

OXYGEN SENSOR UPDATE

Introduction

The purpose of the oxygen sensor is to measure the oxygen content of the exhaust gases. The sensor passes a signal voltage back to the Electronic Control Module (ECM). The ECM uses the signal voltage to regulate the quantity of fuel injected into the engine.

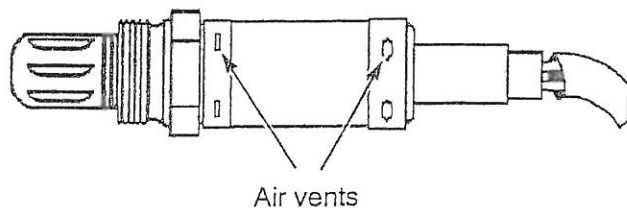
The O2S is fitted into the exhaust manifold or front down pipe of petrol-engine cars. The O2S has up to 4 wires which are connected to the vehicle wiring loom. The sensor is normally screwed into a boss which is welded directly onto the exhaust pipe or catalyst.

The conventional Oxygen Sensor is of the **Zirconium Dioxide** type. More recently a type known as a **Titanium Oxide** oxygen sensor has been introduced to later production vehicles. The Titanium Oxide type sensor is similar in operation to the Zirconium Dioxide sensor but there are some notable differences in sensor operation.

Zirconium Oxygen Sensor

The Zirconium O2S consists of 2 platinum electrodes separated by Zirconium dioxide which acts much as the electrolyte in a battery. A signal voltage is produced when a difference is detected between the oxygen in the exhaust pipe and the oxygen in the outside air. the signal voltage varies between 0.2V and 1V depending on the oxygen content in the exhaust gases.

The oxygen sensor has vents in the outer body which allows air to come into contact with the Zirconium Dioxide electrodes.

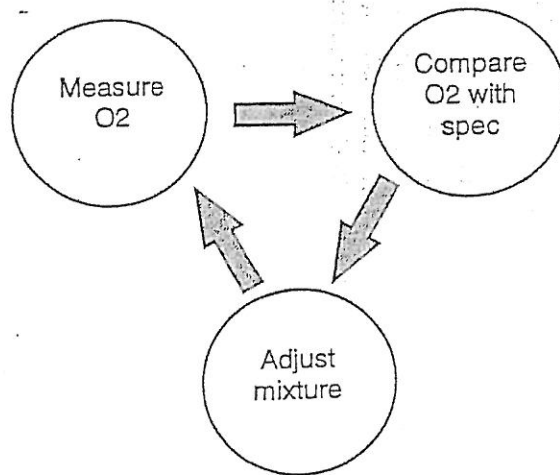


Typical heated Zirconium type Oxygen Sensor

The oxygen content of the exhaust gas is low when the mixture is too rich, producing a high signal voltage. The ECM reacts by reducing the injection duration (the period of time which the injectors are open).

When the mixture is too lean the oxygen in the exhaust is high and the signal voltage of the O2S is low. The ECM reacts by increasing the injection duration.

The constant adjustment of the mixture, referred to as Closed Loop Control, is necessary to enable the catalytic converter to operate efficiently. The catalyst operates efficiently when the Air/Fuel ratio is close to 14.7:1 (Lambda 1).



Closed loop mixture control diagram

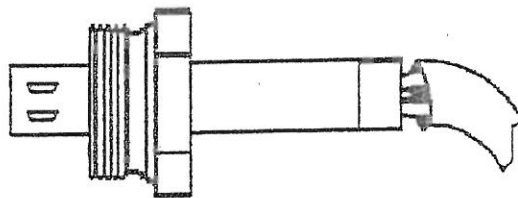
Many Zirconium Dioxide O₂S's are of the heated type. The heater assists the sensor to function earlier after a cold start. The heater may either operate continuously (when the engine is running) or with some later systems the heater operation may be controlled by the ECM.

Titanium Oxygen Sensor

A Titanium type oxygen sensor contains a strip of ceramic covered in Titanium Dioxide. The sensor also contains a heater element.

Unlike the Zirconium Dioxide sensor, which produces a voltage, the Titanium sensor changes resistance in relation to the oxygen content in the exhaust.

When the engine is warm, the fuel system operates in Closed Loop Control. The ECM supplies the oxygen sensor with a reference voltage which is typically 5 or 12 volts. The reference voltage passes through the resistive Titanium Dioxide and the ECM monitors the voltage that returns to the ECM terminal. The voltage that returns to the ECM is referred to as the signal voltage. The Titanium oxygen sensor functions using a similar operating principle to that used with an engine coolant temperature sensor electrical circuit.



Typical Titanium Dioxide Oxygen Sensor

When the exhaust gases contain excess oxygen (mixture lean) the resistance of the Titanium is high. The resistance of the sensor can be over 20 k Ohms.

When the exhaust gases have little or no oxygen (rich mixture) the resistance of the Titanium sensor is low. In an extremely rich condition the resistance of the sensor could be less than 1 k Ohm.

Note that the Titanium Dioxide sensor makes no reference to the outside air for its measurements.

The Titanium sensor has to reach a high temperature to function correctly, typically 600-800 degrees C. All Titanium Dioxide sensors are of the heated type. _____

The resistance of the heater element in a Titanium O2S is constantly changing with temperature. The change in resistance of the element is monitored by the ECM. The heating element can be switched on and off by the ECM as the O2S sensor heats up or cools down. The ECM is therefore able to keep the sensor at its most efficient operating temperature.

In most cases the Titanium O2S heater is not switched on for long periods of time once the engine is at operating temperature. Instead the heater is usually pulsed on and off quite rapidly.

The ON time is constantly adjusted according to the temperature and therefore the resistance of the sensor heater element circuit.

Advantage of Titanium

One disadvantage of the Zirconium sensor is that they require a reference of the oxygen level from the outside air surrounding the sensor.

The typical oxygen content in the atmosphere is 20.7%. In heavy traffic (at ground level or close to the O2S) pollution from vehicles and other sources means the oxygen content in the outside air may be lower.

In these conditions, as the Zirconium O2S makes its comparison between the oxygen in the exhaust and the oxygen in the outside air, the sensor may therefore assume that the oxygen content in the exhaust is high (normally indicating a lean mixture). The signal voltage will cause the ECM to make the fuel / air mixture unnecessarily rich, preventing the catalyst working at peak efficiency as well as affecting exhaust emissions.

A similar problem can exist with off-road vehicles, water or contamination can enter the vent holes in the sensor body causing the sensor to pass false O2S signals to the ECM.

Because the Titanium Dioxide sensor makes no reference to the outside air for its measurements, these contamination situations cannot affect this type of sensor. The air/ fuel mixture therefore remains closer to ideal for more of the time, improving catalyst operation.

The temperature of the Zirconium O2S is very variable, which is mainly dependent on the exhaust temperature (changes with engine speed and load). The operating temperature can affect the signal voltage to the ECM even though the mixture has not altered.

The Titanium sensor is maintained at a more constant temperature. The sensor signal voltage is more reliable and is therefore effective for more of the time.

Oxygen Sensor Identification

Identifying the different type of oxygen sensor fitted to the vehicle is relatively simple.

Zirconium Oxygen sensors - usually physically larger than Titanium sensors and may have up to 4 wires connected to the sensor:

- Single wire sensors – the single wire is used for the signal wire (usually black).
- 2 wire sensor – signal wire (usually black) and an earth wire (usually grey).
- 3 wire sensors – signal wire (usually black) and 2 white heater wires (supply voltage / earth).
- 4 wire sensors – signal wire (usually black), earth / sensor shield wire (usually grey) and 2 white heater wires (supply voltage / earth).
- The thread size is normally 18 mm.

Titanium Oxygen sensors - have 3 or 4 wires.

3 wire sensors have the following connections:

- Signal wire to the ECM (usually black).
- Heater supply and sensor reference voltage (usually red).
- Heater earth circuit (switched by the ECM) (usually white).

4 wire sensors have the following connections:

- Signal wire to the ECM (usually black).
- Heater supply (usually red).
- Sensor reference voltage (usually yellow).
- Heater earth circuit (switched by the ECM) (usually white).
- The thread size is typically 12 mm or 18 mm.

Titanium sensors are more compact than the Zirconium type and there are no air vents in the outer section of sensor casing. The section exposed to the exhaust gas still has vents which allows exhaust gas to pass over the sensor element.

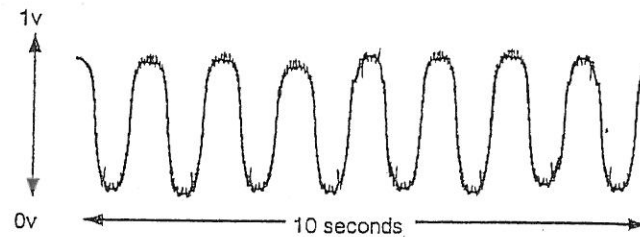
Testing Zirconium O2S Sensors

The ideal test procedure is to check the signal voltage of any sensor is to create conditions which should promote a change in the sensor signal voltage.

In the case of the Zirconium sensor, connect an oscilloscope or digital multi-meter to the signal wire at the sensor harness plug or at the applicable ECM harness plug terminal. Connect the test equipment earth probe to a good earth connection.

- Make sure the sensor is at the correct operating temperature by running the engine at a fast idle for a few minutes. Check the signal voltage from the sensor with the engine at 2000 rpm.

- The signal voltage should fluctuate between 0.2V and 1V at least once per second. The signal voltage will average approximately 0.5V. If the average is high, the mixture is rich. If the average is low, the mixture is lean. Note that a low voltage may also be caused by a misfire, or an exhaust leak near to the sensor.



Zirconium O2 sensor signal voltage waveform

- To test the sensor's reaction to changes in mixture, snap the throttle fully open a few times to richen the mixture. The voltage should be seen to rise in response to the change in mixture. Alternatively, create an inlet air leak by disconnecting a vacuum hose. In this case the voltage should fall, until the ECM corrects the lean mixture created.

Replace any sensor which fails any of the above tests. Checks to the heater circuits should be carried out when the engine has just been started from cold.

Typically these types of sensors have an ignition controlled battery supply (usually supplied from a relay). The earth circuit may either be connected directly to earth or controlled by the ECM.

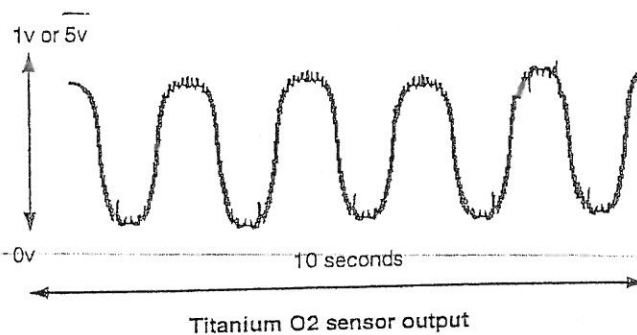
If the ECM controls the heater earth circuit, the heater will normally be switched ON for only a short time as the engine warms up.

- Check for a power supply (battery voltage) with a multi-meter. If battery voltage is not available check the circuit and any applicable relay.
- Back probe the sensor harness plug heater earth connection.
- If the heater earth circuit is a direct connection through to earth, the voltage should be almost zero (0.25V max). If the voltage exceeds 0.25 volts it indicates a fault (high resistance) in the earth circuit.
- If the earth circuit is controlled by the ECM, when the heater is switched ON (earth circuit completed by the ECM) the voltage should be zero (0.25V). When the heater is switched OFF, the heater supply voltage should be available. If the supply voltage (battery voltage) is available at the heater earth terminal it indicates that the ECM is not completing the earth circuit. Check the wiring, relays and ECM earth connections.
- The resistance of the sensor heating element can be checked by measuring between the heater supply terminal and the heater earth terminal with the sensor disconnected. Typically the heater resistance will be 5 – 10 Ohms.

Testing Titanium Sensors

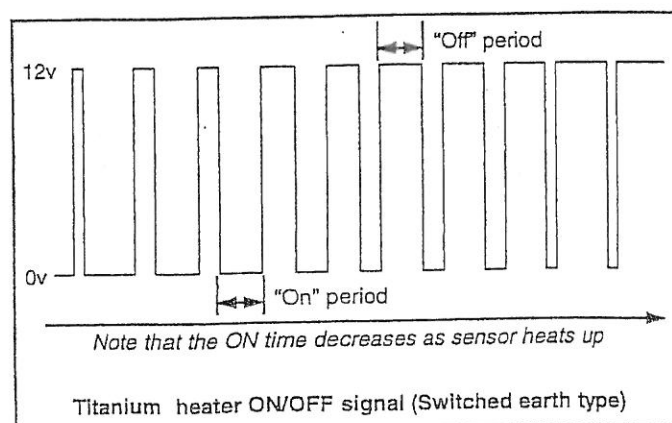
Check at the sensor harness plug for the supply voltage to the sensor and heater. The supply voltage is typically 5V or 12V depending on the system. Note that with 3 wire sensors, the supply voltage to the sensor and heater is combined.

- Test the signal voltage of Titanium sensors using the same method as for the Zirconium type sensor. The oscilloscope pattern looks very similar in appearance to the Zirconium type sensor. The sensor signal voltage may either fluctuate between 0V – 1V or may fluctuate between 0V – 5V (depending on the system).
- The voltage should fluctuate, although the frequency of the signal is often less. The ECM can react to smaller changes in the Titanium sensor signal voltage more quickly.
- The Titanium sensor signal voltage may respond to rich and lean mixtures in the same way as the Zirconium oxygen sensor. However, with some systems, the Titanium sensor signal voltage may respond in reverse to the Zirconium ie. high voltage when the mixture is lean / low voltage when the mixture is rich. Always refer to vehicle specific information for the correct specifications.



- It is also possible to measure the resistance change of the sensor circuit as the mixture changes. Disconnect the sensor and connect an ohmmeter between the sensor input and output terminals. With the engine running, expect a sensor circuit resistance change of approximately 1 k Ohm – 20 k Ohms.

Note. Disconnecting the sensor will probably generate a fault code which must then be erased.



Testing the heater is similar to the Zirconium sensor checks. Use an oscilloscope with a long time base, back probe the sensor heater terminal that is controlled by the ECM.

- If the supply is switched, a rise in voltage indicates the heater is being turned ON. If the earth is switched a fall in voltage indicates the heater is ON.
- The ON time pulses should slowly but constantly change as the ECM maintains the correct sensor operating temperature.
- If a digital voltmeter is used the peak voltages should be seen to fluctuate. The AVERAGE voltage will also change, but more slowly.

Note. Be careful not to confuse the changing heater voltage with that of the signal voltage.

Sensor Fitting Precautions

Common problems that typically occur when fitting oxygen sensors are over-tightening, which can damage the internal ceramic components and poor electrical connections.

- Avoid over tightening oxygen sensors. Normally a torque of 47 Nm is sufficient. Use a suitable socket or ring spanner to avoid damage caused by slipping tools.
- Oxygen sensors operate at a very low voltage / current. Poor electrical connections will easily prevent the sensor from operating correctly. Make sure all connections are clean and dry.
- Clean all connections and check with a multi-meter after fitting. If necessary use a small amount of contact spray. The use of silicone grease should be avoided.

