

OBD-II and Oxygen Sensors

The oxygen sensor has to be one of the most important sensors on a modern automobile. It helps the ECM maintain the optimum air/fuel ratio for effective catalytic converter operation, and with the advent of OBD-II it monitors the effectiveness of the converter as well.

The main oxygen sensor lives in one of the harshest operating environments in the car. In a relatively short period of time, its operating environment can go from sub-zero to well over 1500 degrees Fahrenheit (during a catalytic converter meltdown, for example). Even under 'normal' conditions, the sensor is surrounded by hot gas and caustic chemicals whenever the engine is running. This environment may not be as severe as the surface of the sun, but for a man-made sensor, it comes pretty close.

When a good oxygen sensor goes bad, it can cause all sorts of driveability and emission problems, ranging from too much fuel consumption to lean misfires. For these reasons it seems only fitting that OBD-II regulations specify exactly how the vehicle's onboard monitoring systems must keep watch on this important sensor.

Different types of oxygen sensors are used on today's cars and trucks, but to simplify this discussion we'll focus on the familiar zirconia-type sensor.

This sensor is composed of a steel housing wrapped around a ceramic thimble. The zirconium dioxide thimble is coated with platinum. These materials produce a low-voltage signal reflecting the difference between the oxygen content in the exhaust gas and the oxygen content in the outside air. This voltage is then used to determine whether the fuel system is providing a rich mixture (low relative oxygen content in the exhaust) or a lean mixture (high relative oxygen content in the exhaust) and to correct the mixture as needed. The idea is to get the mixture in the best range for catalytic converter operation.

Oxygen Sensor Heaters

Before the oxygen sensor can send a voltage to the ECM, it must reach a minimum temperature of 600 degrees Fahrenheit. Until the sensor produces voltage, the fuel control system remains in open loop. When the sensor begins to operate, the ECM can then enter closed loop.

Once it has an oxygen sensor input, *exactly when* the system enters closed loop is determined by several additional factors. Later models tend to enter closed loop operation much faster than earlier models. Tighter emission restrictions have forced emissions control calibration changes for most cars.

If you haven't done so already, hook up your scan tool and observe what happens during a cold-start on a late-model vehicle. These cars can enter closed loop seconds after startup. This could not be accomplished without a heated oxygen sensor.

Oxygen sensor heaters have been used for many years to bring the sensor to operating temperature more quickly and to maintain the sensor at operating temperature when exhaust heat falls. While most front oxygen sensors now utilize heaters, some manufacturers find they can still use the less expensive unheated oxygen sensor in this location. This style relies on combustion temperature alone to bring it to operating temperature. Due to their remote downstream location, away from the main heat source (the combustion chambers), all post-catalyst oxygen sensors are equipped with heaters.

Contrary to widespread belief, oxygen sensor heaters are not turned ON all the time. Some ECM programming prevents heater operation to protect the oxygen sensor. Under certain conditions (usually immediately after the engine is turned OFF after a very short trip), water vapor may form in the exhaust. If the heater were turned ON as soon as the engine was restarted, rapidly heating this condensation might crack the sensor's ceramic shell. Some systems are programmed to prevent this by disabling the sensor heater circuit at certain ambient temperatures and other conditions.

Another strategy turns the oxygen sensor heaters OFF as rpm increases. Nissan uses this strategy on some of its models, and other manufacturers may employ this strategy as well. On Nissan models, the front oxygen sensor heater is turned OFF above 3600 rpm for automatic transmission-equipped models and above 4000 rpm for manual transmission-equipped models. The rear oxygen sensor heaters are turned OFF above 3600 rpm on all models (Refer to **Figure 1**). Instead of turning the heater completely OFF or ON, its operation is controlled via a variable duty-cycle signal on other Nissan models.

Heater Monitoring Strategies

OBD-II regulations require heater circuit monitoring if a heated oxygen sensor is installed on an OBD-II-compliant vehicle. The oxygen sensor heater is monitored once per driving cycle and will set a pending code the first time it fails. If it fails again under similar conditions, the MIL turns ON. The circuit is monitored for proper current and voltage drop. Any other monitoring strategy requires EPA Executive Officer approval. Alternate approved methods involve monitoring the time it takes for the oxygen sensor to begin producing voltage after the engine first starts.

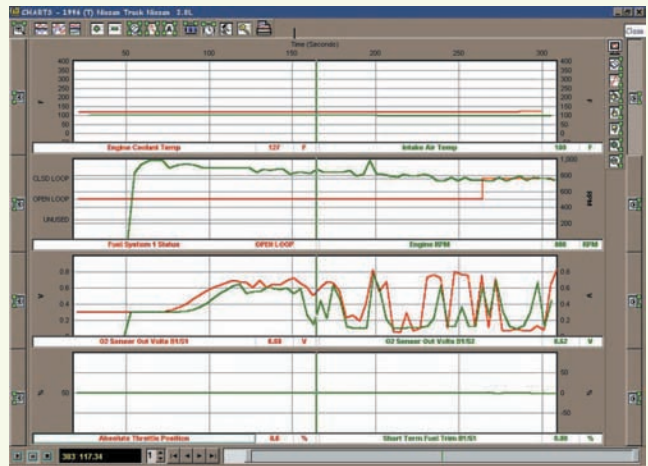


Figure 1: This Nissan did not have OBD codes, and we can see the heaters functioning for both oxygen sensors. As mentioned in the text, not all heaters are turned on all the time. This is only a quick test and shouldn't substitute for a complete diagnosis after an oxygen heater code.

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Figure 2: A simple digital multimeter (DMM) is all that's needed to test oxygen sensor heater resistance, but the test temperature is critical. Never check the resistance of a hot sensor heater and then just compare those readings to the manufacturer's specification. Manufacturers' specifications for heater resistance are given in connection with a specific temperature (usually room temperature). Heater supply voltage and ground can also be checked with the DMM.

Figure 3: A graphing multimeter (GMM) can be used to test the oxygen sensor heater as well. A GMM provides a linear graph of the heater resistance as the temperature of the heating element changes. Current can be graphed with a GMM as well.



For example, GM uses an approved alternate monitoring strategy, and employs a specific sequenced procedure to make it work. Load, rpm and temperature are key inputs to run this monitor. The monitor runs as the engine starts, measuring the time it takes for the sensor to begin producing voltage. If too much time elapses, a pending code is set. If the vehicle is operated under conditions that would cause the sensor to heat up without the aid of the sensor heater, the heater monitor is suspended until the next driving cycle.

Chrysler uses a second alternate method on vehicles equipped with Single Board Engine Controller systems (SBEC III). This is the most interesting heater monitor I have seen, and it works like this:

- After the key is shut off, the PCM sends a bias voltage to the oxygen sensor heater element.
- The bias voltage is applied once every 1.6 seconds for a duration of 35 ms each time.
- The bias voltage is increased as the sensor cools. When it reaches the proper voltage, the OBD-II heater monitor begins to run.
- At this time the PCM energizes the auto shutdown relay to provide battery voltage to the heater element.
- The PCM continues to send the bias voltage to the heater element at the predetermined intervals until it sees the voltage to the heater element decrease.
- A decreasing voltage indicates the heater element has changed resistance.
- If it reaches the proper voltage, the heater passes the test.
- If it fails, a pending code is set.
- If two consecutive tests fail, the MIL turns on the next time the car is started.

A quick way to tell which heater monitoring method is used is to check the wiring diagram and see how the heater circuit wiring is routed. If neither the power nor the ground for the oxygen sensor heater is wired through the ECM, it's safe to assume the ECM is not monitoring the circuit for proper current or voltage drop. Of course, the service manual is usually the best source of information to determine the actual system used.

Heater Diagnostic Trouble Codes

OBD-II codes P0135, P0141, P0155 and P0161 are the most common oxygen sensor heater diagnostic trouble codes you'll see. These are the generic codes defined by the SAE, but manufacturers may also use P11xx (manufacturer-specific) codes to help further identify oxygen sensor heater problems. P0147 and P0167 can be used for systems with a third oxygen sensor. P0135 is for Bank 1, Sensor 1; P0141 is for Bank 1, Sensor 2; P0155 and P0161 are for Bank 2, Sensor 1 and Bank 2, Sensor 2, respectively.

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Figure 4: A bench test on this oxygen sensor shows how current changes as the heater warms up. Current is measured through the sensor heating element with battery voltage applied.

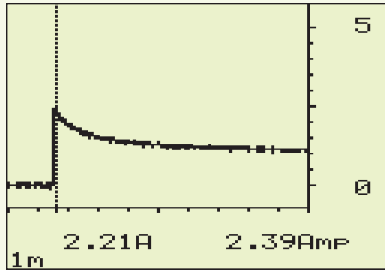
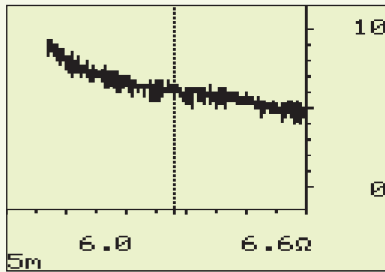


Figure 5: After heating the element by applying battery voltage, I connected an ohmmeter and graphed the resistance as the heater cooled. The heating element's positive thermal coefficient (PTC) function is evident because the element's resistance drops as it cools.



Testing an oxygen sensor heater circuit is fairly easy. Most testing can be done with a digital multimeter (DMM), using the voltmeter function to test heater supply voltage and ground and using the ohmmeter function to check heater element continuity.

Oxygen sensor heaters are *positive thermal coefficient (PTC)* devices. This means the heater resistance increases as the sensor element temperature increases, and this presents a problem when measuring the heater with an ohmmeter. Read carefully when checking resistance specifications in a manual. The specification should give the ohmic value along with the temperature at which you should take the measurement. Most specifications are for room temperature, which can present a problem if the vehicle was just driven before testing begins. A shortcut here could cause a misdiagnosis (Refer to **Figures 2 through 5**, pp. 38-40).

Sensor Performance Monitoring

OBD-II regulations also require monitoring for oxygen sensor deterioration by measuring sensor voltage and response rate. This monitor must run once per drive cycle. If the sensor does not pass this test, a pending code is set. If it fails again on the next drive cycle under similar conditions, the MIL is illuminated.

Several codes exist for front oxygen sensors. P0131, P0132, P0133 and P0134 are four generic codes available for Bank 1, Sensor 1. Similar codes exist for other sensor configurations, and some cars may utilize manufacturer-specific codes as well.

- P0131 is Bank 1, Sensor 1, low voltage.
- P0132 is Bank 1, Sensor 1, high voltage.
- P0133 is Bank 1, Sensor 1, slow response rate.
- P0134 is Bank 1, Sensor 1, no activity detected.

Failure Diagnosis

Oxygen sensor codes are a common occurrence on OBD-II cars. They can also be very intermittent, which makes them tough to diagnose. I use my DSO to test the functionality of the sensor, but the intermittent nature of the failures can make this difficult. One clue is to check the OBD-II freeze-frame data to see what the conditions were when the sensor failed.

Oxygen sensors seem to fail more often during high temperature conditions, so a freeze frame indicating moderate load and highway driving may help you duplicate the condition. Don't overlook simple damaged wiring as a possible cause for an oxygen sensor problem, including a heater code.

OBD-II strategy calls for the rear oxygen sensor to be tested at startup, before the catalytic converter has a chance to heat up and get to work. Always make sure the heater is functioning properly before condemning a rear sensor. This type of mistake can occur if the DTC and freeze-frame data has been erased before you see the vehicle. If the heater monitor does not run before the oxygen sensor fails a startup test, a catalyst deterioration code may set first.

Another strange scenario can occur if the rear oxygen sensor fails after it gets hot. Since the rear sensor monitor is only run at start-up, the temperature-sensitive sensor is assumed functional when it is not. This may cause a problem with the catalyst monitor or even affect fuel control on those systems in which the rear sensor is also used as an input for that purpose.

Oxygen sensors and their monitoring systems are not difficult to understand, but knowing the system you are dealing with will help avoid costly mistakes. Zirconia-type sensors were addressed in this article. Just remember other types also exist. Always consult your manuals or CD-based information sources before assuming you know the system. ■

—By Randy Bernklau