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Making Sense of Engine Sensors

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Computers can only do what they are programmed to do. If they get garbage in, they put garbage out. In an automotive engine control computer (called a Powertrain Control Module or PCM), the input data is not from a keyboard but electronic signals from various sensors. They act the like the engines eyes and ears helping it make the most of its driving conditions. Consequently, the Powertrain Control Module (PCM) can't do this if the inputs it receives are faulty or missing.

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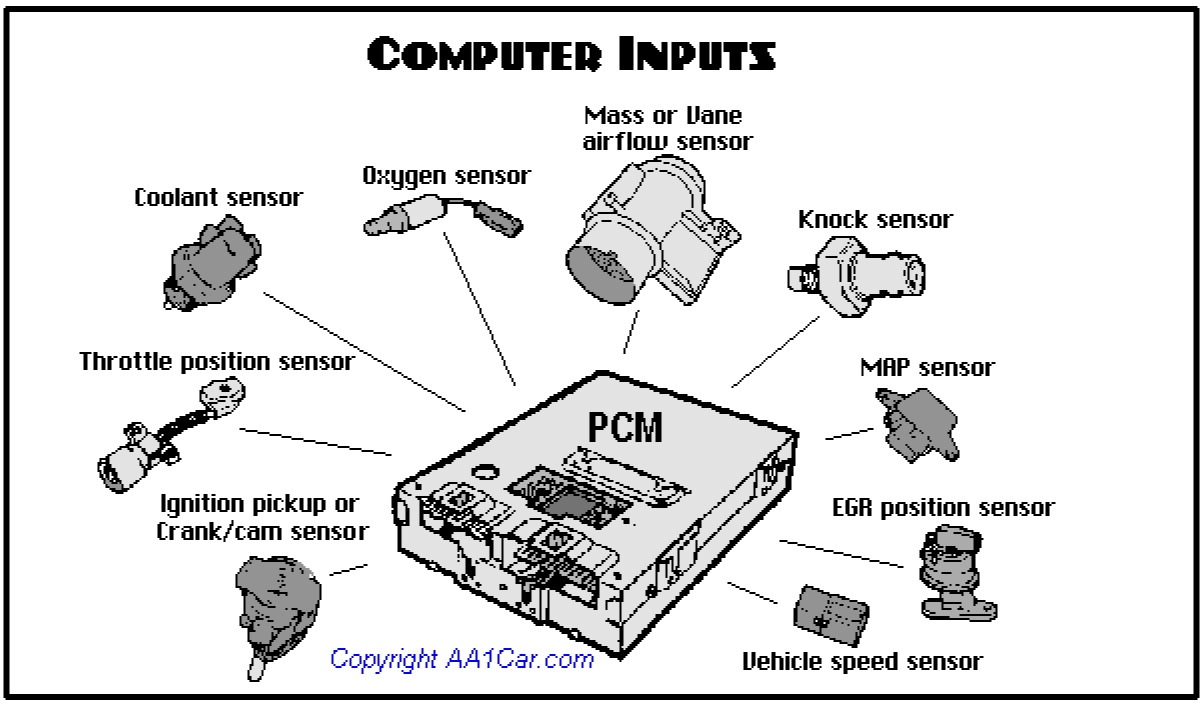

The engine control system will not go into "closed loop," if the PCM does not receive a good signal from the coolant sensor or oxygen sensor. Nor can it balance the fuel mixture correctly if it does not receive good inputs from the throttle position sensor, MAP sensor or airflow sensor. The engine may not even start if the PCM does not get a signal from the crankshaft position sensor.

Sensors monitor all the key functions necessary to manage ignition timing, fuel delivery, emission controls, transmission shifting, cruise control, engine torque reduction (if the vehicle has antilock brakes with traction control) and charging output of the alternator. On most late model vehicles the PCM also controls the throttle. There is no mechanical linkage or cable between the gas pedal and throttle. Reliable sensor inputs are an absolute must if the whole system is to operate smoothly.

COOLANT SENSOR

Usually located on the cylinder head or intake manifold, the coolant sensor is used to monitor the temperature of the engine coolant. Its resistance changes in proportion to coolant temperature. Input from the coolant sensor tells the computer when the engine is warm so the PCM can go into closed loop feedback fuel control and handle other emission functions (EGR, canister purge, etc.) that may be temperature dependent.

Coolant Sensor Strategies: The coolant sensor is a pretty reliable sensor, but if it fails it can prevent the engine control system from going into closed loop. This will result in a rich fuel mixture, excessive fuel consumption and elevated carbon monoxide (CO) emissions - which may cause the vehicle to fail an emissions test.

A bad sensor can be diagnosed by measuring its resistance and watching for a change as the engine warms up. No change, or an open or closed reading would indicate a bad sensor.

OXYGEN (O2) SENSOR

Used on both carbureted and fuel injected engines since 1981, the oxygen (O2) sensor is the key sensor in the fuel mixture feedback control loop.

Mounted in the exhaust manifold, the O2 sensor monitors the amount of unburned oxygen in the exhaust. On many V6 and V8 engines, there are two such sensors (one for each bank of cylinders).

The O2 sensor generates a voltage signal that is proportional to the amount of unburned oxygen in the exhaust. When the fuel mixture is rich, most of the oxygen is consumed during combustion so there is little unburned oxygen in the exhaust. The difference in oxygen levels between the exhaust inside the manifold and the air outside creates an electrical potential across the sensors platinum and zirconium tip. This causes the sensor to generate a voltage signal. The sensor's output is high (up to 0.9v) when the fuel mixture is rich (low oxygen), and low (down to 0.1v) when the mixture is lean (high oxygen).

Sensor output is monitored by the computer and is used to rebalance the fuel mixture for lowest emissions. When the sensor reads "lean" the PCM increases the on-time of the injectors to make the fuel mixture go rich. Conversely, when the sensor reads "rich" the PCM shortens the on-time of the injectors to make the fuel mixture go lean. This causes a rapid back-and-forth switching from rich to lean and back again as the engine is running. These even waves result in an "average" mixture that is almost perfectly balanced for clean combustion. The switching rate is slowest in older feedback carburetors, faster is throttle body injection systems and fastest in multiport sequential fuel injection.

If the O2 sensor's output is monitored on an oscilloscope, it will produce a zigzagging line that dances back and forth from rich to lean. Think of it as a kind of heart monitor for the engine's air/fuel mixture.

O2 Sensor Strategies: Unheated one- or two-wire O2 sensors on 1976 through early 1990s applications should be replaced every 30,000 to 50,000 miles to assure reliable performance. Heated 3 and 4-wire O2 sensors on mid-1980s through mid-1990s applications should be changed every 60,000 miles. On OBD II equipped vehicles, the recommended replacement interval is 100,000 miles. The O2 sensor's responsiveness and voltage output can diminish with age and exposure to certain contaminants in the exhaust such as lead, sulfur, silicone (coolant leaks) and phosphorus (oil burning). If the sensor becomes contaminated, it may not respond very quickly to changes in the air/fuel mixture causing a lag in the PCMs ability to control the air/fuel mixture.

The sensor's voltage output may decline giving a lower than normal reading. This may cause the PCM to react as if the fuel mixture were leaner than it really is resulting in an overly rich fuel mixture.

How common is this problem? One EPA study found that 70 percent of the vehicles that failed an emissions test needed a new O2 sensor.

MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR

The MAP sensor is mounted on or connected to the intake manifold to monitor intake vacuum. It changes voltage or frequency as manifold pressure changes. The computer uses this information to measure engine load so ignition timing can be advanced and retarded as needed. It performs essentially the same job as the vacuum advance diaphragm on an old fashioned mechanical distributor.

On engines with a "speed density" type of fuel injection, the MAP sensor also helps the PCM estimate airflow. Problems here may cause an intermittent check engine light (light comes on when accelerating or when the engine is under load), hesitation when accelerating, elevated emissions and poor engine performance. The engine will run with a bad MAP sensor, but it will run poorly. Some PCMs can substitute "estimated data" for a missing or out of range MAP signal, but engine performance will be drastically reduced.

MAP Sensor Strategies: Some MAP sensor problems are not the fault of the sensor itself. If the vacuum hose that connects the MAP sensor to the intake manifold is loose, leaking or plugged, the sensor cannot produce an accurate signal. Also, if there is a problem within the engine itself that causes intake vacuum to be lower than normal (such as a vacuum leak, EGR valve that is stuck open or leaky PCV hose), the MAP sensor's readings may be lower than normal.

THROTTLE POSITION SENSOR

Mounted on the throttle shaft of the carburetor or throttle body, the Throttle Position Sensor (TPS) changes resistance as the throttle opens and closes. The computer uses this information to monitor engine load, acceleration, deceleration and when the engine is at idle or wide open throttle. The sensor's signal is used by the PCM to enrich the fuel mixture during acceleration, and to retard and advance ignition timing.

Throttle Position Sensor Strategies: Many TPS sensors require an initial voltage adjustment when installed. This adjustment is critical for accurate operation. On some engines, a separate idle switch and/or wide open throttle (WOT) switch may also be used. Driveability symptoms due to a bad TPS can be similar to those caused by a bad MAP sensor: The engine will run without this input, but it will run poorly.

MASS AIRFLOW SENSOR (MAF)

Mounted ahead of the throttle body on multiport fuel injected engines, the MAF sensor monitors the volume of air entering the engine. The sensor uses either a hot wire or heated filament to measure both airflow and air density.

MAF Sensor Strategies: The sensing element in MAF sensors can be easily contaminated causing hard starting, rough idle, hesitation and stalling problems. Cleaning a dirty MAF sensor with electronics cleaner can often restore normal sensor operation and save the cost of having to replace the sensor (which is very expensive!).

VANE AIRFLOW SENSOR (VAF)

The VAF sensor has a mechanical flap-style sensor that is used on Bosch and other import multiport fuel injected engines. The function is the same as a mass airflow sensor, but air pushing against a spring-loaded flap moves a rheostat to generate an electronic signal.

VAF Sensor Strategies: The drivability symptoms for the VAF are the same as those of a mass airflow sensor if the sensor fails.

MANIFOLD AIR TEMPERATURE (MAT) SENSOR

Mounted on the intake manifold, this sensor changes resistance to monitor incoming air temperature. The sensor's input is used to adjust the fuel mixture for changes in air density.

MAT Sensor Strategies: Problems with the manifold air temp sensor can affect the air/fuel mixture, causing the engine to run rich or lean.

CRANKSHAFT POSITION SENSOR

Used on engines with distributorless ignition systems, the crankshaft position (CKP) sensor serves essentially the same purpose as the ignition pickup and trigger wheel in an electronic distributor. It generates a signal that the PCM needs to determine the position of the crankshaft and the number one cylinder. This information is necessary to control ignition timing and the operation of the fuel injectors. The signal from the crank sensor also tells the PCM how fast the engine is running (engine rpm) so ignition timing can be advanced or retarded as needed. On some engines, a separate camshaft position sensor is also used to help the PCM determine the correct firing order. The engine will not run without this sensor's input.

There are two basic types of crankshaft position sensors: magnetic and Hall effect. The magnetic type uses a magnet to sense notches in the crankshaft or harmonic balancer. As the notch passes underneath, it causes a change in the magnetic field that produces an alternating current signal.

The frequency of the signal gives the PCM the information it needs to control timing. The Hall effect type of crank sensor uses notches or shutter blades on the crank, cam gear or balancer to disrupt a magnetic field in the Hall effect sensor window. This causes the sensor to switch on and off, producing a digital signal that the PCM reads to determine crank position and speed.

Crank Position Sensor Strategies: If a crank position sensor fails, the engine will die. The engine may, however, still crank but it will not start. Most problems can be traced to faults in the sensor wiring harness. A disruption of the sensor supply voltage (Hall effect types), ground or return circuits can cause a loss of the all-important timing signal.

KNOCK SENSOR

The knock sensor detects engine vibrations that indicate detonation is occurring so the computer can momentarily retard timing. Some engines have two knock sensors.

Knock Sensor Strategies:A failure with the knock sensor can cause spark knock and engine damaging detonation because the PCM will not know to retard ignition timing if knock is occurring.

BAROMETRIC PRESSURE (BARO) SENSOR

The baro sensor measures barometric pressure so the computer can compensate for changes in altitude and/or barometric pressure that would affect the fuel mixture or timing. Some MAP sensors also perform this function.

VEHICLE SPEED SENSOR (VSS)

The vehicle speed sensor, or VSS, monitors vehicle speed so the computer can regulate torque converter clutch lockup, shifting, etc. The sensor may be located on the transmission, differential, transaxle or speedometer head.

Vehicle Speed Sensor Strategies: A problem with the vehicle speed sensor can disable the cruise-control system as well as affect transmission shifting and converter engagement.

MAKING SENSE OF ALL THESE SENSORS

If you have not done your diagnostic homework and are replacing a sensor because you think it might be bad, you may be wasting money. Replacing a sensor won't solve a drivability or emissions problem if the problem is not the sensor. Common conditions such as fouled spark plugs, bad plug wires, a weak ignition coil, a leaky EGR valve, vacuum leaks, low compression, dirty injectors, low fuel pressure or even low charging voltage can all cause drivability symptoms that may be blamed on a bad sensor. If there are no sensor-specific fault codes, these kinds of possibilities should be ruled out before much time is spent on electronic diagnosis. Share

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