Bosch Wideband Oxygen Sensors Precisely Measure Air/Fuel Ratios

Wideband Oxygen Sensors

As engine management and on-board diagnostic systems continue to evolve, so too do the oxygen sensors that monitor the air/fuel mixture. The latest generation of "wideband" oxygen sensors from Robert Bosch are smarter, faster, more durable and capable of precisely measuring exact air/fuel ratios - a feat that was impossible with earlier generations of O2 sensors.

Traditionally, oxygen sensors have been used to monitor the level of unburned oxygen in the exhaust. The amount of oxygen that's left in the exhaust following combustion is a good indicator of the relative richness or leanness of the fuel mixture.

When air and gasoline are mixed together and ignited, the chemical reaction requires a certain amount of air to completely burn all of the fuel. The exact amount is 14.7 lbs of air for every pound of fuel. This is called the "stoichiometric" air/fuel ratio. It's also referred to the the Greek letter "lambda."

When lambda equals one, you have a 14.7:1 stoichiometric air/fuel ratio and ideal combustion. When the air/fuel ratio is greater than 14.7:1, lambda also will be greater than one and the engine will have a lean mixture.

Lean mixtures improve fuel economy but also cause a sharp rise in oxides of nitrogen (NOX). If the mixture goes too lean, it may not ignite at all causing "lean misfire" and a *huge* increase in unburned hydrocarbon (HC) emissions. This can cause rough idle, hard starting and stalling, and may even damage the catalytic converter. Lean mixtures also increase the risk of spark knock (detonation) when the engine is under load.

When the air/fuel ratio is less than 14.7:1, lambda also is less than one and the engine has a rich fuel mixture. A rich fuel mixture is necessary when a cold engine is first started, and additional fuel is needed when the engine is under load. But rich mixtures cause a sharp increase in carbon monoxide (CO) emissions.

When the relative proportions of air and fuel are "just right," the mixture burns clearly and produces the fewest emissions. The trick is balancing the mixture as driving conditions, temperatures and loads are constantly changing. That's where oxygen sensors come in.

By monitoring the level of unburned oxygen in the exhaust, the sensor(s) tell the engine computer when the fuel mixture is lean (too much oxygen) or

The Wideband Air/Fuel Sensor

The newest generation of oxygen sensors are being called "wideband" lambda sensors or "air/fuel ratio sensors" because that's exactly what they do. They provide a precise indication of the exact air/fuel ratio, and over a much broader range of mixtures - all the way from 0.7 lambda (11:1 air/fuel ratio) to straight air!

The Bosch LSU 4 wideband oxygen sensor is a 5-wire sensor that reads oxygen in much the same way as a traditional oxygen sensor. but it uses the latest "planar" construction with a special two-part sensing element to measure how much oxygen is in the exhaust.

In 1997, Bosch developed a new type of construction for oxygen sensors that uses a flat ceramic zirconia element rather than a thimble. It's called a "planar" sensor because the sensor element is a flat strip of ceramic that is only 1.5mm thick. The electrodes, conductive layer of ceramic, insulation and heater are laminated together on a single strip. The new design works the same as the thimble-type zirconia sensors, but the "thick-film" construction makes it smaller and lighter, and more resistant to contamination. The new heater element also requires less electrical power and brings the sensor up to operating temperature in only 10 seconds.

In creating the new LSU 4 wideband air/fuel ratio sensor, Bosch combined the oxygen-sensing "Nernst" cell from the planar sensor with an "oxygen pump" to create a device that can actually measure air/fuel ratios. Here's how it works:

The Nernst cell still senses oxygen in the same way that a conventional thimble-type O2 sensor does. When there's a difference in oxygen levels across the zirconium dioxide sensor element, current flows from one side to the other and produces a voltage. But, as we said earlier, this isn't good enough because it gives only a gross rich-lean indication of the air/fuel mixture.

To get the added precision, the oxygen pump uses a heated cathode and anode to pull some oxygen from the exhaust into a "diffusion" gap between the two components. The Nernst cell and oxygen pump are wired together in such a way that it takes a certain amount of current to maintain a balanced oxygen level in the diffusion gap. And guess what? The amount of current required to maintain this balance is directly proportional to the oxygen level in the exhaust. This gives the engine computer the precise air/fuel measurements it needs to meet the new emission requirements.

rich (too much fuel). To compensate, the computer adjusts the fuel mixture by adding more fuel when the mixture is lean, or using less fuel when it is rich. That's the basic feedback fuel control loop in a nutshell.

The trouble is, conventional oxygen sensors give on a rich-lean indication. They can't tell the computer the exact air/fuel ratio. When the air/fuel ratio is perfectly balanced, a convention O2 sensor produces a signal of about 0.45 volts (450 millivolts). When the fuel mixture goes rich, even just a little bit, the O2 sensor's voltage output shoots up quickly to its maximum output of close to 0.9 volts. Conversely, when the fuel mixture goes lean, the sensor's output voltage drops to 0.1 volts.

Every time the oxygen sensor's output jumps or drops, the engine computer responds by decreasing or increasing the amount of fuel that is delivered. This rapid flip-flopping back and forth allows the feedback fuel control system to maintain a more-or-less balanced mixture, on average. But this tried-and-true approach that has worked so well thus far isn't accurate enough to meet the latest emissions requirements.

The new NLEV (national low emission vehicle) standards plus California's LEV (low emission vehicle), ULEV (ultra low emission vehicle) and SULEV (super ultra low emission vehicle) standards all require very precise control over the air/fuel ratio. Reducing cold emissions when the engine is first started is absolutely critical to meeting these standards. But conventional oxygen sensors (even with heaters) warm up too slowly to provide the degree of accuracy needed to meet cold emissions. They also lack the ability to tell the PCM the exact air/fuel ratio, something that is becoming increasingly necessary as advanced fuel control strategies are introduced. A simple rich-lean indication is not enough in today's world.

The wideband oxygen sensor receives a reference voltage from the engine computer and generates a signal current that varies according to the fuel mixture.

When the air/fuel mixture is perfectly balanced at 14.7:1 (the stoichiometric ratio and lambda equals 2), the sensor produces no output current. When the air/fuel mixture is rich, the sensor produces a "negative" current that goes from zero to about 2.0 milliamps when lambda is 0.7 and the air/fuel ratio is near 11:1.

When the air/fuel mixture is lean, the sensor produces a "positive" current that goes from zero up to 1.5 milliamps as the mixture becomes almost air.

The Bosch LSU 4 wideband oxygen sensor has a response time of less than 100 milliseconds to changes in the air/fuel mixture, and reaches operating temperature of 700 to 800 degree Centigrade (1,400 degree F) within 20 seconds or less using its internal heater. This is nearly twice the operating temperature of a conventional oxygen sensor.

Other Uses

Many performance engine builders and tuners have discovered the benefits of using the wideband oxygen sensor technology to monitor air/fuel ratios. Being able to see the actual air/fuel ratio at any given instant in time allows the fuel mixture to be fine-tuned and adjusted on the fly - something which previously could only be done on a dynamometer using expensive equipment.

The air/fuel ratio is critical with high performance, turbocharged and supercharged engines to make power and to keep the engine from leaning out at high rpm and boost pressures. If the mixture leans out, it can send the engine into self-destructing detonation.

Bosch Wideband Oxygen Sensor Diagnostics

Diagnostics

Because of the internal circuitry used in a wideband oxygen sensor, you can't hook up a voltmeter or oscilloscope to read the sensor's output directly. A wideband O2 sensor produces a current signal that varies not only in amplitude but direction. That makes it quite different from a conventional oxygen sensor that produces a voltage signal that bounces back and forth between 0.1 and 0.9 volts.

The only way you can currently diagnose a wideband oxygen sensor is through the vehicle's on-board diagnostic system using a scan tool.

You can use the scan tool to read the actual air/fuel ratio, and to check the sensor's response to changes that should cause a change in the air/fuel ratio. Opening the throttle wide, for example, traditionally causes a sudden and brief lean condition followed by a richer mixture as the computer compensates. But with the new control strategies made possible with wideband O2 sensors, the air/fuel ratio remains steady when the throttle is snapped open.

The diagnostic strategies for wideband O2 sensors vary from one vehicle manufacturer to another but, as a rule, you'll get an oxygen sensor code if the sensor reads out of its normal range, if the readings don't make sense to the computer (should indicate lean when lean conditions exist, etc.) or if the heater circuit fails.

One thing to keep in mind about wideband O2 sensors is that they can be fooled in the same way as a conventional oxygen sensor by air leaks between the exhaust manifold and head, and by misfires that allow unburned oxygen to pass through into the exhaust. Either will cause the sensor to indicate a false lean condition which, in turn, will cause the computer to make the engine run rich.

Other Wideband Sensors

It's important not to confuse Bosch wideband O2 sensors with those produced by other OEM suppliers. With some other wideband O2 sensors (such as those used in 1996 and newer Toyotas, for example), a scan tool will display a "simulated" voltage reading between 0 and 1 volt. The actual voltage output from the sensor is much higher, but the computer is calibrated to divide the sensor's actual output by 5 to comply with OBD II regulations that require a display reading of 0 to 1 volts (these regulations have since been revised to allow the actual voltage to be displayed.)

Sensor Replacement

Bosch wideband oxygen sensors are designed for an operational life of 100,000 miles. Replacement should be needed only if the sensor has failed due to unusual operating conditions, physical damage, or contamination. Blowing a head gasket can allow silicon to enter the exhaust and contaminate the sensor. Oil burning can allow phosphorus to enter the exhaust and contaminate the sensor. If replacement is necessary, use the same type of wideband sensor as the original.