Module 17
Oxygen (O2) Sensor

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17 Oxygen Sensor

17.1 General Overview

The oxygen (O2) sensor is a special sensor in that it actually produces the reference voltage used by the ECM/PCM. All the O2 sensors used by Honda (except for the LAF sensor) are standard zirconia type sensors and produce up to one volt under periods of low O2 in the exhaust.

Image 17-1

This chapter focuses on both the pre catalyst and post catalyst O2 sensors. These sensors come in an un-heated version (shown on the left in Image 17-1) and a heated version (shown on the right in Image 17-1). The non-heated O2 sensors have only one wire and the heated sensors have 3 or 4 wires. The special lean air fuel (LAF) sensor, which has 5 wires, is covered in Chapter 18.

17.2 How Do They Work?

All zirconia O2 sensors work the same way. The sensor tip is shaped like a thimble. The outside of the thimble is exposed to the exhaust and the inside of the thimble is exposed to the atmosphere. The thimble is made of zirconium dioxide and covered with porous platinum.

Zirconium has a special property that occurs above 600^{o} F. At this temperature the difference in oxygen concentration from the exhaust and the atmosphere will produce a voltage. The larger the difference, the higher the voltage. A zirconium sensor produces .5 volt when the oxygen content indicates a mixture of 14.7:1, often called the stoichiometric ratio.

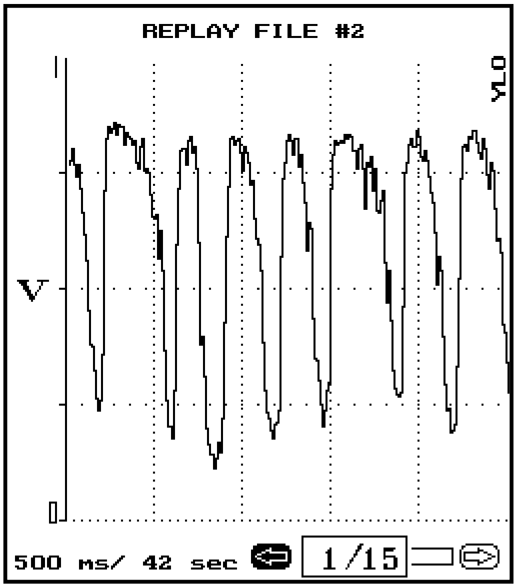
A rich fuel mixture will have the lowest O2 concentration and will produce the largest voltage (approximately .9 volt). A lean fuel mixture will have the highest O2 concentration and will produce the lowest voltage (approximately .1 volt).

The ECM/PCM, while in closed loop (CL), will trim the fuel injector's pulse width (PW) based on the O2 sensor's voltage. When the voltage exceeds .5 volts the PW is narrowed. When the voltage drops below .5 volts the PW is widened. While in closed loop the ECM/PCM is constantly modulating the PW to try and keep the O2 sensor's voltage at .5 volt.

17.2.1 Pre Catalyst O2 Sensor

All Hondas with PGMFI are equipped with a pre-catalyst O2 sensor. The sensor is located somewhere in the exhaust, upstream of the catalytic converter.

Screen Capture 17-1

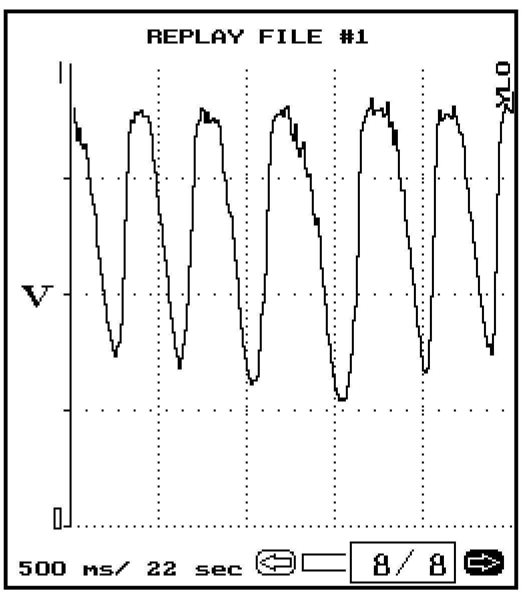


While in the CL mode, the O2 sensor input is used for fuel control. The ECM/PCM is monitoring its voltage and trimming the pulse width to try and hold the mixture close to the stoichiometric ratio.

You can see a typical O2 sensor voltage waveform in Screen Capture 17-1. On each cycle the voltage should sweep between approximately .1 volts and .9 volts. The cycle should repeat about 2-3 times a second at 2500 RPM.

The frequency of the cycles is controlled by the ECM/PCM not by the O2 sensor's response. The O2 sensor can respond much faster to O2 changes than is indicated on a typical O2 sensor waveform.

Screen Capture 17-2

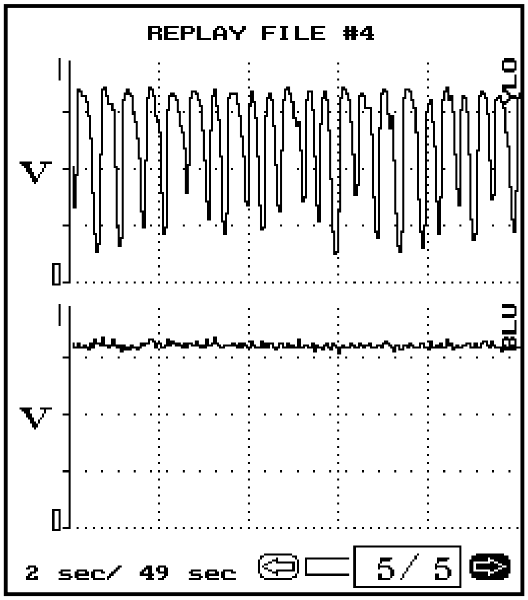


Manufactures can actually bias the sensor slightly rich or lean by modifying how it trims the PW. Screen Capture 17-2 is showing the waveform of a sensor that is being rich biased by the PCM (more of the waveform is above the .5 volt line). This is typically done so that the car can enter CL before the engine is warm enough to run on 14.7:1. The ECM/PCM will not typically bias the signal on a fully warmed engine.

The ECM/PCM can start modulating at a slightly richer mixture by controlling how quickly, and how much, the PW is changed to make a mixture correction. In Screen Capture 17-2 you can see that the correction in the rich direction are quicker than the corrections in the lean directions. Notice the sharp points at the lean to rich corrections Vs the subtle rounded points of the rich to lean corrections. The ECM/PCM is making the lean to rich corrections much faster than the rich to lean correction and therefore keeps the mixture more rich than normal.

17.2.2 Post Catalyst O2 Sensor

Screen Capture 17-3



On OBD-II equipped Hondas there is a second zirconium O2 sensor. It is located downstream of the catalytic converter.

This O2 sensor is not used for fuel control like the pre-cat O2 sensor is. The post-cat O2 sensor is used by the OBD-II system to monitor the efficiency of the catalytic converter. When the OBD-II system runs the catalyst monitor, the pre and post cat O2 sensor signals are compared. The pre and post cat O2 sensor voltages from a 1996 Civic are shown in Screen Capture 17-3.

During steady cruise, the post cat O2 sensor should read between .5 to .8 volts and not vary widely.

17.2.3 O2 Sensor Heaters

An O2 sensor must reach at least 600^{o} F before it begins producing a useable input signal. The earlier O2 sensors were heated by the temperature of the exhaust gases. These O2 sensors had only one wire and are called un-heated sensors.

Emission laws now require that an engine's fuel system go into the closed loop mode shortly after start-up. To assure that the O2 sensors reached their operating temperature fast enough, heaters were added. The heated O2 units will have 3 to 4 wires. One of the extra wires will be the heater's ground wire and one will be a battery voltage positive feed for the heater unit. The positive voltage is supplied from the ECM/PCM.

17.3 Component Location

The pre cat O2 sensor can be virtually anywhere upstream of the catalytic converter. They can be mounted in the exhaust manifold or the A-pipe, depending on the location of the catalytic converter. The following images show some of the typical locations.

Image 17-2

The typical exhaust manifold location is shown in Image 17-2

Image 17-3

A few models were equipped with two O2 sensors, such as the Honda shown in Image 17-3. They were both pre-cat O2 sensors and apparently each one monitored 2 cylinders.

Image 17-4

The typical post-cat O2 sensor location is shown on Image 17-4.

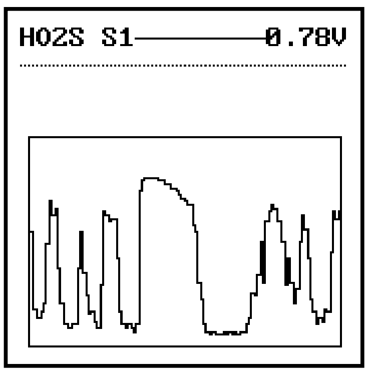
17.4 How Do You Test Them?

During normal combustion the O2 sensor voltage will indicate a rich mixture by a high reading and a lean mixture by a low reading. The sensor does not directly measure fuel, it measures O2. If incomplete combustion is occurring, such as a misfire, the unburned oxygen will cause a low O2 sensor reading when in fact the mixture is rich.

Typically a tech will find the O2 sensor voltage fixed at rich (high) or lean (low). When this happens the first thing to do is to determine if the O2 sensor is reporting correctly or is the sensor defective. If the sensor is stuck lean see if the sensor responds to a rich mixture. If the sensor is stuck rich, see if the sensor will respond to a lean mixture. These two tests are covered below:

17.4.1 O2 Sensor – Response to Rich Test

Screen Capture 17-4



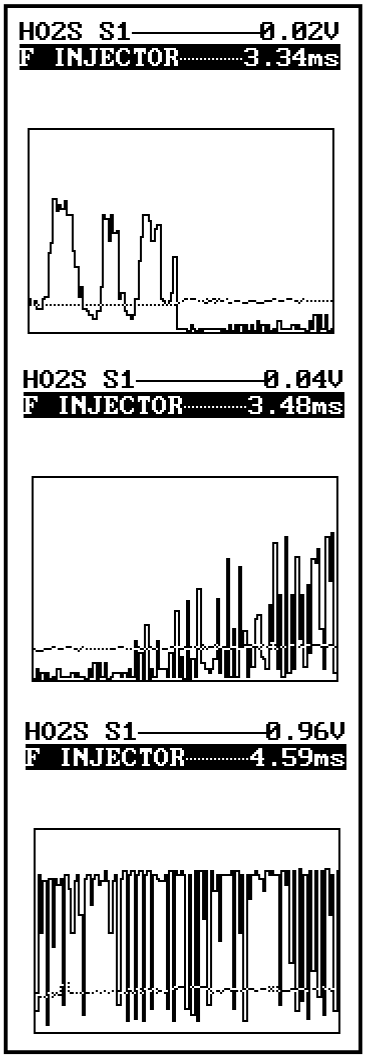
There are a couple of ways to create a temporary rich condition, to do a quick check on a Honda O2 sensor. You can quickly snap the throttle and the drop in vacuum will cause the manifold absolute pressure (MAP) sensor to temporarily richen the mixture. You can also temporarily unplug the vacuum hose on the pressure regulator to create a rich condition.

The best way to create a temporary rich condition is to not use an existing fuel injection component but to use an artificial fuel source. Introducing a shot of propane into the air intake will create an immediate rich mixture that is hard to duplicate. Propane will not damage O2 sensors or an exhaust analyzer's gas bench. The Screen Capture 17-4, on the left, shows the O2 sensor voltage of a Honda after a shot of propane was added to the air intake. Note the almost vertical upward line indicating the O2 sensor's response to the rich mixture. The O2 sensor's voltage should reach approx. .9 volts within 100ms, when subjected to a rich mixture. An O2 sensor that is "slower" than this should be replaced.

17.4.2 O2 Sensor – Response to Lean Test

An O2 sensor should also be tested to see how it responses to a lean condition. Since all Hondas are speed / density type injection systems, you cannot create a significant lean condition by pulling a vacuum line. A speed / density system does not actually measure the airflow, but injects fuel based off engine speed and manifold vacuum. Pulling a vacuum line on a Honda, for the most part, just causes the RPMs to increase.

Screen Capture 17-5



The quickest and best way to create a temporary lean condition is to unplug an injector. The top frame in Screen Capture 17-5 shows the O2 sensor voltage after an injector was unplugged. Unplugging an injector creates an immediate lean condition, as can be seen by the vertical drop in the O2 sensor voltage. If the O2 sensor voltage does not drop to approx. .1 volt within 100ms, the sensor is slow and should be replaced.

We can also check an ECM's ability to make corrections to the fuel, while in CL, with one injector unplugged. You can see this over these three consecutive screen captures. In the top screen capture one injector is unplugged and instantly that cylinder is pumping air into the exhaust. This obviously created an instant and significant lean condition. The O2 sensor responded immediately by dropping to near 0 volts, but as you look at the O2 sensor voltage over the remainder of the screen captures you will see something interesting going on.

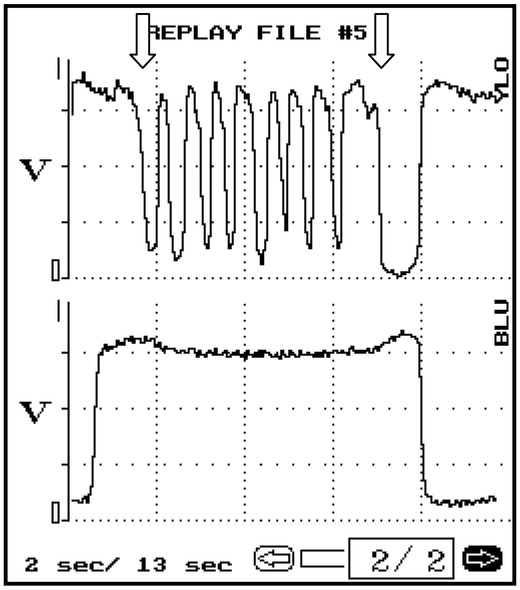
When the ECM gets a low voltage reading (lean condition) signal, it attempts to deliver more fuel by driving the PW wider. You can see the ECM "fight back" and eventually deliver enough fuel through the other plugged up injectors to make up for the one unplugged injector. It takes the car a couple of minutes to recover since the PW of the other injectors is only allowed to widen a little at a time. The authority for the PW to go wider and wider is issued by the ECM through a "block learning" approach. By the third screen, the ECM is delivering a "fairly normal" O2 sensor voltage waveform using just three injectors. Notice that the PW has increased to 4.6ms in an attempt to deliver enough fuel.

17.4.3 Post Catalyst O2 Sensor Testing

The post-cat O2 is only used to test the efficiency of the catalytic converter. On each trip the OBD-II system will typically run a test on the converter by comparing the pre and post cat O2 sensor voltages to each other.

As stated earlier, the post-cat O2 voltage should read steady and between .5 to .8 volts. If the post cat O2 voltage varies widely or drops below .5 volts follow this test procedure:

Screen Capture 17-6



If the post-cat O2 Sensor voltage is dropping below .5 volt and fluctuating, follow this test procedure:

1. Measure the catalytic converter inlet and outlet temperatures.

2. If outlet temperature is not at least 100^{o} F hotter than the inlet temperature, replace the converter. If it is at least 100^{o} F hotter go to step 3.

3. On deceleration (during fuel cut) the voltage should drop to .1 volt or less. If it does not, replace the converter.

Screen Capture 17-6 shows the waveform of a pre-cat O2 (on top) and a post-cat O2 (on bottom). Between the two arrows is a period of steady cruise. The post-cat voltage is steady and above .5, so it passes that part of the test.

At the right arrow the throttle was closed to force the car to go lean (fuel cut strategy). The post-cat voltage dropped to about .1 volt, so it passes that part of the test also.

17.5 Service Issues

17.5.1 O2 Sensor Contamination

O2 sensors do not "wear out", they typically fail due to contamination. The material that the sensing tip is made of is porous and many types of material will clog the pores or the O2 sensor. As the sensor becomes contaminated it slowly gets slower and slower in it response to changes in the oxygen content of the exhaust. Eventually the sensor may totally fail.

Silicone Deposits	This is the number one killer of LAF sensors. The most common source is from RTV sealant.
Solvents Lubricants Cleaners Adhesives	Do not spray or pour solvents, lubricants, cleaners, or adhesives into the intake air stream of a running engine. Take care as to not let any of these chemicals enter the combustion chamber in any way.

Gasoline Additives	Make sure all the additives that you may sell to the motoring public is O2 sensor safe. Educate your customers about the importance of using O2 sensor safe fuel additives
Lead	This should no longer be a problem, since leaded gas is no longer available for street use.
Carbon Deposits	Carbon deposits can come from rich fuel mixtures and/or an engine that is burning oil.
Engine Oil	An engine that is using an excessive amount of oil could contaminate the O2 sensor
Anti-Freeze.	A car that is leaking anti-freeze into the combustion chamber (like a leaking head gasket) can contaminate the O2 sensor.

Due to the fact that an O2 sensor can become contaminated from excessive oil or antifreeze consumption, it should not be overlooked when pricing certain engine repair jobs!

17.5.2 Clogged External Air Vents

For the O2 sensor to work properly the inside layer of the sensor's tip must be exposed to the atmosphere. This is done through vents that are built in to the O2 sensor body. If these vents get clogged, the sensor will not operate correctly.

Avoid getting material such as: rust proofing, undercoating, solvents, brake fluid, or power steering fluid in the sensor vents. Also be careful when pulling heads for engine work. If you set the head down just right, the oil from the head could end up dumping over on the O2 sensor vents.

17.5.3 Voltage Bleedover

The O2 sensor puts out a maximum voltage of close to one volt. There have been several cases of this voltage getting much higher than the one volt. If the O2 sensor input voltage is significantly higher that 1-1.2 volts, you are probably seeing voltage bleed over onto the signal wire.

The most common cause of this is a defective O2 that is letting the heater voltage bleed over onto the sensor's input wire. This can be tested by temporarily disconnecting the heater wire and see if the O2 sensor's input voltage returns to a normal range.

Note also that there have been a few cases of ECM/PCMs that were damaged due to the excessive current draw requirements of non-stock O2 sensors. All the current used by the O2 heaters is supplied directly from the ECM/PCM.