INTRODUCTION TO ENGINE MANAGEMENT SYSTEMS

The OBD II Home Page

The performance and emissions that today's engines deliver would be impossible without the electronics that manage everything from ignition and fuel delivery to every aspect of emissions control. Electronics make possible V8 engines that deliver excellent performance, good fuel economy and produce almost no pollution. But there's a price to be paid for today's technology, and that price is complexity.

Many powertrain control modules (PCMs) today have 16-bit and even 32-bit processors. Though not as powerful as the latest desktop personal computers, PCMs can still crunch a lot of information. It's been said that today's automotive PCMs have more computing power than the Space Shuttle's main processors. Kind of scary to think about, isn't it?

Does it take a rocket scientist to troubleshoot and repair drivability problems in today's cars? No, but it does take some knowledge, experience and diagnostic equipment that can access the onboard electronics.

IN A NUTSHELL

From the outside, most PCMs look similar: just a metal box with some connectors on it. The PCM's job is to manage the powertrain. This includes the engine's ignition system, fuel injection system and emission controls. The PCM receives inputs from a wide variety of sensors and switches. Some of the more important ones will be discussed in the following paragraphs.

THE SENSORS

The oxygen sensor provides information about the fuel mixture. The PCM uses this to constantly re-adjust and fine tune the air/fuel ratio. This keeps emissions and fuel consumption to a minimum. A bad O2 sensor will typically make an engine run rich, use more fuel and pollute. O2 sensors deteriorate with age and may be contaminated if the engine burns oil or develops a coolant leak.

On 1996 and newer vehicles, there is also an additional O2 sensor behind the catalytic converter to monitor converter efficiency.

Though most O2 sensors have no recommended replacement interval (replace "as needed" only), sluggish O2 sensors can be replaced to restore like-new performance. Unheated one- or two-wire O2 sensors on 1976 through early 1990s applications can be replaced every 30,000 to 50,000 miles. Heated three- and four-wire O2 sensors on mid-1980s through mid-1990s applications can be changed every 60,000 miles. And on OBD II equipped vehicles, the sensor could be replaced once it has seen 100,000 miles.

The coolant sensor monitors engine temperature. The PCM uses this information to regulate a wide variety of ignition, fuel and emission control functions. When the engine is cold, for example, the fuel mixture needs to be richer to improve drivability. Once the engine reaches a certain temperature, the PCM starts using the signal from the O2 sensor to vary the fuel mixture. This is called "closed loop" operation, and it is necessary to keep emissions to a minimum.

The throttle position sensor (TPS) keeps the PCM informed about throttle position. The PCM uses this input to change spark timing and the fuel mixture as engine load changes. A problem here can cause a flat spot during acceleration (like a bad accelerator pump in a carburetor) as well as other drivability complaints.

The Airflow Sensor, of which there are several types, tells the PCM how much air the engine is drawing in as it runs. The PCM uses this to further vary the fuel mixture as needed. There are several types of airflow sensors including hot wire mass airflow sensors and the older flap-style vane airflow sensors. All are very expensive to replace.

Some engines do not have an airflow sensor and only estimate how much air the engine is actually taking in by monitoring engine rpm and using inputs from the throttle position sensor, a manifold absolute pressure sensor (MAP) and manifold air temperature (MAT) sensor. Problems with the airflow sensor can upset the fuel mixture and various drivability problems (hard starting, hesitation, stalling, rough idle, etc.)

The crankshaft position sensor serves the same function as the pickup assembly in an engine with a distributor. It does two things: It monitors engine rpm and helps the computer determine relative position of the crankshaft so the PCM can control spark timing and fuel delivery in the proper sequence. The PCM also uses the crank sensor's input to regulate idle speed, which it does by sending a signal to an idle speed control motor or idle air bypass motor. On some engines, an additional camshaft position sensor is used to provide additional input to the PCM about valve timing.

The manifold absolute pressure (MAP) sensor measures intake vacuum, which the PCM also uses to determine engine load. The MAP sensor's input affects ignition timing primarily, but also fuel delivery.

Knock sensors are used to detect vibrations produced by detonation. When the PCM receives a signal from the knock sensor, it momentarily retards timing while the engine is under load to protect the engine against spark knock.

The EGR position sensor tells the PCM when the exhaust gas recirculation (EGR) valve opens (and how much). This allows the PCM to detect problems with the EGR system that would increase pollution.

The vehicle speed sensor (VSS) keeps the PCM informed about how fast the vehicle is traveling. This is needed to control other functions such as torque converter lockup. The VSS signal is also used by other control modules, including the antilock brake system (ABS).

A couple of things to keep in mind when replacing sensors: Parts that are physically interchangeable may not be calibrated the same and won't work properly if installed in the wrong application. To make sure you get the correct replacement part, it may be necessary to refer to the vehicle VIN as well as OEM numbers on the original part. Some aftermarket parts may not look exactly the same as the original. A "universal" O2 sensor, for example, may fit a large number of applications but usually requires cutting and splicing wires to install.

OTHER PCM FUNCTIONS

On many vehicles the PCM also controls the transmission. But on some vehicles, a separate transmission control module (TCM) is used to oversee gear changes and the torque converter. But even if there's a separate module for the transmission, the PCM and TCM talk to each other and share data so each knows what the other is doing.

On many newer vehicles, the PCM also regulates charging system voltage; cycles the cooling fan on and off; interacts with the antilock brake system (ABS) module to reduce power if the vehicle has traction control; and may even interact with the automatic temperature control (ATC) module to operate the cycling of the air conditioning compressor clutch. The PCM may also be assigned vehicle security tasks.

One of the PCM's most important jobs is to make sure all the engine's sensors are working properly and that the engine isn't polluting. Since the earliest days of the onboard computer, a certain amount of self-diagnostic capability has always been required to detect problems that might upset the smooth operation of the system. On older vehicles, the diagnostics were relatively crude. If a sensor circuit went open (no signal) or shorted, the gross failure would set a trouble code and turn on the check engine light. But many conditions that didn't cause a total failure could also upset engine performance and drivability. What's more, the earlier systems had no way of monitoring many conditions that could increase pollution. So the Environmental Protection Agency (EPA) required every city and state that didn't meet Federal clean air standards to institute some type of vehicle emissions inspection program.

EMISSIONS AND OBD II

Emissions testing has certainly helped boost the sales of aftermarket PCMs, sensors and emission control parts. But more importantly, it has made a significant improvement in the air quality of most large metropolitan areas. Even so, many motorists will only seek repairs if forced to do so because their vehicle failed an emissions test. Many put off repairs until their vehicle is barely drivable or dies and leaves them stranded.

With computerized engine control systems, it doesn't take much of a sensor input problem to adversely affect drivability and emissions. A sluggish O2 sensor, a defective coolant sensor that always stays cold, a throttle position sensor that has a dead spot, an airflow sensor that isn't reading accurately, etc., can all hurt performance, fuel economy and emissions.In an attempt to ratchet up the self-diagnostic capability of PCMs, the California Air Resources Board developed a "next generation" onboard diagnostic system called OBD II. "OBD" is an acronym for "On Board Diagnostics." The "II" stands for "second-generation system." OBD II first appeared in 1994, and it has been required on all cars and light trucks since 1996.

Unlike earlier onboard diagnostic systems that set a diagnostic trouble code only when a sensor failed or read out of range, OBD II monitors most engine functions while the vehicle is being driven. It is designed to detect almost any problem that can cause emissions to exceed the federal limit by 1.5 times.

OBD II is extremely sensitive. Some say it is overly sensitive because the vehicle manufacturers have been overly cautious in setting trigger points below the 1.5 threshold to reduce the risk of expensive emission recalls. As a result, some vehicles may not actually have an emissions problem when the Check Engine light is on. Nevertheless, the problem should always be investigated to determine the cause.

CHECK ENGINE LIGHT

The check engine light, which is technically called the "Malfunction Indicator Lamp" or MIL, is supposed to alert the driver when an emissions or sensor problem occurs. Depending on how the system is configured and the nature of the problem, the lamp may come on and go off, remain on continuously or flash - all of which can be very confusing because you have no way of knowing what the light means. Is it a serious problem or not?

For example, let's say a vehicle has an OBD II code for the oxygen sensor circuit (code P0130). The code might indicate a bad sensor, or it might indicate a loose connector or wiring problem.

Harder to diagnose are misfire codes. OBD II can detect misfires in individual cylinders as well as random misfires. If it generates a misfire code for a single cylinder (say P0301 for the #1 cylinder), it only tells you the cylinder is misfiring - not why. The underlying cause could be a bad spark plug, a bad plug wire, a weak coil on a distributorless ignition system (DIS) or coil-on-plug (COP) system, a dirty or dead fuel injector or a compression problem (bad valve, leaky head gasket, rounded cam lobe, etc.). As you can see, there are multiple possibilities, so it takes some diagnostic expertise to isolate the fault before any parts can be replaced.

A "random misfire code" (P0300) is even harder to diagnose because there can be numerous causes. A random misfire usually means the air/fuel mixture is running lean. But the cause might be anything from a hard-to-find vacuum leak to dirty injectors, low fuel pressure, a weak ignition coil, bad plug wires or compression problems.

Something else to keep in mind about OBD II fault codes is that some codes are false codes. GM has had problems with certain 3.8L engines setting P1406 codes, which indicates a fault in the EGR valve. Replacing the EGR valve doesn't fix the problem because the OBD II system is overly sensitive to how quickly the EGR valve opens when it is commanded to do so by the PCM. The cure here is not to replace the EGR valve but to "flash reprogram" the computer so it is less sensitive to this condition. Referring to vehicle manufacturer technical service bulletins (TSBs) can save a lot of time and frustration for these kinds of problems.

Something else that complicates diagnosis is that "standardized" OBD II codes really aren't. There are actually two different types. "Generic" OBD II codes are the same in the sense that all vehicle manufacturers use the same code numbers to indicate the same type of problem. But each vehicle manufacturer also has their own special "enhanced" codes that cover problems not included in the basic OBD II code list. These include many problems not covered by the generic codes as well as problems that are outside the engine management system such as ABS codes, climate control codes, body codes, air bag codes, etc.

Generic OBD II codes all start with "P0" while the OEM enhanced codes all start with a "P1." Enhanced codes are often vehicle specific and require a high-quality scan tool such as the AutoTap OBDII scantool for PC or Palm. Diagnosing computerized engine control systems and sensors isn't an easy task, but that's the price we pay for drastically reduced emissions and the feature-laden vehicles we drive today. So do your diagnostic homework before you replace critical engine management system parts. It will save you frustration and needless returns.

INTECHANGE AND CALIBRATIONS

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O2 REPLACEMENT INTERVALS

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