Electronic Engine Management, Part 1

It's good to have an idea of how the engine management system works before you start modifying the engine!

By Julian Edgar

All engines require that the combustion air and fuel get mixed in the right proportions, and that each cylinder's spark plug is fired at the right time. Those are very important points to remember because it's easy to lose sight of these basics when making modifications or considering complex engine management systems.

Remember: it all comes back to:

- how much fuel
- and when does the spark fire.

The amount of fuel that is mixed with the air is described as the air/fuel ratio. A 'rich' mixture (like 12:1) uses lots of fuel and is good for power, while a 'lean' mixture (like 17:1) uses less fuel and so is more economical. The 10:1 air/fuel ratio shown on the meter here is very rich indeed! The ignition timing refers to point during the rotation of the engine's crankshaft that the sparkplug fires. This needs to vary because at high revs there is less time available for combustion to occur, and so the spark needs to start the burn earlier. Changes in timing are also needed at different engine loads, different temperatures and on different octane fuels.

Quick Overview

The first part of an engine management system is the **fuel delivery system**. This starts off at the high pressure fuel pump (pictured) that is mounted in or near the tank. The fuel line from the pump passes through a filter before it runs forward to the engine bay. The fuel line connects to a fuel rail that feeds each of the injectors. At the end of the rail is a fuel pressure regulator, with surplus fuel heading back to the tank in the return line.

The **air supply system** starts at the airbox. A pick-up collects air from the atmosphere and channels it through a filter. From there the air heads off to the engine. On some engines, an airflow meter is located close after the airbox. The throttle body (butterfly) controls how much air enters the plenum chamber. So that idle speed can be regulated, there is a bypass around the throttle body. The amount of airflow flowing through this bypass is regulated by a computer-controlled valve, which here can be seen on top of the throttle body. Once into the plenum (the aluminium box in the engine bay), the air is distributed evenly to each intake runner, flowing down the runner to the intake valve. Just before the air reaches the inlet valve it meets the squirting fuel injector. The air/fuel mixture then passes into the combustion chamber when the valve is open.

The **electronics system** of the engine management uses sensors. Many times each second they tell the computer what's happening to the engine. The computer is the brains behind the system, and in most cars it is called an ECU - an Electronic Control Unit. It is programmed by the factory to give the right outputs when it receives the right inputs. One example of the outputs it controls are the injectors.

The Inlet Sensors

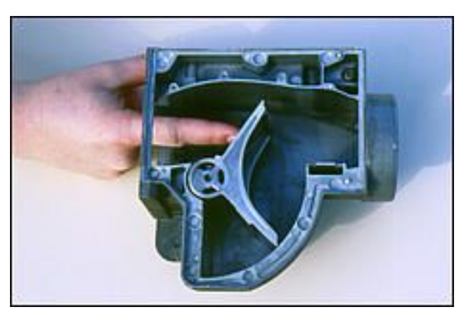
In order that the ECU makes the right decisions about how much fuel to inject and when to fire the spark, it needs to know precisely what the engine is doing. Is the car at full throttle up a long hill at 3000 rpm on a stinking hot day? Or is the cold engine idling down to the shop after it's just been started? It's the input sensors that give this sort of information to the ECU.

The **Coolant Temperature Sensor** tells the ECU how hot or cold the engine is. It is positioned on the thermostat housing on most cars - in this picture it's the sensor with the yellow plug. The sensor has different resistances to electricity at different temperatures. This means that as it get hotter, the sensor resists the flow of electricity less and less. The sensor is fed a regulated voltage by the ECU, and looks at the changing voltage coming back to it. From this, the ECU can work out the temperature of the coolant.

The temperature of the intake air is also measured. The sensor can be located on the airbox (as shown here) or on an intake runner. Just like the coolant temp sensor, the **Intake Air Temp Sensor** is a variable resistor. This particular sensor has a resistance of 3555 ohms at 20° C and just 475 ohms at 70° C. What? Your car wouldn't see an intake air temp of 70° ? It sure does on a hot day....

The ECU must know what the engine load is if it's to squirt in the right amount of petrol, and fire the spark at just the right moment. Some cars use an **Airflow Meter** to measure engine load. The amount of power being developed depends on how much air the engine is breathing. If the engine is drawing in a lot of air (because the throttle is fully open at 5000 rpm up a hill, for example) then lots of fuel will need to be injected to keep the air/fuel ratio correct.

There are a couple of different types of airflow meter available. This airflow meter is a **Hot WireAirflow Meter**. The air rushing into the engine flows around a platinum wire that's been heated by electricity passing through it. The airflow cools down the wire. The ECU tries to keep the wire at the same hot temp at all times, and can work out how much electricity it needs to pump through the wire to do this. The more electricity it needs to use, the more air that must be being breathed by the engine! Hot wire meters automatically compensate fro intake air temperature variations, measure mass flow (not just volume), and cause little restriction to the intake air. In the US a management system using this approach is sometimes called MAF - mass airflow.



This is a **Vane Airflow Meter**. This type of meter works by having a door across the inlet air path. When air passes into the engine, the door is pushed open (as is being manually done here). The wider the door is blown open, the more volume of air that is being consumed. The door is connected to an adjustable electrical device called a pot. The pot has a variable electrical resistance, and it's connected so that the resistance of the pot changes at different airflows. The vane airflow meter always causes a restriction to the inlet air because there's the vane in the way. Because it measures only air volume, vane airflow meters have a built-in temperature sensor. With both volume and temperature inputs, the ECU can work out the mass of air being breathed.

Some cars don't use any form of airflow meter. These cars use the input of three sensors to work out how much air is being breathed by the engine. One is the inlet air temp sensor, the other is a rpm sensor (we'll get to that in a moment), and the final one is a manifold vacuum sensor. This sensor is called a MAP (Manifold Absolute Pressure) sensor. A **MAP Sensor** constantly measures the vacuum in the intake manifold. The amount of vacuum depends on revs and throttle opening. In the US this approach is sometimes "speed density".

If the MAP sensor registers a low manifold vacuum and the rpm sensor indicates that the engine is pulling high revs, the ECU knows that lots of fuel is needed. High manifold vacuum at high **or** low revs means that the throttle is closed - so that's a low load situation. A MAP sensor is tee'd into the intake after the throttle butterfly and doesn't cause any intake restriction at all. Because the same MAP sensor can be used on any naturally aspirated engine, it's the type of load sensor used with programmable management systems like MoTeC.

A big exhaust will make good power on any car. But an EFI car with airflow metering will measure the extra air needed and add the correct amount of extra fuel. A MAP-sensed car with a new exhaust may run lean enough to actually drop power, because the ECU doesn't know that there's the extra airflow. All it knows is that there's a certain manifold vacuum at a certain rpm with a certain inlet air temp. The other thing to be aware of with a car running a MAP sensor is that if you fit a hot cam, the car will run poorly at light loads. This is because the light load vacuum signal is changed by the cam and so the ECU will get confused. This makes ECU modification vital when a new cam is fitted to a MAP-sensed engine.

Measuring engine load is fine, but at times the ECU also needs to know how far open the throttle actually is. A **Throttle Position Sensor** tells the ECU this information, which is used during acceleration enrichment, for example. Most throttle sensors use a variable pot, but some sensors are just two position switches - one position for idle and the other for full throttle. The sensor shown here uses a pot and so the ECU always knows exactly how much throttle opening is being used.

The ECU needs to know how fast the engine's spinning and where the crankshaft is in its rotation. This lets the ECU fire the spark and injectors at the right time. There are a couple of different types of **Crankshaft Position Sensors**. This Nissan **Optical Crankshaft Position Sensor** uses a light shining through slots cut in a circular plate. The plate is attached to the end of the camshaft and is whizzed around past a LED that provides the light. A sensor on the other side of the disc registers when it sees the light shining through one of the slots, with the ECU then counting the light pulses. Some optical sensors use 360 slots in the disc, allowing very fine resolution of engine speed. Different shaped slots positioned elsewhere on the disc allow the ECU to calculate crank position.

This is a **Hall Effect Crankshaft Position Sensor**. It uses a chopper disc that spins around inside the dizzy. Every time the metal vane comes between a magnet and a special Hall sensor, the Hall sensor switches off. The computer looks at the speed of the pulsing and works out engine rpm and where the crank is in its rotation.

The purpose of the **Vehicle Speed Sensor** is dead simple - it tells the ECU how fast the car is going down the road. The sensor can be mounted on the gearbox (as here) or in the speedo. The sensor shown here is driven by a gear on the gearbox output shaft. Speed sensing is used by the ECU in some cars to limit top speed and also to improve fuel economy and drivability.

The **Oxygen Sensor** is located in the exhaust close to the engine. It tells the ECU whether the car is running rich or lean at part throttle. The sensor generates its own voltage output, just like a battery. When the air/fuel ratio is lean, the sensor generates a very low voltage output, like 0.2 volts. When the mixture is rich, the voltage output is higher, like 0.8 volts. The ECU uses the output of this sensor to keep mixtures around 14.7:1 a lot of the time.

The **Knock Sensor** is like a microphone listening for the sounds of knocking (detonation). It's screwed into the block and is designed to separate out the special noise which means that knocking is occurring. Many EFI engines run ignition timing very close to knocking, meaning that this sensor is vital if engine damage isn't to occur on a bad batch of fuel or on a very hot day. Some cars (especially those with V engines) run two knock sensors.

Engine Management, Part 2 - The Outputs
Engine Management, Part 3 - The ECU