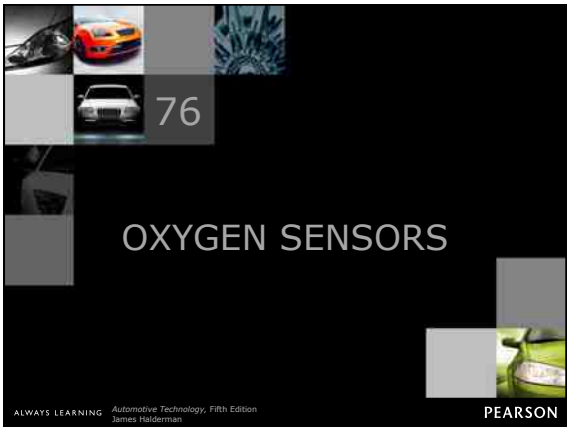


76

OXYGEN SENSORS

Figure 76-1 Many oxygen sensors are located in the exhaust manifold near its outlet so that the sensor can detect the presence or absence of oxygen in the exhaust stream for all cylinders that feed into the manifold.

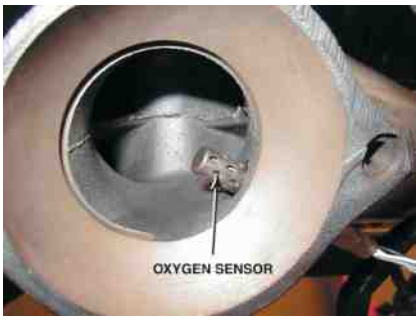


Figure 76-2 (a) When the exhaust is lean, the output of a zirconia oxygen sensor is below 450 mV.

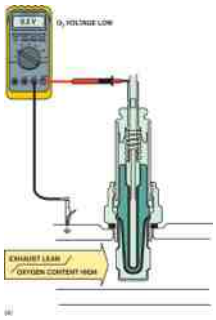


Figure 76-2 (b) When the exhaust is rich, the output of a zirconia oxygen sensor is above 450 mV.

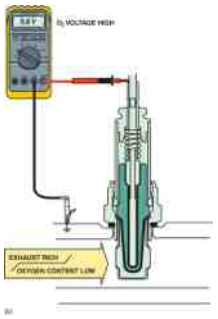


Figure 76-3 Most conventional zirconia oxygen sensors and some wide-band oxygen sensors use the cup (finger) type of design.

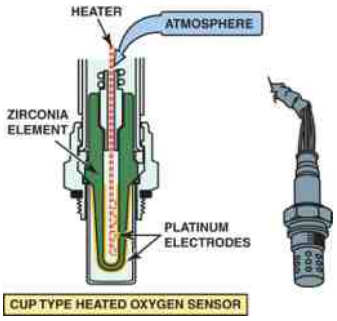


Figure 76-4 A typical heated zirconia oxygen sensor, showing the sensor signal circuit that uses the outer (exhaust) electrode as the negative and the ambient air side electrode as the positive.

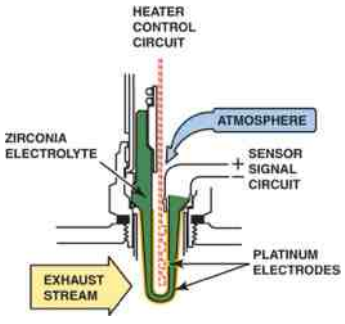
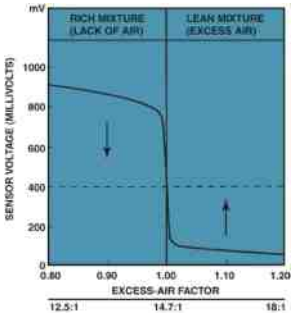


Figure 76-5 The oxygen sensor provides a quick response at the stoichiometric air-fuel ratio of 14.7:1.



FREQUENTLY ASKED QUESTION

What Happens to the Bias Voltage?

Some vehicle manufacturers such as General Motors Corporation have the PCM apply 450 mV (0.45 V) to the O2S signal wire. This voltage is called the **bias voltage** and represents the threshold voltage for the transition from rich to lean.

This bias voltage is displayed on a scan tool when the ignition switch is turned on with the engine off. When the engine is started, the O2S becomes warm enough to produce a usable voltage, and bias voltage "disappears" as the O2S responds to a rich and lean mixture. What happens to the bias voltage that the PCM applies to the O2S? The voltage from the O2S simply overcomes the very weak voltage signal from the PCM. The bias voltage is so weak that even a 20 megohm impedance DMM will affect the strength enough to cause the voltage to drop to 426 mV. Other meters with only 10 megohms of impedance will cause the bias voltage to read less than 400 mV.

Therefore, even though the O2S voltage is relatively low powered, it is more than strong enough to overrule the very weak bias voltage the PCM sends to the O2S.

REAL WORLD FIX

The Chevrolet Pickup Truck Story

The owner of a 1996 Chevrolet pickup truck complained that the engine ran terribly. It would hesitate and surge, yet there were no diagnostic trouble codes (DTCs). After hours of troubleshooting, the technician discovered while talking to the owner that the problem started after the transmission had been repaired. However, the transmission shop said that the problem was an engine problem and not related to the transmission.

A thorough visual inspection revealed that the front and rear oxygen sensor connectors had been switched. The PCM was trying to compensate for an air-fuel mixture condition that did not exist. Reversing the O2S connectors restored proper operation of the truck.

FREQUENTLY ASKED QUESTION

Where Is HO2S1?

Oxygen sensors are numbered according to their location in the engine. On a V-type engine, heated oxygen sensor number 1 (HO2S1) is located in the exhaust manifold on the side of the engine where cylinder 1 is located. ● **SEE FIGURE 76–6.**

REAL WORLD FIX

The Oxygen Sensor Is Lying to You

A technician was trying to solve a driveability problem with an older V-8 passenger car. The car idled roughly, hesitated, and accelerated poorly. A thorough visual inspection did not indicate problems and there were no diagnostic trouble codes stored.

The technician checked the oxygen sensor activity using a DMM. The voltage stayed above 800 mV most of the time. If the technician removed a large vacuum hose, the oxygen sensor voltage would temporarily drop to below 400 mV and then return to a reading of over 800 mV. Remember:

- High CO2S readings = rich exhaust (low O_2 content in the exhaust)
- Low CO2S readings = lean exhaust (high O_2 content in the exhaust)

As part of a thorough visual inspection, the technician removed and inspected the spark plugs. All the spark plugs were white, indicating a lean mixture, not the rich mixture that the oxygen sensor was indicating. The high CO2S reading signaled the PCM to reduce the amount of fuel, resulting in an excessively lean operation.

After replacing the oxygen sensor, the engine ran great. But what killed the oxygen sensor? The technician finally learned from the owner that the heater glazed had been replaced over a year ago. The silicone and phosphate additives in the antifreeze coolant had coated the oxygen sensor. Because the oxygen sensor was coated, the oxygen content of the exhaust could not be detected, resulting in a false rich signal from the oxygen sensor.

Figure 76-6 Number and label designations for oxygen sensors. Bank 1 is the bank where cylinder 1 is located.

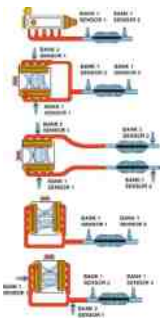


Figure 76-7 The OBD-II catalytic converter monitor compares the signals of the upstream and downstream oxygen sensor to determine converter efficiency.

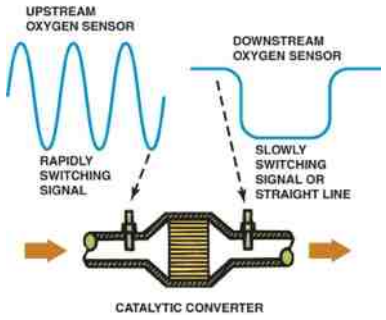
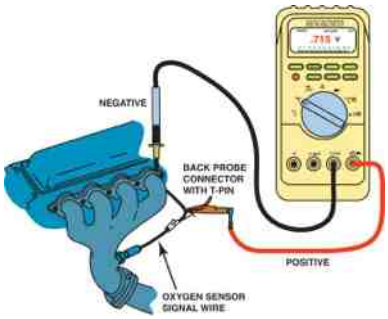


Figure 76-8 Testing an oxygen sensor using a DMM set on DC volts. With the engine operating in closed loop, the oxygen voltage should read over 800 mV and lower than 200 mV and be constantly fluctuating.



REAL WORLD FIX

The Missing Ford

A Ford was being analyzed for poor engine operation. The engine ran perfectly during the following conditions.

1. Engine cold or operating in open loop
2. Engine at idle
3. Engine operating at or near wide-open throttle

After hours of troubleshooting, the technician determined the cause to be a poor ground connection for the oxygen sensor. The engine ran okay during times when the PCM ignored the oxygen sensor. Unfortunately, the service technician did not have a definite plan during the diagnostic process and as a result checked and replaced many unnecessary parts. An oxygen sensor test early in the diagnostic procedure would have indicated that the oxygen (O2S) signal was not correct. The poor ground caused the oxygen sensor voltage level to be too high, indicating to the PCM that the mixture was too rich. The PCM then subtracted fuel which caused the engine to miss and run roughly as the result of the now too-lean air-fuel mixture.

TECH TIP

Do Not Solder Oxygen Sensor Wires

Oxygen sensors must have outside oxygen to compare with the oxygen content in the exhaust. Most oxygen sensors breathe through the signal wire and, if soldered, would block the flow of outside air to the sensor. If a replacement oxygen sensor is used, always use the factory replacement, using the original connectors or a crimp-and-seal connector that will seal out any moisture and still allow air to flow through the connector.

FREQUENTLY ASKED QUESTION

Why Does the Oxygen Sensor Voltage Read 5 Volts on Many Chrysler Vehicles?

Many Chrysler vehicles apply a 5 volt reference to the signal wire of the oxygen sensor. The purpose of this voltage is to allow the PCM to detect if the oxygen sensor signal circuit is open or grounded.

- If the voltage on the signal wire is 4.5 volts or more, the PCM assumes that the sensor is open.
- If the voltage on the signal wire is zero, the PCM assumes that the sensor is shorted-to-ground.

If either condition exists, the PCM can set a diagnostic trouble code (DTC).

TECH TIP

The Key On, Engine Off Oxygen Sensor Test

This test works on General Motors vehicles and may work on others if the PCM applies a bias voltage to the oxygen sensors. Zirconia oxygen sensors become more electrically conductive as they get hot. To perform this test, be sure that the vehicle has not run for several hours.

STEP 1 Connect a scan tool and get the display ready to show oxygen sensor data.

STEP 2 Key the engine on without starting the engine. The heater in the oxygen sensor will start heating the sensor.

STEP 3 Observe the voltage of the oxygen sensor. The applied bias voltage of 450 mV should slowly decrease for all oxygen sensors as they become more electrically conductive as the bias voltage is flowing to ground.

STEP 4 A good oxygen sensor should indicate a voltage of less than 100 mV after three minutes. Any sensor that displays a higher than usual voltage or seems to stay higher longer than the others could be defective or skewed high.

Figure 76-9 Using a digital multimeter to test an oxygen sensor using the MIN/MAX record function of the meter.

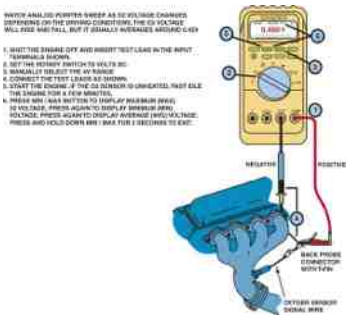


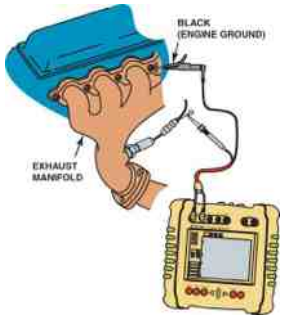
CHART 76–1 The test results of using a digital meter set to read minimum and maximum values while testing a narrow-band oxygen sensor.
* Check for an exhaust leak upstream from the O2S or ignition misfire that can cause a false lean indication before further diagnosis.

MIN/MAX OXYGEN SENSOR TEST CHART

MINIMUM VOLTAGE	MAXIMUM VOLTAGE	AVERAGE VOLTAGE	TEST RESULTS
Below 200 mV	Above 860 mV	400 to 500 mV	Oxygen sensor is okay.
Above 200 mV	Any reading	400 to 500 mV	Oxygen sensor is defective.
Any reading	Below 860 mV	400 to 500 mV	Oxygen sensor is defective.
Below 200 mV	Above 860 mV	Below 400 mV	System is operating lean.*
Below 200 mV	Below 860 mV	Below 400 mV	System is operating lean. (Add propane to the intake air to see if the oxygen sensor reacts. If not, the sensor is defective.)
Below 200 mV	Above 860 mV	Above 500 mV	System is operating rich.
Above 200 mV	Above 860 mV	Above 500 mV	System is operating rich. (Remove a vacuum hose to see if the oxygen sensor reacts. If not, the sensor is defective.)

CHART 76-1

Figure 76-10 Connecting a handheld digital storage oscilloscope to an oxygen sensor signal wire. Check the instructions for the scope as some require the use of a filter to be installed in the test lead to reduce electromagnetic interference that can affect the oxygen sensor waveform.



TECH TIP

The Propane Oxygen Sensor Test

Adding propane to the air inlet of a running engine is an excellent way to check if the oxygen sensor is able to react to changes in air-fuel mixture. Follow these steps in performing the propane trick.

1. Connect a digital storage oscilloscope to the oxygen sensor signal wire.
2. Start and operate the engine until it reaches operating temperature and is in closed-loop fuel control.
3. While watching the scope display, add some propane to the air inlet. The scope display should read full rich (over 800 mV).
4. Shut off the propane. The waveform should drop to less than 200 mV (0.2 V).
5. Quickly add some propane while the oxygen sensor is reading low and watch for a rapid transition to rich. The transition should occur in less than 100 milliseconds (ms).

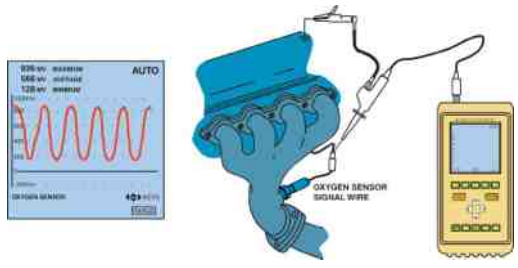
REAL WORLD FIX

How Could Using Silicone Sealer on a Valve Cover Gasket Affect the Oxygen Sensor?

The wrong type of silicone **room temperature vulcanization (RTV)** sealer on a valve cover gasket gives off harmful silica fumes during the curing process. These fumes enter the crankcase area by way of the oil drainback holes in the cylinder head as well as through pushrod openings and other passages in the engine. During engine operation, these fumes are drawn into the intake manifold through the positive crankcase ventilation (PCV) system and are burned in the engine. The harmful silica then exits through the exhaust system, where the contamination affects the oxygen sensor.

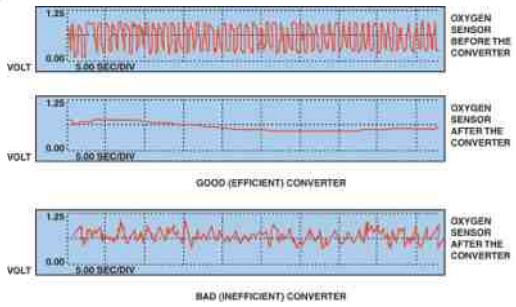
NOTE: Be careful not to spray any silicone lubricant near the engine vacuum, which might draw the fumes into the engine and cause silica damage to the oxygen sensor.

Figure 76-11 The waveform of a good oxygen sensor as displayed on a digital storage oscilloscope (DSO). Note that the maximum reading is above 800 mV and the minimum reading is less than 200 mV.



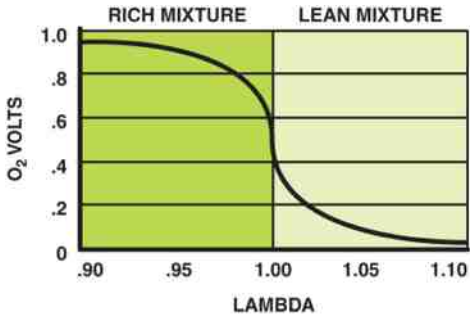
76 OXYGEN SENSORS

Figure 76-12 The post catalytic converter oxygen sensor should display very little activity if the catalytic converter is efficient.



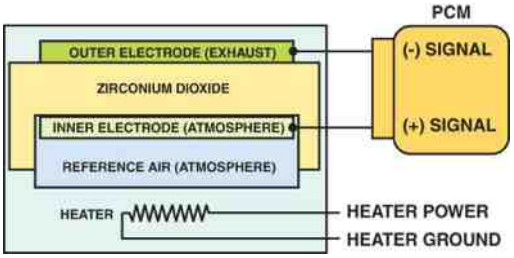
76 OXYGEN SENSORS

Figure 76-13 A conventional zirconia oxygen sensor can only reset to exhaust mixtures that are richer or leaner than 14.7:1 (lambda 1.00).



76 OXYGEN SENSORS

Figure 76-14 A planar design zirconia oxygen sensor places all of the elements together, which allows the sensor to reach operating temperature quickly.



FREQUENTLY ASKED QUESTION

How Quickly Can a Wide-Band Oxygen Sensor Achieve Closed Loop?

In a Toyota Highlander hybrid electric vehicle, the operation of the gasoline engine is delayed for a short time when the vehicle is first driven. During this time of electric operation, the oxygen sensor heaters are turned on in readiness for the gasoline engine starting. The gasoline engine often achieves closed-loop operation during *cranking* because the oxygen sensors are fully warm and ready to go at the same time the engine is started. Having the gasoline engine achieve closed loop quickly, allows it to meet the stringent SULEV standards.

Figure 76-15 The reference electrodes are shared by the Nernst cell and the pump cell.

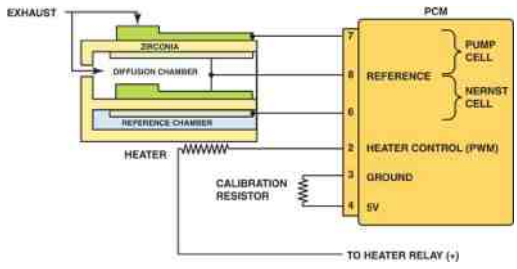


Figure 76-16 When the exhaust is rich, the PCM applies a negative current into the pump cell.

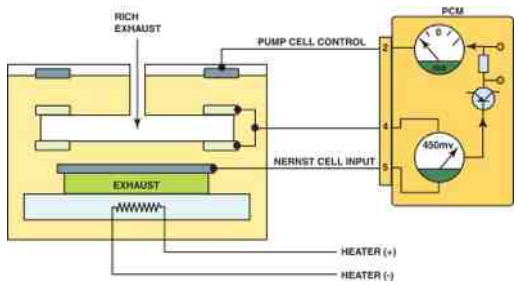


Figure 76-17 When the exhaust is lean, the PCM applies a positive current into the pump cell.

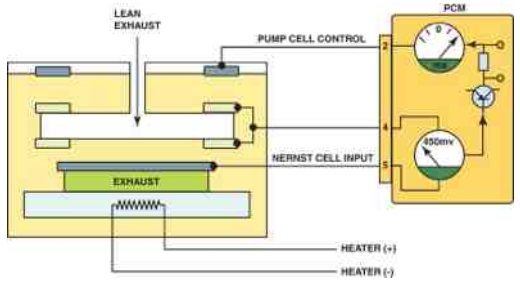
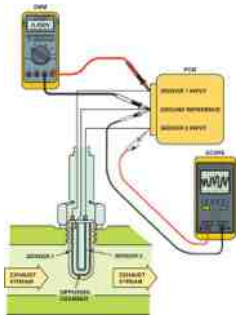


CHART 76–2 A comparison showing what a factory scan tool and a generic OBD-II scan tool might display at various air-fuel ratios.

FACTORY SCAN TOOL	OBD II SCAN TOOL	AIR-FUEL RATIO
2.50 V	0.50 V	12.5:1
3.00 V	0.60 V	14.0:1
3.30 V	0.66 V	14.7:1
3.50 V	0.70 V	15.5:1
4.00 V	0.80 V	18.5:1

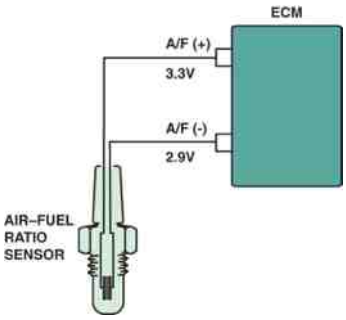
CHART 76–2

Figure 76-18 Testing a dual cell wide-band oxygen sensor can be done using a voltmeter or a scope. The meter reading is attached to the Nernst cell and should read stoichiometric (450 mV) at all times. The scope is showing activity to the pump cell with commands from the PCM to keep the Nernst cell at 14.7:1 air-fuel ratio.



76 OXYGEN SENSORS

Figure 76-19 A single cell wide-band oxygen sensor has four wires with two for the heater and two for the sensor itself. The voltage applied to the sensor is 0.4 V (3.3 – 2.9 = 0.4) across the two leads of the sensor.



76 OXYGEN SENSORS

Figure 76-20 The scan can display various voltages but will often show 3.3 V because the PCM is controlling the sensor through applying a low current to the sensor to achieve balance.