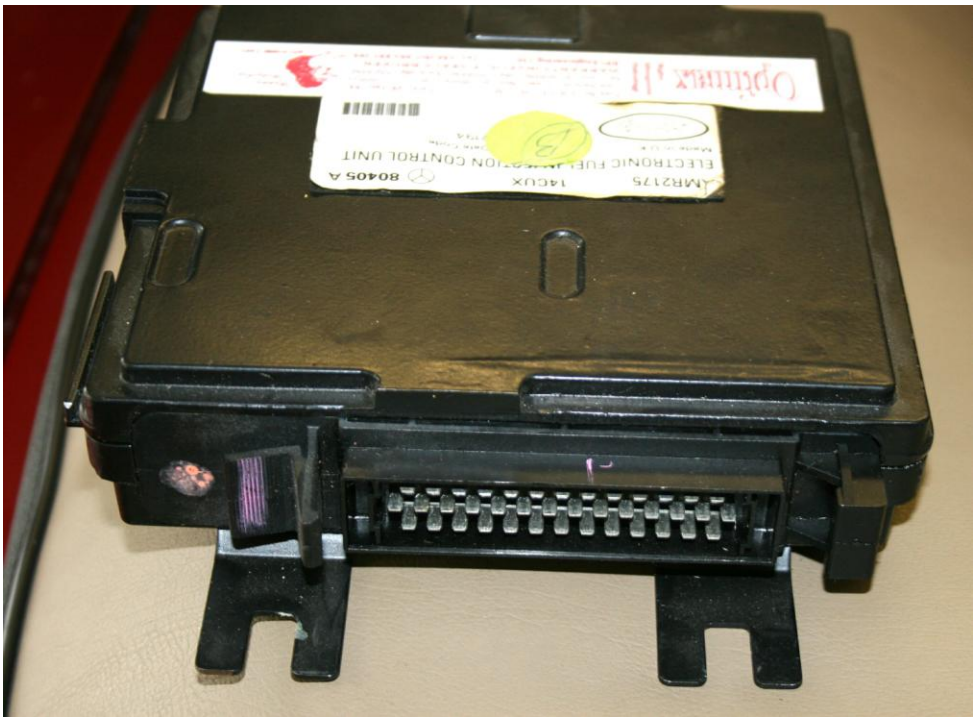


ECU in the RV8 – what is it and what does it do?

At a quick glance the RV8 has the retro MGB Roadster appearance but, developed and produced three decades after the original MGB, it's a substantially re-engineered car in many ways, not least with an engine management system. Many members without the technical knowledge are keen to try an understand how that engine management system works so here Nic Houslip explains what the ECU is and what it does in the RV8's engine management system.

What is the ECU and where is it in an RV8?

An **ECU**, or **Engine Control Unit**, is a powerful electronic control system capable of gathering hundreds of channels of information to control every aspect of an engine, even its own efficiency. In an RV8 his black box is tucked up under the dashboard on the passenger's side and is the electronic brain that controls the fuel injection of the Rover V8 engine. It is a **Lucas 14CUX** developed with input from Bosch.

Fuel injection has been common in production cars since the late 70s and early 80s, but the system has been under continuous development since the early 1940s when both Bosch in Germany and Bendix in the USA developed fuel injection systems for airplane engines. The problem that spurred the development was **something we don't usually suffer from in cars, it is known as negative G**; when the fuel in the carburettor rushes to the top of the float chamber and away from the main jets. Of course this would also occur when flying upside down, but the primary reason is to keep the engine performing when fighting, especially diving and turning under combat conditions when the plane is subject to negative G force.

Almost all fuel injection systems in the world today are developed from the work that Bosch did and then had patents granted for. The Daimler Benz fighter plane engines had fuel injection, whereas the Rolls Royce Merlins in the Spitfire and Hurricanes had carburettors until near the end of the war, when an SU and later a Bendix system was used on very late marques. Bendix didn't succeed in converting its aviation experience into automotive applications anywhere near as well as Bosch.

The **piston engine's need for precise delivery of fuel and air are complex** and great precision is necessary to ensure the right fuel air mix is supplied at all times and under all conditions. Let's think about the main points that need controlling: **starting** must have a richer mixture than the normally accepted 14.7:1 **Air to Fuel** or **AFR** ratio. **Acceleration** demands power, power demands fuel and again richening of the mixture makes this possible, while under normal conditions **running steadily** needs a slightly lean mixture - nearer to 15:1 for economy and complete combustion.

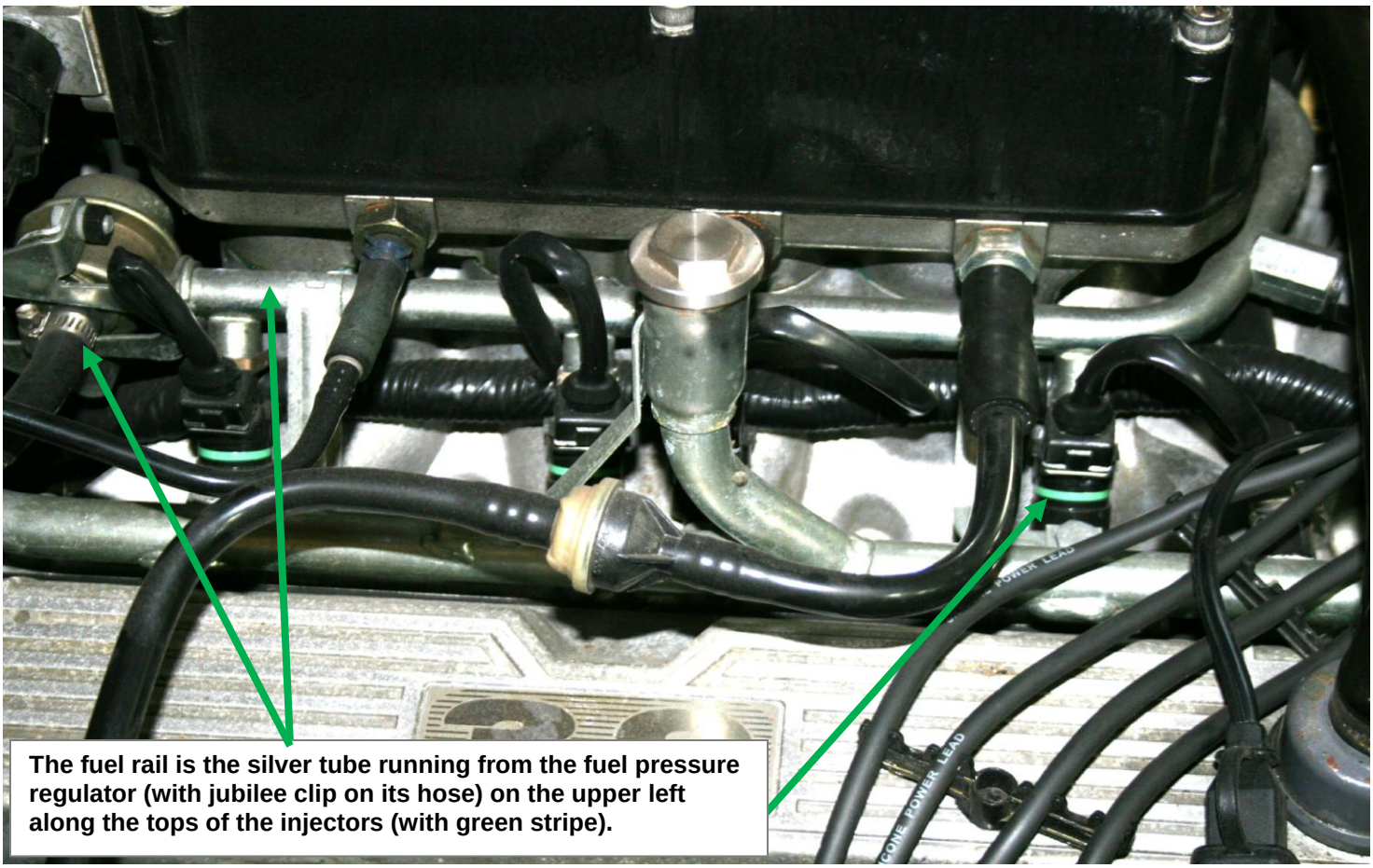
But how do we control this fuel mixture?

The first requirement is to know how much air is going into the engine. If you recall that the throttle opens a butterfly valve that allows more air into the engine to control its speed, a device is needed to measure how much air is going in. The older Bosch Jetronic systems used a flap that was set in the entrance to the inlet manifold but before the throttle and its movement was proportional to the mass of air passing it. The more air that passed, the more it moved and in the early mechanical systems this controlled metering jets allowing more or less fuel to be injected. The immediate benefit was apparent when the first VW Golf GTis came out in late 70s. The performance was incredible, I know, I drove one for many thousands of miles in the 1980s and the difference between a Golf and a car with a carburettor was a revelation at that time.

Knowing the amount of air going into the engine, as measured by the air mass sensor on the RV8 enables the ECU to decide how much fuel to allow in. The correct AFR is described as **Stoichiometric**, which means that all the fuel and all the oxygen is consumed in the reaction we call burning. In actual fact the ratio varies slightly with the additives used in the fuel. The air mass sensor, also known as the **Hot Wire AFM (Air Flow Mass) sensor** is a clever device using two fine wires whose resistance increases as they cool – one is stretched across the middle of the air pipe and is heated by a small current and the second wire is unheated and is located in a bypass port and compensates for air temperature variations. A sensitive circuit detects this change of resistance in both wires and sends an analogue electrical signal to the ECU that is proportional to the Mass air flow.

So the ECU now has a signal that tells it how much air is flowing and has to decide when and how much fuel to admit via the injectors. The heart of the ECU is a device called a microprocessor. For all of you who understand microprocessors, please skip this section of the note, because I don't want any nit-picking; but for those who do not, here is a **simple analogy**.

A **man sitting at a desk** has a list of things to do from his boss. The man works as the microprocessor in our analogy; a description of this part would take up several pages and we don't need to know more for our purpose. The list the man has in our analogy is known as the Program. He has "In and Out Trays" and a filing cabinet where the "Look Up Table" resides. The "Look Up Table" information is stored as digital data in a memory chip known as an EEPROM or



The fuel rail is the silver tube running from the fuel pressure regulator (with jubilee clip on its hose) on the upper left along the tops of the injectors (with green stripe).

an **Electrically Erasable Programmable Read Only Memory**, but much more commonly as the **Chip**. This contains the data that tells him how much fuel and when to inject it. There is another filing cabinet with instructions on what to do under any circumstance (the **Firmware**) and an "Out Tray" where he puts the instructions to the injectors.

The data in the "In Tray" indicates that a certain amount of air is flowing, what the throttle position is, the engine's speed, its temperature, the air temperature and many other variables. The "**man sitting at a desk**" collates the data checks, the Firmware and makes the calculations that tell him where to "Look Up" in the EEPROM the amount of fuel and when to inject it, and puts the answer in his "Out Tray".

These tasks are done very rapidly and repeatedly. Typically, the microprocessor might be making hundreds of thousands of calculations per second, so you can see that whatever is going on in the engine, although fast by engine standards, it's like treacle flowing on a flat surface to that in the microprocessor. And just to put that into perspective, the microprocessor in the PC that I'm writing this note on is currently running at a clock rate of 1.5 GHz or 1,500,000,000 cycles per second. That means that it can, and usually does, make in excess of 150 Million calculations per second.

OK, you say, I can grasp all that, so what is next?

The ECU needs to know all the things that are going on in and around the car, but how does it get the data it needs? There are **sensors** located in the engine and on ancillaries so it knows what is going on. These inputs are converted into data that the microprocessor can use by small chips called **Analogue to Digital convertors in the ECU**. Think of them like a translator, the sensors speak an analogue language and the microprocessor only speaks digital.

The ECU needs the temperature of the engine coolant so it knows how to fuel it correctly, the incoming air temperature because its density and mass change with temperature and the fuel because its density and its viscosity changes. It also needs to know the engine speed which it gets from the ignition system and the throttle position, from the throttle potentiometer which is the primary indicator of the engine's load.

All of these variables are entered into the calculations that the ECU performs and eventually the result has to be translated into a signal to the injectors (into the "Out Tray") thus allowing fuel into the inlet manifold. But how does it do this?

Having looked up in the EEPROM to find out what the right amount of fuel is at any time, the microprocessor will pulse each injector with an electrical signal that opens and shuts a tiny electrically operated valve. The valve is operated by a **Solenoid**, something we are all familiar with for the starter motor, but in this case much smaller. The electric current moves an iron core to open the valve. The solenoid and valve are contained in the injectors that sit on the inlet manifold and spray fuel supplied by the fuel rail into the inlet port of each cylinder.

When the signal arrives it snaps the valve open and then a spring snaps it shut, they are extremely fast acting and allows precise metering. Because the flow through a given orifice is a function of the pressure difference either side of the orifice, the fuel pressure regulator holds the pressure at a constant 2.5 bar above the manifold pressure, so you can see that as the manifold pressure varies according to throttle opening, the regulator ensures that the fuel flow is correct. One small point here, the **fuel rail** is located above the

manifold and gets heated by air and contact with engine warming the fuel, the leak back from the regulator ensures that a continuous supply of relatively cool fuel from the tank is always present.

This metering has to be very precise and in very small quantities. Think about one cylinder; with the car running at 2000 rpm (about 60 MPH or 1 mile per minute] that cylinder will fire 1,000 times per minute (because there are 2 revolutions for each power stroke) and will require a tiny drop of fuel every time it fires. If the car burns fuel at 30 MPG, or for convenience 30 miles per 5 litres, this will be roughly 6 miles per Litre. In 6 miles the engine will turn 12,000 times and fire 6,000 times, so we know that the eight injectors in total would pass 1 Litre of fuel, thus the injector for our cylinder will pass 125 cc of fuel. Divide this 125 cc by 6,000 and you get the answer, about 0.02 cc per injector per firing stroke. The injector has to deliver this 1,000 times per minute! Hour after Hour, Day after Day, Year after Year. If during hard acceleration the engine speed exceeds a certain pre-set rev limit, such as a missed gear change or if you deliberately keep your foot down, the fuelling is reduced until the RPM drop down below that limit to prevent damage to the engine.

Another important function for the ECU

The ECU has to control mixture strength, which is monitored continuously by the **Lambda sensors** which sense the amount of oxygen in the exhaust gas. It does this by means of a "**feedback loop**" that signals to the ECU the how much oxygen is present in the exhaust gas and attempts always to keep it stable and the mixture correct. If it is too rich it reduces by a small amount the fuel injected and increases it if too weak. Imagine this as a nudge to the man doing the calculations on how much to inject, so he turns a little knob one way or the other to bring it back into range. You may have heard of a system running "open loop" which is when the feedback loop isn't completed and the ECU is allowed to run as it thinks it should without regard to the Lambda sensor. There are cases where this is necessary. The Lambda sensors are made of a special ceramic material that needs to be heated above 300 deg C by passing a current through a heater in contact with them to operate, this current is controlled by the ECU to ensure that they heat up quickly and are able to sense, and enable the ECU to maintain correct mixture to avoid poisoning the **Catalysts** with unburned fuel.

In case you wonder **why it is called a Lambda sensor**, the oxygen content is assigned the Greek letter **λ** (Lambda). Nothing mystical, no more unusual than **π** (Pi) which I think we are all familiar with; it's just that all the other Greek letters were used for something else. Lambda is also used in radio work denoting the wavelength of the signal because it is pretty close to our letter L.

The **ECU also receives signals from the road speed sensor** to decide if the fuel should be shut off entirely when coasting downhill with a closed throttle and to control the idle speed when the car is stationary. You may notice that as you roll to a stop, the idle speed is usually a bit higher and drops quite quickly to its correct speed. It does this by means of a small motor driven valve that admits more or less air into the manifold (effectively bypassing the throttle). More air leans the mixture and the idle speed rises, less air richens it and it falls. The idle speed is also increased for starting and is monitored and adjusted continuously. For example, if you switch on the headlights, or the air conditioning if you have Japanese re-import, while the engine is idling you will see the engine speed drops slightly and then recovers as the idle speed is adjusted to cope with extra load the alternator or refrigerant pump imposes on the engine. This is **another example of closed loop control**, the ECU gets a signal from the distributor in the form of pulses as each plug fires and counts these to determine engine speed. The motor driving the valve is called a **Stepper Motor**, because it is fed with a signal that is in effect a series of pulses, the number of which determine where the motor actually comes to rest by stepping it in tiny parts of a degree of rotation. A very common type of motor these days, ideally for driving by a microprocessor because they are both "digital". There are at least three in your inkjet printer for example!

ECU control

All of the functions mentioned are continuously under the ECU's control and the mixture is monitored according to demands made on the engine. You might wonder how the ECU knows what the engine is being asked to do, well the control that indicates it is the **throttle position sensor**. That tells the ECU where the throttle is and also how fast it changes position. If you are cruising at a steady speed and open the throttle gently and slightly more, the ECU knows how much more load the engine is going to be subject to and adjusts fuelling accordingly but if you snap the throttle open it knows two things - one that the throttle moved quickly so richens the mixture to cope with that and also it adjusts the fuelling for a large load so that the engine responds as quickly as you need it to.

Diagnostic routines built in too

Built into this magic box - and it is pretty clever - are a number of diagnostic sub routines in the software that check that all the sensors are sending out signals that are usable, that the sensor is in fact connected and if it finds things that are not what it thinks they should be then it will set a fault code in a place called a register where an **OBD (On Board Diagnostic) fault code** reader can display it so you know where to look for the problem. The various parameters that the microprocessor controls can be read by using an electronic device (either a standalone one like the **ECUmate** or the **Rover TestBook** or a **Laptop PC** with the right program) that talks to the microprocessor so the values that the microprocessor is reading (engine temperature, rpm, fuel temperature, etc.) and the outputs it is making (idle speed, fuelling etc.) can be displayed.

Chipping an engine

It should be clear that the engine's power output is controlled, within certain limits, by the ECU. **You will have heard of people "Chipping" their engine's ECU to get them more power**. This is certainly possible, but there is a caveat. The manufacturers of the engine will have spent thousands of hours running engines on dynamometers to make sure that the engine not only performed as required under any and all conditions, but also met regulations on emissions of noxious substances, was easy to drive and would last a lifetime. What is not always made clear is that this extra power from chipping comes at a cost; Longevity. If an engine is expected to last say, 100,000 miles with the OEM chip installed, we can be sure that the majority of engines produced will meet that. But if you "Chip" the engine to give you 20% more power that must increase the load on the engine's bearing surfaces and parts like the pistons that are subject to great increases in pressure and temperature.

What will the increase in power do to your engine?

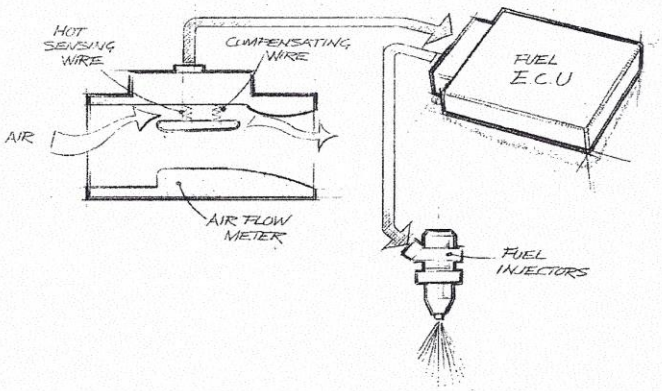
If you don't use it often, because you have a light right foot, probably not much. If you do use the available power, and why would you go to the expense of chipping and not do so, then wear will be increased. Sufficient to say that re-chipping will invalidate your warranty.

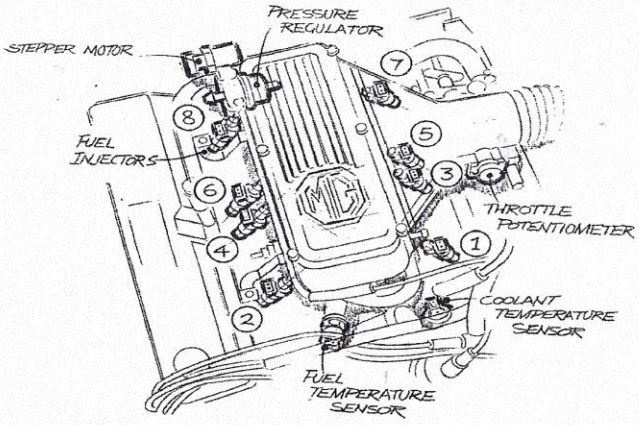
ENGINE MANAGEMENT

Introduction

Fuelling on the MG RV8 is controlled by the well proven Hot-Wire system. The Hot-Wire system gained its name because it controls fuelling by measuring the resistance of a pre-heated wire located in the air inlet system. As the amount of air passing across the wire increases, so its temperature decreases. This decrease in temperature causes the wires resistance value to increase.

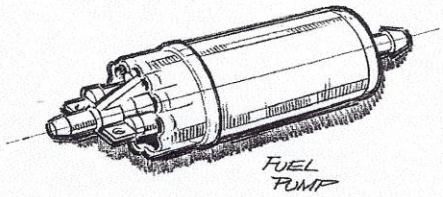
This increase in resistance is registered by the ECU, which then alters the fuelling accordingly. This isn't the only reading taken by the ECU though. In this section we'll look at the complete fuel management system; its components, and their operation.





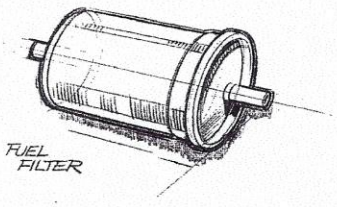
The Fuel System

Fuel is drawn from the tank by an electrically driven pump located below the right hand rear wing.
The pump also increases the pressure of the fuel.



Now at high pressure, the fuel travels along the fuel supply line and enters a fine mesh (2 Micron) filter. The filter is a vital part of the fuel system as it protects the finely machined injectors against small particles that may be present in the fuel. If these particles were allowed to reach the injectors, their lifespan and operating efficiency would be seriously affected.

When fitting a new fuel filter, make sure the arrow on the filter body is pointing in the correct direction. i.e. in the same direction as the flow of fuel.
The filter is located forward of the fuel tank.



After leaving the filter, the fuel travels towards the left hand fuel rail (cylinders 1, 3, 5, & 7). The injectors open alternately in groups of four. Injectors 1, 3, 5, & 7 all open at the same time, followed by injectors 2, 4, 6, & 8.

Not all the fuel entering the fuel rail is injected into the inlet tracts. Some is used by the injectors as both a coolant and lubricant. The remainder of fuel continues to travel along the fuel rail until it reaches the Pressure Regulator. The Pressure Regulator, as its name suggests, controls the pressure within the fuel rail.

When inlet manifold depression is high, it tries to suck fuel from the injector. In this case, the Pressure Regulator will lower the pressure in the fuel rail, to ensure that the correct amount of fuel is injected.

As depression inside the inlet manifold reduces, the Pressure Regulator raises the pressure inside the fuel rail. This extra pressure is needed to help "push" the correct amount of fuel into the inlet manifold.

Injector opening time is controlled by the ECU. Located under the glovebox, it uses readings sent from several sources (see Electronics section) to determine when, and for how long, to open the injectors. As we have just mentioned, each bank of injectors opens alternatively, with each bank firing once per engine cycle (two engine revolutions).

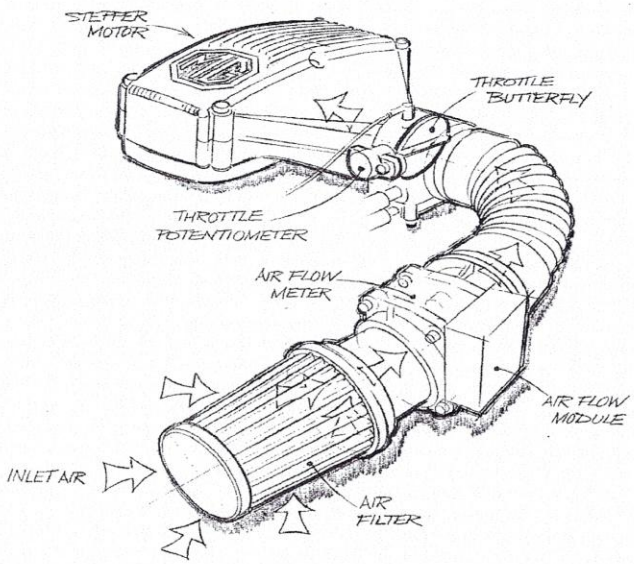
Fuel that hasn't been used by the injectors is allowed to pass through the Pressure Regulator and returns to the fuel tank via the aptly named Fuel Return Pipe.

The Air System

In addition to controlling the amount of fuel that enters the combustion chamber, we also need to control the amount of air. If the correct volume of air isn't drawn into the combustion chamber, the fuel will not burn efficiently.

Inlet air enters the system through the air filter located at the front of the engine bay. From here it enters the Air Flow Meter. The Air Flow Meter is perhaps the most important component in the whole engine management system.

It is the Air Flow Meter that contains the heated sensing wire we mentioned earlier.



Inside the Air Flow Meter is a by-pass port. The heated wire runs across the port, and is accompanied by an un-heated "compensating" wire. Both have a small electric current running through them, and are connected to the Air Flow Module on top of the meter.

As air flows into the meter, a proportion of it is allowed to flow through the by-pass port. The un-heated "compensating" wire now registers the temperature of the inlet air, which is sent to the ECU via the Air Flow Module. The heated "sensing" wire is used to find out how much air is entering.

As we mentioned earlier, inlet air cools the heated wire as it passes over it. The greater the volume of air passing over, the cooler the wire gets. As the temperature of the wire goes down, its electrical resistance increases. This change in resistance is registered by the Air Flow Module and the information sent up to the ECU.

After leaving the Air Flow Meter, the inlet air travels towards the Throttle Butterfly. The Throttle Butterfly is controlled by the accelerator, and controls the amount of air allowed to enter the Plenum Chamber. The further down the driver presses the accelerator, the further the butterfly opens.

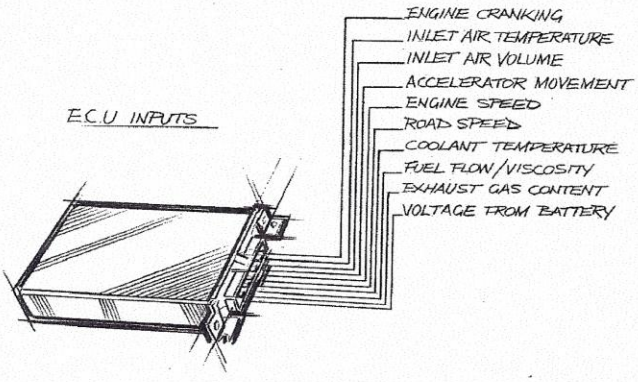
At idle, the butterfly is fully closed. In this condition, air is supplied to the Plenum Chamber via the air by-pass valve. The by-pass valve itself is mounted on the side of the Plenum chamber and is controlled by the stepper motor.

The stepper motor controls the amount of air allowed to pass through, keeping the idle speed stable. If the engine is fully warmed, and there are no additional loads, the stepper motor will create a small opening.

When the engine is cold, or there is a load acting on it, the stepper motor widens the opening, and in so doing, raises the idle speed. The stepper motor is controlled by the ECU.

Once in the Plenum Chamber, the air is drawn down into the inlet manifold, where it is mixed with the correct amount of fuel before entering the combustion chamber.

The Electronics System.

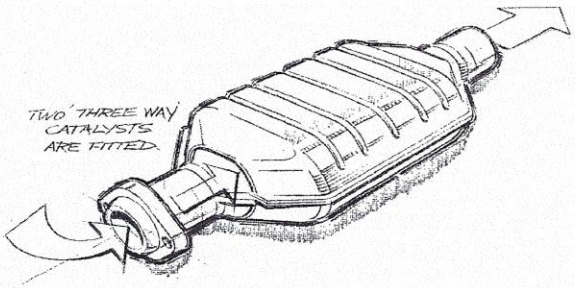


The "brains" behind the Hot-Wire system is the ECU. It receives the following inputs:

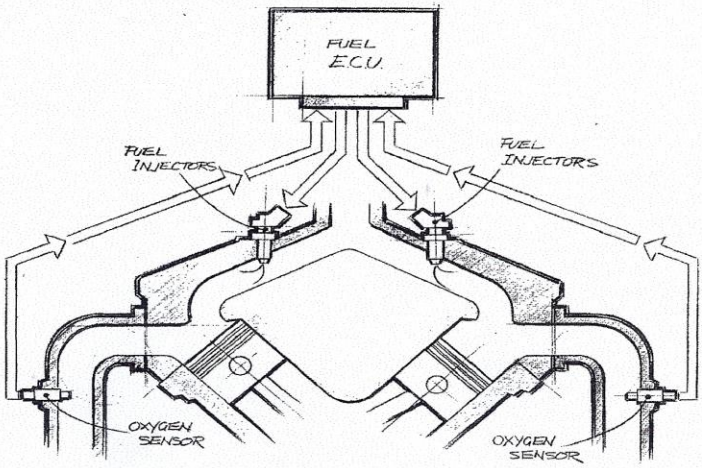
- An engine cranking signal from the ignition barrel.
- An inlet air temperature signal from the compensating wire.
- An inlet air volume signal from the sensing wire.
- An accelerator movement signal from the throttle potentiometer.
- An engine speed signal from the coil.
- A road speed signal from the speedo cable transducer.
- A coolant temperature reading from the coolant temperature sensor.
- A fuel flow/viscosity signal from the fuel temperature sensor.
- An exhaust gas content signal from the oxygen sensors.
- A voltage signal from the battery.

Using these signals, the ECU controls the opening times of the injectors, the idle speed (via the stepper motor), and exhaust emissions. In the event of a problem with the Hot-Wire system, the ECU can be interrogated using Microcheck and an updated Hot-Wire card (SMD 4072/12). The diagnostic port is next to the ECU.

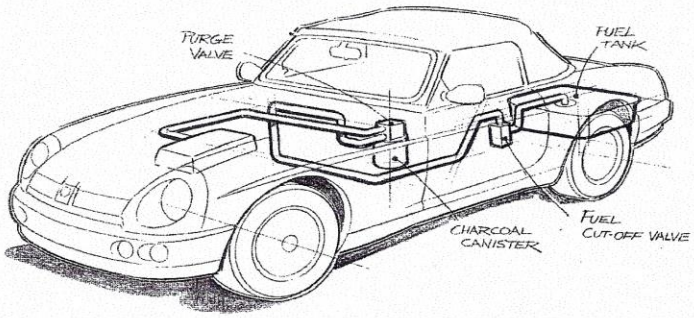
Emissions



The MG RV8 is fitted with a three way, closed loop catalyst system. The system comprises of two three way catalysts, and two heated oxygen sensors. Both sensors send messages up to the ECU, which then alters the fuelling accordingly. For more in-depth information on the operation of closed loop catalyst systems, refer to the Service Insight training package "Exhaust Emissions and Catalysts".



Caution:
Only ever use unleaded fuel in a car fitted with a catalyst. Failure to do so will seriously damage the catalyst. Similarly, never drive a catalyst equipped car suffering from a misfire. If unburnt fuel reaches the catalyst it will again, cause serious damage.



Further to the catalyst system, the MG RV8 is also fitted with a Fuel Evaporative Loss system. A charcoal canister, mounted on the bulkhead, is connected to the fuel tank to collect vaporised fuel when the engine is not running.

Mounted on the side of the charcoal canister is a purge valve. Controlled by the ECU, the purge valve empties the contents of the charcoal canister into the Plenum Chamber when engine temperature is above 54°C (130°F) and a manifold depression exists.

What handbooks and manuals are there for the RV8 and where can you get them?
http://www.v8register.net/subpages/BandGRV8technicalinfoCD.htm