Subject:
Evolution of Engine Load Measurement Devices. *[Part One]*

Overview

The evolution of load measurement devices has been driven by improvements in materials, manufacturing and technology. The two most critical pieces of data required by the modern engine management system is engine speed/crankshaft position and engine load. As engine load input has the largest effect on injector pulse time of all engine sensors, accuracy of measurement is of prime overall importance to deliver premium system performance.

Since the use of electronic fuel injection systems commenced as far back as the early 1950's, certain critical factors of engine operation have been required to be monitored. There are several key pieces of engine data required by the electronic control unit [*ECU*] to control even the simplest of systems. These include,

- Engine Speed [*RPM*]
- Engine Load
- Coolant Temperature
- Air Temperature
- Throttle Position

Whilst the sensors that generate these signals have evolved with technology to allow the ECU to support more functions with greater clarity, the methods for measuring engine load have gone through many interesting phases to provide more accuracy, less complexity and increased reliability. The engine load signal has the biggest effect on fuel injector "on time" of any of the signal inputs to the ECU, hence its accuracy is critical for fuel control.
Essentially there are two operating strategies that are used in the design of an engine management system in reference to how engine load is measured. These two methods are,

- ***Manifold Pressure Control [MPC] or Speed/Density*** – uses a Manifold Absolute Pressure or MAP Sensor.
- ***Air Flow Controlled [AFC]*** – uses an air flow or air mass sensor.

There are various advantages and disadvantages of both of these strategies that we will discuss. It must be understood in all systems, the ECU must finally arrive at a calculation of the ***mass*** of air inducted by the engine in order to calculate the correct volume of fuel to be injected.
As manufacturing processes and technology has improved, this has allowed us to improve on some design issues.

MAP Sensor versus Air Flow Sensor.

There is no rule to say whether MPC systems are better than AFC or vice-versa, manufacturers choice relates to many factors including performance, cost and reliability. Some of the issues are,

- MPC systems solely utilise manifold vacuum as an indication of engine load. Normal engine wear causes manifold vacuum to reduce, the system will interpret this as an increase in engine load and therefore increase the amount of fuel injected. The basic result is that as the engine wears the mixture becomes richer and richer over time.

- MPC systems are less affected by air leaks and generally have less complex inlet ducting.

- MPC systems are re-active to throttle movement due to the fact that manifold vacuum changes after the throttle has moved. AFC systems however have immediate reaction to changes in incoming air flow.

- As the engine wears and manifold vacuum drops, so does air flow. Hence the output from the air flow sensor reduces with the result that AFC type systems tend to maintain a serviceable air/fuel ratio over the entire life of the engine.

- Air flow sensors tend to be more expensive and complex than MAP sensors, they are also more susceptible to backfire damage and external tampering.

Manifold Absolute Pressure [MAP] Sensors.
Released in 1967, the Bosch D-Jetronic *[“D” standing for the German word “Druck”, meaning pressure]* fuel injection system utilised the first “MAP” sensor, a sophisticated mechanical device. Referred to simply as a pressure sensor or aneroid, this device contains a brass diaphragm attached to a metal “slug” that moves in and out of two electrical coils affecting their inductance. As the engine load changes so manifold vacuum alters, the diaphragm within the sensor moves, and the electrical output to the ECU changes giving it a variable “load” signal. Due to the mechanical nature of this device, it is inherently slow. To aid in overcoming any flat spotting issues, D-Jetronic uses a sophisticated throttle position switch assembly that causes the ECU to provide multiple injection pulses on rapid throttle opening.
Although certain vehicle manufacturers utilised D-Jetronic up until the early 1980’s, MPC type systems were not the system of choice of most manufacturers.
MAP Sensor technology changed dramatically during the mid 1980’s with the introduction of a piezo-crystal type sensor. Simply a piezo-crystal will produce a small voltage as it is subjected to pressure. By connecting a sensing chamber to the inlet manifold via a hose, changes in manifold vacuum will distort the piezo-crystal causing it to produce an output. This signal is then amplified and transmitted to ECU as a load signal. These sensors are much faster, cheaper and more reliable than the old mechanical D-Jetronic version. It is interesting to note however that the design problem related to flatspotting with MPC type systems still exists. Modern engine management systems using a MAP sensor use an injection mode referred to as “Asynchronous” injection to resolve flatspotting. This design feature allows the ECU to provide multiple injector pulses irrespective of crankshaft position and normal injection frequency.

Continual development and investment in this technology by Bosch has seen MAP Sensor design take a further evolutionary step with the creation of the ***“T-MAP Sensor”***, an integrated temperature and MAP sensor. These sensors allow the engine management system to accurately detect both manifold pressure and inlet air temperature within one sensor at one point in order to make an accurate assessment of the weight or mass of air being inducted by the engine.

The next section of this article will deal with the design, construction and operation of Bosch Air Flow and Air Mass Sensors including the latest “Reverse Flow Detection” sensors. These sometimes complex devices are often mis-understood and the true design brilliance for their day is not fully recognised.