Verifying the Oxygen Sensor

PART 5

by Steve Bodofsky

Figure 1 — No other tool provides more information about an oxygen sensor's condition than a digital oscilloscope.

Figure 2 — You can use a digital meter to check the oxygen sensor's condition, but you won't be able to measure rise and fall times.

So far, you've learned how the oxygen sensor can be invaluable for identifying problems in the computer system. And not just for determining there *is* a problem; when compared with the mixture commands, the oxygen sensor signal can help you figure out where to look for a failure in the system.

But only if the oxygen sensor's working properly: If the sensor's damaged or out of calibration, its signal becomes meaningless. So before you can use the oxygen sensor signal for diagnosing computer operation, first you have to check the sensor itself, to make sure it's working properly. This process is called *verifying the oxygen sensor*.

Tools You'll Need...

There are a few basic tools necessary for verifying the oxygen sensor. Some you probably already have; others you may want to consider purchasing.

1. Digital Oscilloscope (DSO; figure 1) — This is probably the best tool for measuring oxygen sensor operation. It's fast enough to capture intermittent glitches, while providing a graph of voltage readings over several minutes. A graphing multimeter will also work, but may be too slow to catch momentary glitches in the signal.
2. Digital Multimeter (figure 2) — If you don't have a scope and don't want to buy one, you can use a digital multimeter instead. A good quality meter will provide the voltage measurements you're looking for; if it offers MIN MAX, it'll also provide glitch capture, although not as accurately as a good scope will. The only real drawback to using a meter instead of a scope is you won't be able to measure rise time and fall time — more about that later.
3. Propane Enrichment Tool (figure 3) — While you may not need this for most cars, a propane enrichment tool will

enable you to force the vehicle mixture rich, even if the injectors are plugged and the system won't go rich on its own. They're usually relatively inexpensive, as most only consist of a propane regulator and a hose.

4. Oxygen Sensor Socket (figure 4) — This is a special socket with a slit for the sensor wire. Not critical, but makes sensor removal and replacement somewhat easier.

At this point, you're probably thinking that you could use your scan tool instead of a scope or meter. Sorry; most scan tools are too slow at updating to be of much value for verifying the oxygen sensor. What's more, most won't display negative voltages, a critically important step in this test.

Figure 3 — If the fuel system isn't providing adequate response to the throttle, you may need a propane enrichment tool to force the oxygen sensor rich.

Figure 4 — Not a necessity, but nice to have around, an oxygen sensor socket make's removing the oxygen sensor easier.

What You're Looking For...

Before we get into the connection and testing process, let's discuss what we should expect from a good oxygen sensor (figure 5). In general…

1. The voltage should rise to at least 850 mV.
2. The voltage should drop below 150 mV.
3. The voltage should never drop below zero.
4. The voltage should switch anywhere from once every two seconds, to 5 times per second. Carbureted vehicles will tend to switch the slowest, followed in this order: throttle body injection, bank injection, and sequential injection, which tends to switch the fastest.
5. The voltage rise time should be less than 80 ms.
6. The voltage fall time should be less than 100 ms.

Just a quick note: I've never seen a sensor that met the voltage specs and didn't meet the rise and fall time specs. So, while this is a legitimate spec for measuring oxygen sensor performance, if the sensor meets voltage specs okay, it'll *probably* meet the rise and fall time specs.

Connecting Your Scope or Meter

IMPORTANT: In this series, we're only covering the standard zirconia oxygen sensor, used in most vehicles

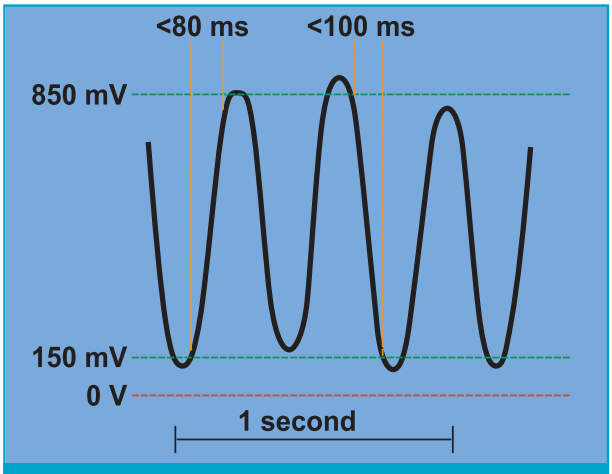

Figure 5 – Here's what you're looking for in a good oxygen sensor: Voltage limits, rise and fall times. And the voltage should never drop below zero.

on the road. We won't be examining titania sensors, which hardly exist anymore, or the special Honda 7-wire sensors used on their low-emission vehicles, which are an article unto themselves.

You might think that connecting your scope or meter would be the easy part. After all, how much can be involved in connecting your meter to a simple oxygen sensor? Well, it may be a little more involved than you'd think. Here's why:

Figure 6a and 6b show two oxygen sensor waveforms. Both were taken from the same car, with the same oxygen sensor, within minutes of each other. There was only one difference: the ground. Figure 6a was taken with the scope connected to a good chassis ground. Figure 6b was taken with the scope connected to the oxygen sensor ground.

As you can see, the second waveform — figure 6b — is much smoother, without all the spikes and noise in the waveform. Figure 6a even has one spike that drops below zero; usually a sure sign of a bad sensor. But in this case, it was just a good example of a bad connection.

To connect your scope or meter to the oxygen sensor, always use the sensor ground. On one-wire sensors, that's easy: the sensor ground *is* the chassis ground. But other types of sensors require more involved connection procedures.

On all sensors, connect the positive lead to the oxygen sensor signal wire. You can do this by backprobing the sensor connector, or by using a piercing probe on the sensor wire — just remember to seal the hole from the piercing probe when you're finished.

To connect the negative lead (figure 7):

1-Wire Sensors: Connect the negative lead to a good ground, as close to the sensor as possible.

2-Wire Sensors: Connect the negative lead to the negative sensor wire.

3-Wire Sensors: Connect the negative lead to the negative wire from the sensor; this ground is shared with the oxygen sensor and the sensor heater.

4-Wire Sensors: This is the tough one — these sensors have two grounds: one for the heater and one for the sensor. So avoid the whole issue: Connect your negative lead to a sensor ground on a different sensor, such as the TPS or the MAP sensor, because most systems use the same ground for every sensor.

Once you have your scope or meter connected, set them to read the oxygen sensor signal.

Digital Multimeter:

- Set the voltage scale to the 2- or 4-volt scale. Don't leave it on autorange, or it'll switch back and forth between millivolts and the low voltage range.
- If your meter has MIN MAX or Peak MIN MAX capabilities, you'll want to activate it during the test procedure. That way you won't have to watch the display every second during the test; the meter will capture minimum and maximum voltages for examination later.

Scope:

- Set the voltage scale to 0.2 volts per division.
- Set the ground level to the first or second division from the bottom of the display.
- Set the timebase to about 500 ms per division (you may want to adjust this up or down later, depending

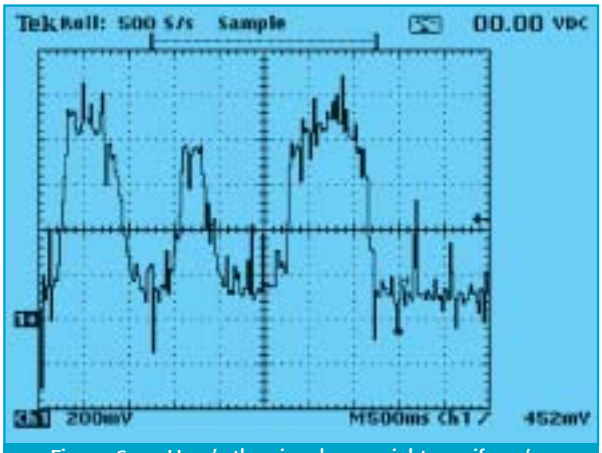

Figure 6a — Here's the signal you might see if you've connected your scope to the system ground instead of the oxygen sensor ground.

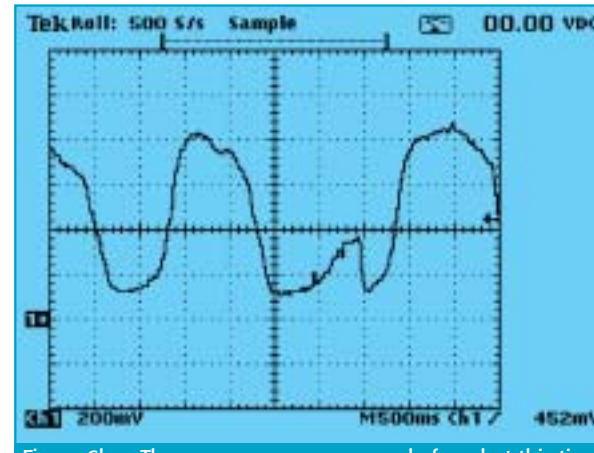

Figure 6b — The same oxygen sensor as before, but this time the scope was connected to the sensor ground instead of the system ground.

on the signal.

Don't forget that the oxygen sensor has to reach normal operating temperature to create a signal. In most cases, that's over 400º F. If it's a heated sensor, it should get there on its own, after the engine runs for a couple minutes. For an unheated sensor, you'll have to raise the engine to about 2000 RPM for a couple minutes to bring the sensor to light-off temperature.

Once the oxygen sensor gets hot enough to begin catalyzing hydrogen in the exhaust with oxygen from the surrounding atmosphere (see the first part of this series for more on that!), it's ready for testing.

Testing the Oxygen Sensor

If the rest of the fuel delivery system is working properly, you'll probably get enough response for a valid test just by goosing the throttle a few times (figure 8). All you're trying to do is force the mixture full rich and full lean, and goosing the throttle may be enough to do that.

If goosing the throttle doesn't provide enough range for the sensor to reach the specs listed, you may want to have someone drive the car while you monitor the sensor signal from the passenger seat. If you're using a scope, capture a couple waveform samples to measure later.

If the oxygen sensor signal still won't reach the limits set for it, it could be because the sensor is bad… or it could be because the fuel injection system is clogged or isn't responding properly. To be sure, you may want to use a propane enrichment tool to force the system rich and lean (figure 9). Here's how:

Test Tip: You may have to raise the idle slightly to prevent stalling the engine during this test.

1. Apply a small amount of propane to the air intake while monitoring the oxygen sensor signal. The voltage should go high for a moment, then drop back to normal as the system leans out to compensate for the propane.
2. Keep increasing the propane, a little at a time, until the fuel injection can't compensate, and the oxygen sensor signal voltage stays high: That's the full-rich voltage you needed.
3. Shut the propane off quickly. The oxygen sensor voltage should drop to minimum levels as the system recovers.

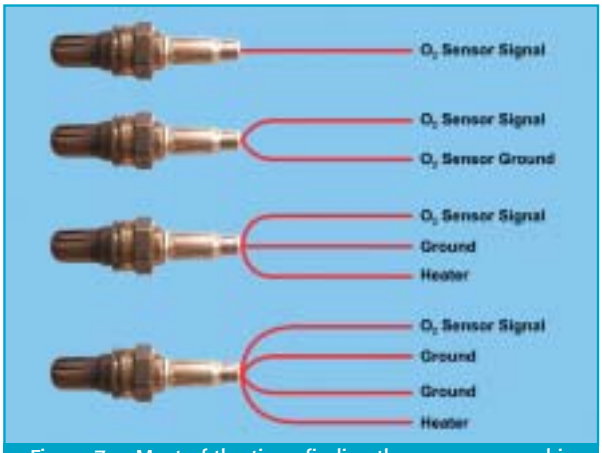

Figure 7 — Most of the time, finding the sensor ground is easy. The only problem is on a 4-wire sensor; for that, take your ground from another sensor altogether.

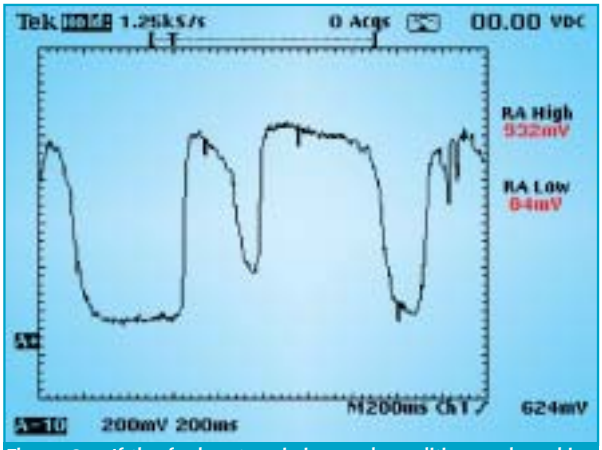

Figure 8 — If the fuel system is in good condition and working properly, you can verify the oxygen sensor simply by goosing the throttle a few times.

Figure 9 — If you can't get the system rich enough by goosing the throttle, a propane enrichment tool is the easiest way to force the system rich.

If you're using a scope display, the signal should look something like figure 10. Capture that waveform; you'll be able to use it to measure the maximum voltage, minimum voltage, and fall time. If the sensor passes those readings, it's

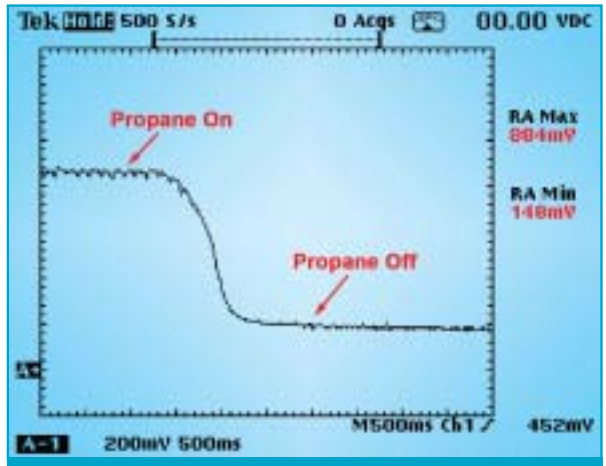

Figure 10 — Here's the signal you're looking for using a propane enrichment tool to force the system rich.

fine. If not, replace the sensor and check it again.

Replace the oxygen sensor if:

- The signal doesn't reach 850 mV or drop below 150 mV.
- The signal doesn't switch quickly enough — at least once every two seconds on a carbureted vehicle, faster on fuel injected systems.
- The voltage drops below zero volts — this is a deal-breaker; if the signal goes negative even once, replace the sensor.
- The voltage rise time or fall time are too slow (you won't be able to check this without a scope or graphing meter). These times get measured from just before the signal begins to peak; or about 90% of maximum and minimum voltage.

Repair Tip: When replacing an oxygen sensor, always use one designed for the specific application you're working on. Never use one of the universal sensors that requires you to splice the wires to the original connector; it's too easy to cross a wire, and build in more problems than you correct.

Once you've replace the oxygen sensor, check the new one to make sure it's working right. Then you're ready to check the rest of the computer control system.

A note of caution: In some cases, it's possible for the engine to start pinging right after you replaced the oxygen sensor. This is because the oxygen sensor was keeping the mixture too rich, causing carbon to build up in the combustion chamber. Once the mixture goes back to normal, the engine starts to ping or knock.

The fix? Run a can of top engine cleaner through the engine, to break up the carbon and allow it to blow out the exhaust. A good fuel system service will also loosen the carbon and correct the ping. In either case, it doesn't mean you did anything wrong. Just the contrary: It means the oxygen sensor should have been replaced long ago.