Speed-Density
Fuel Injection Systems

With no mass or volume air sensor, it's sometimes hard to understand just how a speed-density system works. But it turns out to be the simplest of all fuel injections.

I t's the descendant of the D-Jet fuel injection system (see "D-Jet Rules!," May 2000 *Import Service*) and the electromechanically simplest form of fuel injection currently in manufacture — simplest, that is, if you don't count the system's software operations as electromechanical. We'll not quibble about what word to use, though. The sensors on the system don't include any kind of air mass or air volume measurement. That's all inferred by the computer from the other sensor's information and then corrected later as reflected in the oxygen sensor's feedback reports. Let's see how Honda's popular and long-developed speed-density system works and what can go wrong with it.

It's not a very exciting box to look at, but here's where all the interesting things are in a speed-density system. The computer memory includes very extensive look-up tables enabling it to set a fuel mixture very close to the money from little more information than the crankshaft position and the MAP sensor signals.

The essential structure of the speed-density system is that the computer estimates the amount of air from reading a variety of sensors and from information stored in its look-up tables. This is not the vague 'guesstimation' it seems because the carmakers have over fifty years of research data on just what kind of fuel and air combinations work best on their various engines at every conceivable combination of temperature, engine speed and intake manifold vacuum/pressure. They get this information from extensive road and dynamometer testing at their research facilities around the world, test results they keep very close to their vests.

Couple that information, encoded in the look-up tables, with the feedback signal information from the oxygen sensor or sensors, and you have a fuel injection system that can yield the same mixture accuracy as systems that directly measure the incoming air mass or volume, either by hotwire/hot-film or swinging-door potentiometer. And this speed-density system avoids employing an expensive and delicate airflow sensor.
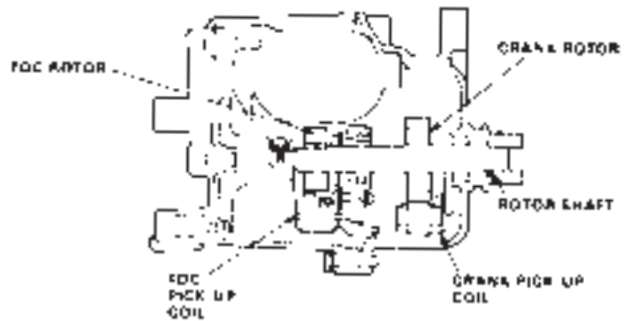
The Sensors

So the computer gets two fundamental pieces of information: the engine speed from the crankshaft position sensor and the intake manifold pressure from the intake manifold absolute pressure (MAP) sensor. With these two factors, it consults its look-up tables for the injector pulse-width listed for that combination of speed and pressure. With that tabular pulsewidth, the computer then scans its auxiliary sensors to modify the planned pulsewidth accordingly.

For example, it will increase the pulsewidth if the throttle is suddenly opening or if the engine is cold. It will decrease the pulse width under the opposite conditions. It will shut off the fuel entirely if the throttle is closed, the manifold pressure is low enough and the engine speed is above a certain threshold. None of this should be particular news to an experienced mechanic, because all engine management systems do the same kinds of things, even those that do not work by speed-density formulas, because all of them should generate roughly equivalent injection commands.

In a moment, we'll go over a typical set of sensors used to come up with the fuel-quantity estimate and correct it to stoichiometry. Keep in mind that while all of them are used to various extents, the system does have provision to substitute a plausible value if one or the other sensor fails. This works for most of the sensors, like the coolant temperature sensor, but not for all, such as perhaps the camshaft position sensor. Some are relatively predictable (engines tend to get warmer at a known rate, and coolant temperature rarely changes abruptly), while others must appear in the right form and at the right time or it will be impossible to sequence the injection, much less to time the spark. Some lost signals, in other words, allow a limp-home strategy; others shut the engine down.

Keep in mind also there is probably no carmaker that makes major design changes to their engines and engine controls as frequently as Honda, so while speed-density remains the overall structure of their system, there may not be a single interchangeable part from a given model year to the next. This is not a criticism of Honda's engine and engine system design but a recognition that they will change something as soon as they invent an improvement. It does mean you need current information for the car you have in your workbay, though. Another carmaker you may have heard of with extensive speed-density products is General Motors.


The speed factor comes from the crankshaft and camshaft position sensors, often closely adjacent on Honda systems shown here in schematic and in the other column in photo. These are conventional inductive pulse generators.

The Big Two

First let's look at the two major sensors, electromechanical perceptors of speed and density, of course. There are many different Honda crankshaft position sensors, but they do the same thing, generate a pulse or train of pulses to indicate an identifiable position of the crankshaft on each revolution. It doesn't matter which position they pick to flag with the pulse, since the computer can calculate how far from it to the optimal positions for spark and for fuel injection. To tell where the engine is in the 720 degrees of the full ignition cycle, there is also a camshaft position sensor. The sensors in our illustration are both on the distributor shaft, spinning at the end of a camshaft, with multiple pulses for the crankshaft signal and one for the cam.

You can test inductive sensors like these in two different ways, by measuring the resistance through their coil or by scoping their output signal. Many experienced mechanics rely only on the latter, having been fooled once or twice by a defective sensor that still sported good ohm numbers.
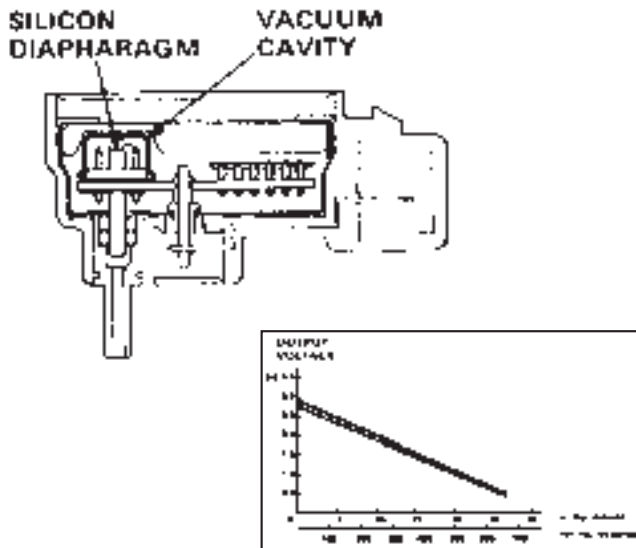
Density information comes from the intake manifold MAP sensor, telling the computer just what the pressure is in the intake manifold. This allows a close if not exact calculation of the amount of air and oxygen available for combustion and thus of the amount of fuel the computer should inject.

Why do they describe manifold absolute pressure as *density*? I don't know, but I suppose it's close enough to the right word. The version in our illustrations includes a vacuum chamber connected to the intake manifold with a vacuum hose. As the absolute pressure in the manifold changes, its effect on the silicon diaphragm changes the resistance through the terminals. The graph shows the correlation between vacuum and voltage and the relatively small tolerance for variation in the sensor's signal. Some MAP sensors are mounted remotely from the engine to protect them from the block's high-G-force, low-amplitude vibrations, while others are directly attached to the intake manifold. As with any other pressure sensor connected to the intake manifold by a vacuum hose, your first diagnostic suspicions should aim at the hose and its connections. Porosity, cracks or debris in the rubber hose are much more common than failure of the sensor itself. Check the condition of the electrical connectors next.

As described, with those two signals the computer can draw from its look-up library a fuel injector pulsewidth close enough to right so the engine will run reasonably well under almost any conditions, assuming spark, compression and the usual rest of the story. Merely running, however, is not enough, either for driveability or for emissions. We'd like the car to run predictably and don't want to poison-gas the neighbors, at least by mistake. So the system has to include a full set of emissions control sensors and actuators to keep the engine running clean.
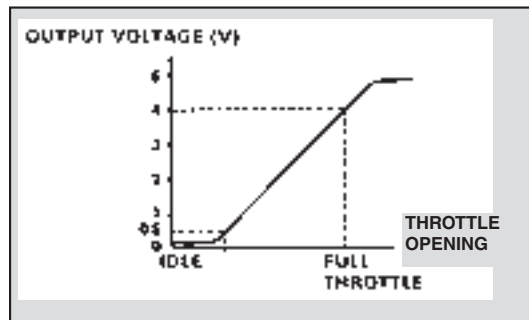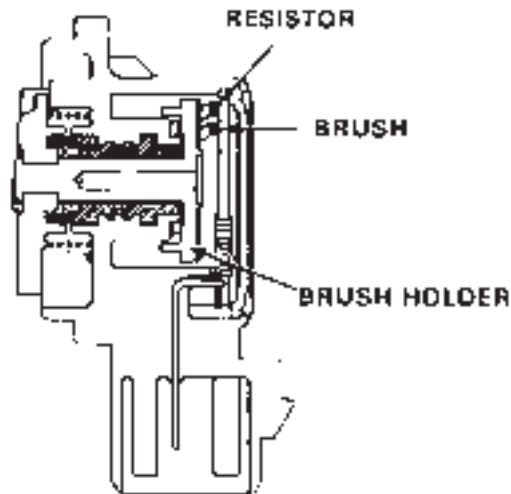

The throttle position sensor on a speed-density system works just like the corresponding sensor on most other fuel injection systems, with a varying return voltage depending on the position of the throttle pedal. This sensor also provides information about the speed of throttle plate movement to the computer.

Rounding Up the Usual Suspects

Like almost all fuel injection systems, a speed-density system requires a throttle position sensor. While the system can estimate it under limp-home conditions, there is no way to accurately estimate the speed the throttle opens under quick changes of throttle position. That means the acceleration enrichment mixture may go inaccurate, either too rich or too lean, if the TPS signal falls out. As sliding-resistance potentiometers, of course, the TPS can also lose its signal altogether in one or more spots on the sliding scale but be accurate at all other positions.
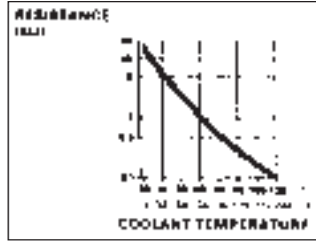
The engine coolant temperature sensor and the intake air temperature sensor measure different things but in the same way. Both sensors are negative-temperature-coefficient sensors whose resistance goes down as their temperature goes up. The Honda coolant temperature sensor is a problem-intermittent for certain model years.

The coolant temperature sensor works by changing its resistance as the engine coolant temperature rises. On our sample, the sensor is a negative temperature coefficient (NTC) sensor, like most carmakers' corresponding input. That means the resistance goes down as the temperature goes up. For certain model years, Honda coolant temperature sensors had a reputation for being more dubious than most, with intermittent supercold signals causing engine flooding at the next hot start. Sometimes, but not always, this sets a code since the computer's memory knows the engine coolant does not suddenly plummet under normal conditions.

The intake air temperature sensor is almost identical in structure to the coolant temperature sensor. The signal from this sensor tells the computer to richen the mixture somewhat for colder, denser air and to lean it when the weather is hotter and thinner.

Feedback Format

The final fuel trim is based on the return feedback signal from the oxygen sensor. Honda uses more than one kind of oxygen sensor to determine fuel mixture, though most of their cars employ the traditional zirconium sensor with an internal heater to get its signal working as fast as possible. Trouble codes and the diagnosis of oxygen sensor failures are by straightforward industry-standard voltage oscillations across the stoichiometric notch, except for the special lean mixture sensor, which we covered in June ("Drawing a Line In the Mixture"). The location of the Honda oxygen sensor makes checking it easier than most.

The computer itself is the central element in this system, of course. Receiving all the sensors' signals and sending out all the actuator's commands, the computer ties it all together, relying as we learned at the beginning on the research done over many years and miles at the carmaker's research facilities. The result is a system that is simpler in its hardware but more complex in its software to achieve the equivalent mixture controls.

—By Joe Woods