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Understanding the Air/Fuel Ratio Sensor

VEI Web site: www.carcare.azdeq.gov

Understanding the Air/Fuel Ratio Sensor

by Alex Studham, VEI

Some techs have expressed a lack of understanding of the newer oxygen sensors and the role they play in the control of emissions. The new sensors don't work the same as the old. So here is a breakdown on the air/fuel ratio sensor.

OBD II (on-board diagnostics) vehicles require two oxygen sensors: one before and one after the catalytic converter. The oxygen (O_2) sensor, or air/fuel ratio sensor, before the catalytic converter is used by the computer to adjust the air/fuel ratio. This sensor in OBD II terms is referred to as sensor 1. On V-type engines one sensor will be referred to as bank (1) Sensor (1) and the other as bank (2) sensor (1). The oxygen sensor after the catalytic converter is used by the computer primarily to determine catalytic converter efficiency. The sensor is referred to as sensor (2). With two catalytic converters, one sensor will be bank (1) sensor (2) and the other bank (2) sensor (2).

Depending on the manufacturer and function, operational differences exist. An A/F ratio sensor is nothing more than a zirconium O_2 sensor with the addition of one or two more extra wires, called a pump circuit. By combining some of the grounds, the number of wires can be kept to four.

The Rich and the Lean: The old O_2 sensor did not update quickly enough and was not continually monitored by the onboard computer. When an O_2 sensor was at 14.7:1 A/F ratio, the output voltage was 450 mv. Anything above that threshold was seen by the computer as rich, and anything below was lean. When the computer saw a rich voltage it drove the mixture lean, resulting in an average mixture of 14.7:1. However, the exact mixture was always unknown.

The pump circuit is nothing but a milliamp pump. When the O_2 volts exceeded normal (rich mixture), negative current is pumped into the O_2 sensor. This instantly returns the normal voltage to 450 mv. Then, the computer measures the amount of amperage used to determine the actual mixture.

For example, the mixture went lean (low O_2 volts), then the computer would flow positive amps in the pump circuit, raising the O_2 volts back to 450 mv. The PCM records how many amps it took to get it back to 450mv. A higher positive ampere reading means a leaner mixture. The computer constantly monitors the required amperage in the pump circuit, which indicates the exact A/F ratio. Because the computer constantly monitors A/F ratio, it ensures that the vehicle receives maximum fuel economy and gives off lower emissions. Some vehicles even use the sensor's output to deliver increased engine power.

Big Changes: The change in operating strategy means a big change in the way you diagnose and repair an A/F ratio sensor. With a conventional O_2 sensor, it is possible to back probe the sensor's signal wire and observe its signal to the computer with a DVOM (digital volt ohmmeter), lab-scope or graphing multimeter. While it is still possible to back probe the A/F ratio sensor's signal wire, the information you receive by doing so may be of little use to you, especially if it is incorrectly interpreted.

An A/F ratio sensor has two signal wires, not one. The computer provides a set voltage on each of these wires (neither is a ground). One wire is set at 3.0 volts, the other at 3.3 volts. With the A/F ratio sensor connected to the computer, attaching the leads of a DVOM to these sensors' two wires would reveal little change. The reading should remain nearly constant at 0.3 volts (300 mv), regardless of any changes in the A/F ratio. As the A/F ratio sensor changes its output in response to fluctuations in the A/F mixture ratio, the computer's detection circuit maintains the steady 300 mv output.

To measure a four-wire A/F ratio sensors response using a voltage, disconnect the sensor's four-wire connector, then attach jumper wires to maintain power to the sensor heater. Next, connect a scope or multimeter to the two **disconnected** sensor signal wires. When the A/F mixture is artificially richened or leaned, you'll see that the A/F ratio sensor responds just like a normal oxygen sensor. Its response swings between 0 and 1 volt, with 0 indicating a lean mixture and 1 indicating a rich mixture.

The Red and the Black: To measure a four-wire A/F ratio sensors response using **amperage**, install an

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Vehicle Emissions Inspection
600 N. 40th Street
Phoenix, Arizona 85008

Contact *Fleets in Review*:
(602) 207-7000
Contact: John Gibbons
gibbons.john@azdeq.gov

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ammeter in series with the computer's 3.3 volt signal wire. The ampmeter's negative (black) lead should be connected to the sensor lead and the positive (red) lead should be connected to the computer wiring. The 3.0 volt signal wiring as well as the heater wires must remain connected (jumpered between connectors) during this test.

Think of the A/F ratio sensor as a tiny generator that is capable of changing polarity. A lean exhaust will cause the A/F ratio sensor to produce a positive going ammeter reading, while a rich exhaust will cause it to produce a negative going ammeter reading. When the A/F ratio is at the stoichiometric point, no current is generated and the ammeter shows 0 milliamps.

If you decide to forgo testing the A/F ratio sensor directly at the sensor, always remember that the data you see on your scan tool has been processed and interpreted by the computer. And in the case of the A/F ratio sensor, the data that has been converted from a current reading into the voltage reading you see on the scanner screen.

Matters of interpretation: If your scanner is equipped with the necessary software, the computer's voltage detection circuitry will produce the following readings on your scan tool for the A/F sensor parameter identification (PID):

- Low exhaust oxygen content causes a negative current flow at the A/F sensor. The computer detection circuit produces a voltage signal below 3.3 volts, indicating the air/fuel mixture is judge to be rich.
- Exhaust oxygen content as stoichiometric produces no current flow at the A/F sensor, the computer detection circuit produces a voltage signal of 3.3 volts, indicating the air/fuel mixture is judged to be at 14.7:1.
- A high exhaust oxygen content causes a positive current flow at the A/F sensor. The computer detection circuit produces a voltage signal above 3.3 volts, indicating the air/fuel mixture is judged to be lean.

Some scan tools are not equipped to read the data from the PCM's A/F ratio sensor detection circuit. You may see no PID for the A/F sensor, which may lead you to believe the A/F sensor is faulty or the vehicle does not have an A/F ratio sensor. Other scan tools apply a conversion factor to bring the A/F sensor PID into the more familiar 0 to 1 volt output range. This is accomplished by dividing the sensor detection circuit's original output by 5. So a stoichiometric reading of 3.3 volts becomes 0.66 volts on the scan tool. A 4.0 volt (lean) detection circuit reading becomes 0.8 volts on the scan tool. And a 2.5 volt detection circuit reading becomes 0.5 volts on the scan tool.

No fooling: Everything seems fine until you notice that the A/F sensor voltage PID on your scan tool is exactly the opposite of what you're accustomed to seeing from a conventional oxygen sensor. The voltage output through the computer's detection circuit and interpreted PID on your scanner increases as the mixture gets richer. Don't be fooled by your scanner.

During normal operation, the swings between rich and lean A/F ratios will be more subdued than you're accustomed to seeing. Don't look for the traditional toggle between very rich and very lean. The A/F mixture ratio commanded by the computer will remain fairly constant, unless there's a big change in engine speed or load. It's that consistency that helps the computer deliver the cleanest possible emissions while retaining performance and drivability.

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