system is that it is built utilizing off of the shelf components and I was fortunate to locate the same water proof connectors used in the injection kit on Amazon and purchased a kit with multiple sizes. I first cut the fuel pump wire and installed a two wire connector so that the component tray could be removed without needing to remove or cut the fuel pump wire. I also reduced the length of the exhaust gas amplifier wire by about two feet by cutting the lead and installing a new four wire connector.

The fuel pump and filer mounted under the trunk between the fuel tank and the second spare tire well.

Fuel Pump Installation

My car currently has an electric fuel pump installed under the trunk in the gap between the fuel tank and the second spare wheel well. Since the new 45psi high pressure pump is the same size as my current pump, it easily fit in the same location and was secured by a bracket bolted into a stand-off bolt from the gas tank mount. I connected the fuel pump wire to my existing fuel pump wire above the transmission tunnel. For the record, my existing wire accompanied the rear wiring harness down the left side of the tunnel, under the rug of the foot well and into the trunk.

Fuel Lines

The metal main fuel pipe is connected to the fuel hose that leads to the throttle bodies. The fuel return line from the fuel pressure regulator is connected to the metal reserve fuel line.

Fuel Injectors require a consistent high pressure fuel supply. This is done by circulating the fuel from the high pressure fuel pump, through a fuel rail past the injectors, to a fuel pressure regulator that maintains the fuel pressure and adjusts it based of manifold vacuum. Low pressure fuel is returned back to the tank. Fortunately, the 190SL has two metal fuel lines from the tank to the engine compartment, the main and reserve line. I removed the reserve fuel valve and used a hose splice to connect the main fuel line to the high pressure fuel hose and routed it around the front of the engine to the front throttle body, then to the rear throttle body and then to the fuel pressure regulator. The return fuel hose from the regulator follows along the rear of the engine compartment above the water heater lines, and connects with the reserve fuel metal line. I removed the reserve valve control rod and used that firewall hole and grommet for the fuel pump wire.

Throttle Bodies

The fuel line connects the two Jenvey throttle bodies and then connects to the fuel pressure regulator. Note that the original accelerator linkage is utilized.

I chose the Jenvey throttle bodies because they resemble a Weber DCOE carburetor and they would utilize the stock air log and air filter. The throttle body contains two fuel injectors and the master throttle body contains a throttle position sensor. A nice feature of this throttle body is that it utilizes the Weber fuel line banjo fittings. Because the dimensions are the same as the Weber, the stock throttle linkage was utilized. I will add one lesson learned; the carburetors came with a device that connected the two throttle shafts. The 190 SL carburetors sit at different height so that this device would not work. I needed to order another throttle shaft link from Jenvey but a universal 5/16 inch throttle link worked well until the Jenvey link arrived. *(continued)*

A view of the components with the air filter installed. The idle air step valve with a small air filter is next to the battery and connected to the vacuum pipe.

Maxx Engine Control Unit (ECU)

A sample of the tuning parameter tables. This is the ignition advance map that sets the ignition based on the vacuum (an indication of the throttle opening) and engine RPM. Note that at wide open throttle, the ignition advance is reduced from the maximum.

The heart of the engine management system is the Maxx Mini ECU and the software that sets its parameters. This is a sophisticated unit that manages each parameter in small but manageable increments. The Maxx ECU contains a manifold absolute pressure (MAP) sensor which is the heart of the ECU. I sometime use the term vacuum but MAP is the correct technical term for an injection system. The ECU utilizes a three dimensional fuel map to compute the fuel requirements of the engine at any instant in time bases on engine temperature, MAP and RPM. The fuel delivery, determined by the fuel map, is constantly adjusted based on the amount of oxygen measured in the exhaust stream by the exhaust analyzer. ECU manages the fuel delivery based on engine temperature, manifold vacuum, and engine RPM and it adapts the fuel delivery and ignition cycle through all driving conditions from constant speed driving to spirited acceleration. The ECU has a special routine for managing the startup and the idle conditions.

Initial Static Tuning

With everything installed, the ECU required some initializing tasks. With the tuning software installed on my laptop and the laptop connected to the ECU with a USB cable, I turned the ignition switch on and opened the tuning software. It first recommended an update to the firmware which took about 3-4 minutes (note: do not turn off the ignition during this process). Next, it was time to un-check the static ignition setting used to set up the distributor and to set the basic system configuration; piston displacement, sensor types (Bosch water and air temperature sensors), injector capacity and to calibrate the throttle position sensor by clicking on calibrate at the open and closed position. The software can appear a little daunting but the instructions included with the kit are very clear and the software interface is intuitive.

Starting the Engine

It is time to see if the system works. To my surprise, the engine started on the first try. It coughed a few times as air was purged from the injectors but it quickly settled down to a smooth but fast idle. The engine revved up with the ease and speed that I had never experienced with a carburetor. I let the engine warm up to operating temperature so I could burp the air from of the cooling system. I started the engine a number of times and it started quickly and easily every time. After adjusting the idle speed parameters, it idled smoothly around 1000 RPM. I think that I must have a small vacuum leak as that was the lowest that I could get the engine to idle. But even with a vacuum leak, it idled smoothly at a constant speed.

Idle Control

The engine idle speed can be adjusted to varying speeds as the engine temperature rises.

The idle management system is not simple. It uses the distributor pickup to establish the engine speed and it maintains the assigned speed by controlling the air bleed into the manifold with the stepper air bleed valve. The idle speed is based on engine temperature. The idle fuel mixture is first determined by the fuel map and then modified by an idle enrichment map. My engine will not idle below 1000 RPM because vacuum leaks from various sources. The ECU, however, will manage the fuel delivery so that the idle is smooth. This system replaces the carburetor choke, fast idle cam and idle speed and mixture adjustment screws.

Driving and Adaptive Tuning

The fuel delivery parameter map is the heart of the engine management system and the Maxx ECU utilizes an adaptive routine to update and adjust the fuel map as the car is driven. Basically, the adaptive tuning feature is turned on so that the ECU could create recommended changes to the fuel map for a specific engine temperature, engine speed and manifold pressures. The process is to drive the car smoothly at various speeds, review the recommended changes and then merge the changes into the fuel map. The process is repeated until the car runs well under all conditions and the table of changes contains only small changes. This process easily resulted in an excellent fuel map for this engine.

I found it interesting the level of control that the software provided to tune every aspect of the engine envelope. Just looking at the startup cycle, the software will enrich the fuel mixture for the first six minutes of the engine running and the level of enrichment can be adjusted for each minute.

I looked at the ignition advance map and was somewhat surprised; the ignition advance varies with both the engine RPM and manifold vacuum. Additionally, the map can be fully revised to achieve tuning goals.

While the tuning of the ECU may appear daunting, the default parameters work well and with adaptive learning of the fuel delivery, the system works well enough so you do not need to get into the details unless it interests you.

With the installation complete, it is hard to put into words the improvements to the feel and drivability of the car. The engine performs like a modern engine in the way it starts, idles, and drives. It pulls strong in all gears from 1200 to 5500 RPM and it quickly hits the rev limiter in second gear. It is now a modern engine within a classic shell.

In my mind, there is no longer a Solex/Weber choice, just choose a modern engine management system.

Jim, thank you for the great photos and detailed explanation of the EFI conversion process. The "step-by-step" documentation you've created is invaluable, especially for those of us considering this type of modification. Well done!

Thanks again, Bill & John