Module 18
Lean Air Flow (LAF) Sensor

Author: Grant Swaim

E-mail: sureseal@nr.infi.net

URL: www.tech2tech.net

Phone: (336) 632-9882

Fax: (336) 632-9688

Postal Address: Tech-2-Tech Website
PO Box 18443
Greensboro, NC 27419

Physical Address: 220-4 Swing Rd
Greensboro, NC 27409

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18 Lean Air Fuel Sensor

18.1 General Overview

The zirconia oxygen (O2) sensor has been at the heart of the fuel feedback systems going all the way back to the 1984 feedback carbs. The O2 sensor is still used today, virtually unchanged except for the addition of a heater.

The standard O2 sensor has its limitations since it can only be used to maintain the air / fuel (AF) mixture to within a range of approximately 14.7:1. This ratio, sometimes called stoichiometric, was once considered to be the most efficient AF ratio. With the development of improved engine designs, more powerful engine control modules, and more accurate fuel controls, engines can now run at leaner mixtures. A special O2 sensor, called a lean air fuel (LAF) sensor, can be used to detect AF ratios in a range from approximately 12:1 to 22:1.

Image 18-1 LAF Sensor

The LAF sensors have only been used on the high efficiency Civic models. They are used on the 1992-95 Civic VX and the 1996-98 Civic HX. The LAF sensor looks just like a traditional O2 sensor except that it has 5 wires, as shown in Image 18-1.

Honda, at present, uses the LAF to control the mixtures in the range of 12:1 to 22:1 and will go into open loop (OL) when richer mixtures are required. At least one company (Bosch) is developing a similar sensor to control fuel at all mixtures. Anytime a fuel delivery system is operating in the OL mode it is not as efficient as it is when running in CL mode.

18.2 How Does It Work?

The LAF sensor is a somewhat complicated sensor. Even though the LAF is using two standard O2 sensors in tandem, the way it works is a lot different than the way a single O2 sensor works. If you do not get this on the first read, do not get discouraged, read it again. Luckily the sensor is virtually trouble free and many techs do not even know this sensor exists. Lets charge on and take a systematic approach to learning how this sensor works.

Zirconia O2 Sensor's Response To Oxygen Concentrations

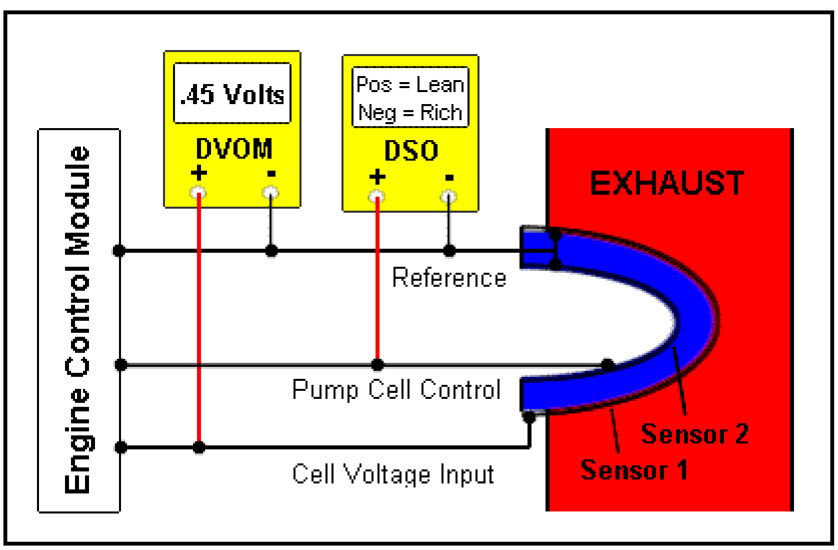
The LAF sensor is basically made up of two standard zirconia O2 sensors that work in tandem. Before we get into the theory behind the LAF sensor, lets take a quick review of how a standard O2 sensor works.

The thimble shaped sensing tip of the O2 sensor is made of platinum coated zirconia. When this tip is heated to at least 600 degrees, it will produce a voltage, if there is a difference in oxygen concentration between the inside of the tip and the outside of the tip. The outside of the thimble shaped sensing tip is exposed to the exhaust gases and the inside of the thimble shaped sensing tip is exposed to the atmosphere.

The atmosphere's oxygen content is approximately 20% while the oxygen content of the exhaust gases are more like 1-2 %. The oxygen ions travel from the higher concentration in the atmosphere to the lower concentration in the exhaust. This flow of oxygen ions through the zirconia produces a voltage that is fed to the ECM. The greater the difference in concentration between the atmosphere and the exhaust the greater the oxygen ion flow and the greater the voltage. For instance when the exhaust goes lean, the exhaust has a higher concentration of oxygen, the flow of oxygen ions is less, and the voltage produced is less. When the exhaust goes rich, the exhaust has a lower concentration of oxygen, the flow of oxygen ions is more, and the voltage produced is higher.

18.3 Construction of the LAF Sensor

Illustration 18-1



Refer to Illustration 18-1 as we discuss both the construction and operation of the LAF sensor. The LAF sensor looks like a traditional O2 sensor on the outside. It also has some similarities in how it is designed internally. As you can see from the illustration, the LAF sensor is actually made from two O2 sensors, sensor 1 and sensor 2. The outside of the sensor 1 thimble shaped tip is exposed to the exhaust gases. The inside of the sensor 1 tip is not exposed to the atmosphere, but to a diffusion chamber. We will see later how the oxygen concentration in this chamber is controlled by the ECM.

Sensor 2 is mounted behind sensor 1 and the outside of sensor 2 creates an airtight chamber between the two sensors. The inside of sensor 2 is exposed to the atmosphere.

A wire, attached to the outside of sensor 1, returns to the ECM and is called the cell voltage input. This wire is similar to a traditional O2 sensor input wire since it produces a voltage that reflects the differences in oxygen concentration between the exhaust gases and the chamber in the inside. The key difference here is that the inside chamber is not the atmosphere but a chamber whose oxygen content can be controlled by the ECM. This chamber is called a diffusion chamber.

A second wire is attached to the inside of sensor 1 and the outside of sensor 2. This is to a common ground for the two sensors. It is best to think of it as a reference voltage since it does maintain close to 3 volts during operation.

A third wire is attached to the outside of Sensor 2 and returns to the ECM. This wire is called the pump cell control since this is the wire that the ECM uses to "pump" oxygen into and out of the diffusion chamber.

18.4 Operation of the LAF Sensor

The LAF sensor can measure a wide range of A/F ratios because the ECM can control the oxygen content of the diffusion chamber. Let's take a look at how it does it.

The ECM monitors the voltage that is produced by sensor 1. Sensor 1 works like a traditional O2 sensor in that it is producing a voltage that reflects the difference in oxygen concentration between the exhaust gases and the diffusion chamber.

The ECM tries to maintain .45 volts on sensor 1 by controlling the amount of oxygen in the diffusion chamber. Oxygen is "pumped" into or out of the diffusion chamber by the current sent over the pump cell control wire to sensor 2.

How can an oxygen sensor be used to pump oxygen? I know it sounds strange, but hey... it works. Just like many other electrical phenomena, the oxygen ion flow to voltage relationship works both ways. Just like electricity makes magnetism and magnetism makes electricity, oxygen ion movement makes voltage and voltage makes oxygen ions move. The voltage applied by the ECM to sensor 2 causes it to either pump oxygen ions into the diffusion chamber, or to pump them out of the diffusion chamber.

OK, lets put the whole thing together! The ECM is monitoring the voltage being produced by sensor 1 via the cell voltage input wire. The ECM attempts to maintain the voltage at .45 volts by controlling the voltage applied to Sensor 2 via the pump cell control wire. The ECM monitors the voltage that must be applied to sensor 2 to maintain .45 volts on sensor 1 and uses this to determine the oxygen content (and subsequently the AF ratio) of the exhaust gases.

18.4.1 Rich Condition Scenario

Lets walk through what happens if the mixture goes rich. As the mixture goes rich (lower oxygen concentration) more oxygen ions flow from the diffusion chamber to the exhaust. This creates a higher voltage output from sensor 1, just like any other O2 sensor would do.

The ECM detects the increase in the cell voltage input and lowers the pump cell voltage to sensor 2 to below the common reference voltage (actually goes to a negative voltage). This will cause sensor 2 to pump oxygen out of the diffusion chamber and into the atmosphere. When the level of oxygen has dropped in the diffusion chamber, the oxygen concentration differential between the diffusion chamber and the exhaust gases is less and sensor 1 cell voltage will drop.

Screen Capture 18-1

ENGINE SPD	705RPM
VSS	0MPH
ECT SENSOR	0.49V
IAT SENSOR	1.15V
MAP SENSOR	1.29V
BARO S	2.83V
TP SENSOR	0.49V
HO2S	14.9A/F
AF FB COND	CLOSED
AF FB CMD	14.7A/F
BATTERY	13.3V
ELD	31.7A

ENGINE SPD	2053RPM
VSS	21MPH
ECT SENSOR	0.62V
IAT SENSOR	1.33V
MAP SENSOR	2.77V
BARO S	2.83V
TP SENSOR	3.96V
HO2S	12.3A/F
AF FB COND	CLOSED
AF FB CMD	12.3A/F
BATTERY	13.9V
ELD	25.1A

ENGINE SPD	2506RPM
VSS	27MPH
ECT SENSOR	0.53V
IAT SENSOR	1.25V
MAP SENSOR	1.97V
BARO S	2.83V
TP SENSOR	1.54V
HO2S	22.1A/F
AF FB COND	CLOSED
AF FB CMD	21.9A/F
BATTERY	13.8V
ELD	27.7A

18.4.2 Lean Condition Scenario

If the exhaust gases go lean the whole process happens in reverse. As the exhaust goes lean (more oxygen) the transfer of oxygen ions from the diffusion chamber to the exhaust slows down and the voltage from sensor 1 drops. The ECM senses this drop and increases the voltage on the pump cell control wire and sensor 2 pumps more oxygen into the diffusion chamber. This increase of oxygen in the diffusion chamber will cause more oxygen ions to flow to the exhaust and increase the voltage.

In summary, the ECM/PCM monitors the voltage needed by the pump cell control to maintain the .45 volts on sensor 1. This voltage is used by the ECM to calculate the A/F ration of the exhaust gases. Using this technique the sensor can be used to monitor ratios between 12:1 and 22:1. As you will see in testing, the pump cell control wire produces a voltage that is proportional to the air / fuel ratio.

18.5 Operation Summary

Feedback control with the LAF sensor is different than how fuel is controlled when using a traditional O2 sensor. When a traditional O2 sensor is used for feedback control the ECM/PCM simply trims fuel down if the voltage is above .5 volts and trims it up if it is below .5 volt. This technique can only control fuel to a 14.7 AF ratio.

The LAF feedback system introduces us to a new parameter called commanded AF ratio. The ECM/PCM determines the optimum AF ratio for each given set of operating conditions. You can see the commanded AF ratio in the three frames of the Screen Capture 18-1.

After the optimum AF ratio has been determined by the ECM/PCM the proper pump cell voltage is looked up in an internal table. The fuel control then modulates on this voltage to control the fuel to the optimum ratio.

For example, if the ECM/PCM has determined that the car can run on a leaner mixture, it will start leaning the mixture by narrowing the fuel injector pulse width (PW). It will monitor the pump cell control voltage so that when the target A/F ratio is reached it will hold it there. With the LAF system, the ECM is determining what ratio the car should run at and is using the LAF sensor to determine when it has met that ratio

18.6 LAF Wire Terminals

Image 18-2

Terminal Location	
1	Heater Positive
2	Chassis Ground
3	ECM Ground
4	LABEL Resistance Input
5	Blank
6	Cell Voltage Input
7	Pump Cell Control
8	Reference Voltage

The wire colors changed a lot, but luckily all the terminal locations in the LAF connector stayed the same. Use the terminal location table when doing these checks. Honda's terminal location numbering scheme, is listed in the glossary.

One other note about the LAF sensor wiring is that you will find seven wires on the engine side wiring harness, and even seven terminals in the LAF connector, but only 5 wires from the connector to the LAF sensor. Two of the terminals are connected to a calibrating resistor that is located in the LAF terminal. This resistor is typically 4.3K ohms. This connector is shown in Image 18-2.

18.7 How Do You Test Them?

Luckily, this complicated sensor is relatively easy to test. It consists mainly of three voltage tests, the reference voltage, the cell voltage and the pump cell voltage. The reference voltage should be 2.7 volts. The cell voltage should be a constant .45 volts. The pump cell voltage is the equivalent of an O2 sensor input voltage. It is the voltage that changes with the air/fuel ratio however it works opposite of a standard O2 sensor (rich = low, lean = high).

Lets take a closer look at these checks. All these checks are done after:

- The car at full operating temperature (radiator fans cycling)
- Running the engine at 2000 RPM for 2 minutes to warm up the LAF sensor

18.7.1 Reference Voltage

The wire that is common to both sensors is a reference voltage wire. It is referred to in some manuals as a ground wire. Do not confuse this wire with chassis ground, since it has voltage on it. It is best to think of it as a reference wire. The reference voltage test is done with a digital volt-ohm meter (DVOM) with the leads attached as follows:

Positive Lead	Negative Lead	Value
Reference Wire (8)	Chassis Ground (2)	2.7 volts

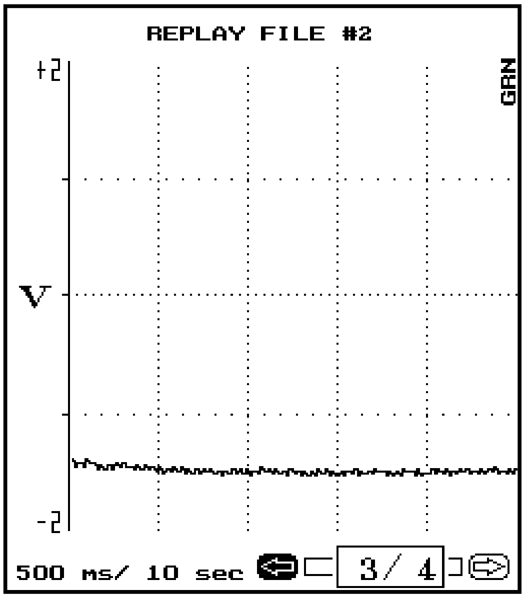
18.7.2 Pump Cell Voltage

The pump cell voltage is the most useful voltage for diagnostic work, since it reflects the air / fuel ratio of the exhaust. This voltage will not be steady and should be checked using a digital storage oscilloscope (DSO). All the following pump cell voltage tests are made with a DSO set at 500mv per division and 200ms per division, with the leads attached as follows:

Positive Lead	Negative Lead	Value
Pump Cell Control (7)	Reference Voltage (8)	Rich approx. - 1.0 Lean approx. 420mv

18.7.3 Rich Response Test

Screen Capture 18-2



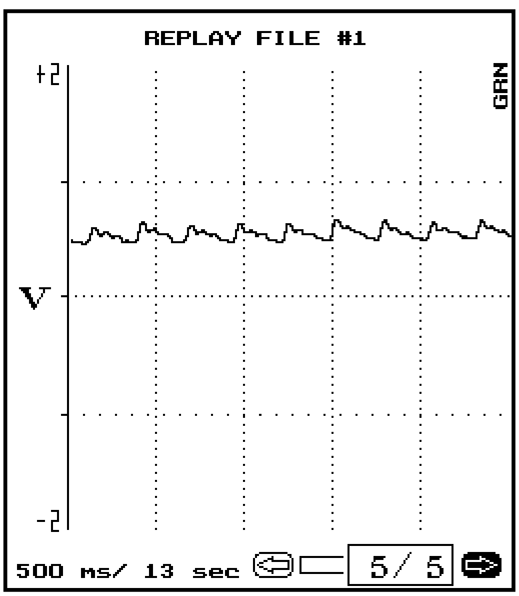
Add propane to the intake to temporarily enrichen the air fuel mixture. The pump cell voltage should go negative. The voltage should be approximately -1.0 volt.

Screen Capture 18-2 shows the results of this test on a 1992 Civic VX with a known good LAF sensor. The value on this car was approximately -1.3 volts.

18.7.4 Lean Response Test

Create a temporary lean mixture. This should occur, momentarily, after the propane is quickly turned off. I prefer to pull an injector connector. This will create an instant huge lean condition for as long as you want it. A lean condition should cause the voltage to increase to close to .400 volts.

Screen Capture 18-3



Screen Capture 18-3 shows the results of this test on a 1992 Civic VX with a known good LAF sensor. The value on this car was approximately .6 volts. This test was done with an injector unplugged.

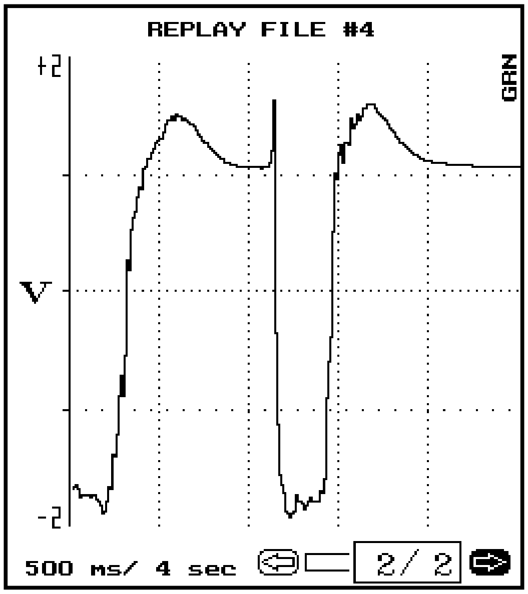
18.7.5 Peak to Peak Pump Cell Voltage Test

In all cases the total voltage range from the rich voltage to the negative voltage should exceed 1 volt. On the test vehicle the rich voltage was -1.3v and the lean voltage was .4v. The peak-to-peak sensor range was 1.7v, which is good.

18.7.6 Response Time

Create a temporary rich condition by snapping the throttle all the way open. The pump cell control voltage should immediately fall. The voltage should fall to full

Screen Capture 18-4



rich within 100ms. If it takes longer than 100ms, the sensor is probably contaminated and should be replaced.

On the test vehicle the throttle was snapped twice. The first snap created a temporary lean condition (immediately after an initial rich condition) and the second snap (in the middle of the screen) tested the sensors ability to respond from lean to rich. The sensor transitioned well within limits. This test is shown in Screen Capture 18-4.

18.8 Service Issues

LAF sensors have service issues similar to a standard O2 sensor. The largest area of concern is sensor contamination. The LAF sensor for the 1996-1998 Civic HX retails for over $400, get the picture.? Here are some of the more common service issues.

18.9 LAF Sensor Contamination

LAF 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 LAF 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 contami-

	nate the LAF sensor
Anti-Freeze.	A car that is leaking anti-freeze into the combustion chamber (like a leaking head gasket) can contaminate the LAF sensor.

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

18.10 Clogged External Air Vents

For the LAF sensor to work properly the inside layer of sensor 2 must be exposed to the atmosphere. This is done through vents that are built in to the LAF 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 LAF sensor.