General information - Various makes and models
Technical Information : 01

System:

Engine management

Lambda sensor general Tec info

General System Information:

Figure 1 - Lambda sensors

The lambda sensor is an electrical sensor mounted inside the exhaust system which can measure how well the combustion is occurring inside the engine. The amount of fuel allowed into the engine is controlled by the engine's fuel injection computer or ECU (Electronic Control Unit).

The purpose of the front lambda sensor or pre cat lambda sensor (eg. one before cat) is to inform the engine ECU of the amount of Oxygen coming out of the engine and then the ECU uses this information to adjust the amount of fuel allowed into the engine for best fuel economy and lowest emissions.

The purpose of the rear lambda sensor or post cat lambda sensor is to check the efficiency of the cat by monitoring the oxygen content coming out of the cat and to inform the ECU on how efficiently the cat is working

You may hear the Lambda Sensor referenced to by other names too, such as:

- HEGO sensor - meaning 'Heated Exhaust Gas Oxygen Sensor'.

- Oxygen sensor - referring to the fact that the Lambda Sensor measures the Oxygen present in the exhaust gas stream
- O2 sensor O2 is the chemical symbol for an Oxygen molecule.
- You may hear the word 'probe' substituted for 'sensor' – e.g. Lambda Probe
- The word 'sonde' is common across mainland Europe – e.g. Lambda Sonde

There are 3 main types of O2 sensors

- Zirconia - the most common and oldest type
- Titanium - Used on some BMW, Volvo and Opel models with Siemens ECU, during the nineties
- Planar - wideband sensor or AFR air fuel ratio sensors, found on some of the latest generations of engines from the 2000's onwards

The main differences in these types of sensors are

Zirconia O2 sensor

This type generates its own voltage which when working correctly will switch from approx 0.20 volts to 0.90 volts about once a second and these voltage signals are sent back to the ECU when the sensor is reading for example 0.20 volts the ECU regards this lower voltage as being a lean mixture and then in turn the ECU will increase the fuelling to the engine to enrich the mixture and the when the mixture enriches the O2 sensor voltage will increase to about 0.90 volt and this higher voltage is regarded as a rich mixture and then the ECU will weaken the mixture and this keeps happing over and over to keep the mixture within the limits .There are different types of Zirconia O2 sensors.

Single wire sensor : this type has no heater circuit and is earthed through the body of the sensor and sends the signal out to the ECU in the single wire normally black in colour. Normally fitted to older vehicles up to about 1995 depending on make and model.

Two wire sensor : this type also has no heater circuit and one of the wires is a ground usually earthed through the ECU and is normally grey in colour and the other wire is the signal wire normally black in colour. Also only fitted on older vehicles.

Three wire sensor : this type has a heater circuit and one of the wires is the heater 12 volt supply normally white in colour and the other wire is the heater ground which is grounded through the ECU is also normally white in colour and the third wire is the signal wire which is normally black in colour. Also only fitted on older vehicles.

Four wire sensor this type also has a heater circuit and one of the wires is the heater 12 volt supply normally white in colour and the other wire is the heater ground which is grounded through the ECU also normally white in colour and the third wire is the sensor earth which is normally earthed through the ECU normally gray in colour and the fourth wire is the signal wire normally black in colour

As mentioned above the wire colours are normally as follows

White = heater circuit

White = heater circuit

Gray = sensor earth

Black = signal wire

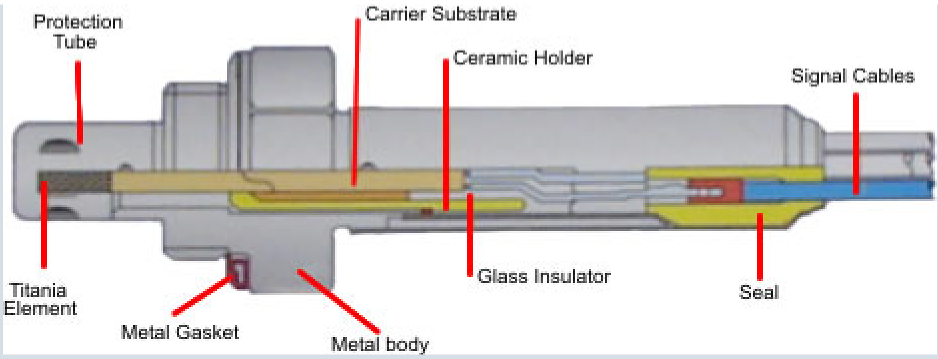
And this is the case most of the time but sometimes some Japanese, and some Opel's and some French cars use different colours as follows

	Type1	Type2	Type3	Type4	Type5
heater circuit	Black	Black	Brown	Red	Purple
heater circuit	Black	Black	Brown	Black	White
sensor earth	White	Green	Beige	Tan	Gray
signal wire	Blue	White	Purple	Purple	Black

As mentioned above the Zirconia O2 sensor is still the most widely used but some brands from approx 2000 on started to use Wide band sensors EG VAG group, BMW, Volvo, and Mercedes amongst others but in most cases where these vehicles use a Wide band sensor before the Cat it is always a 4 wire Zirconia sensor after the Cat

Titanium O2 sensors

Titanium Sensors differ in construction from the more common Zirconia type, and offer several advantages to the engine management system.



The main noticeable differences in a Titanium sensor and a Zirconia are on the Titanium sensor it will have a flat body and different colour wires

Titanium sensors do not generate a voltage as the Zirconia type do. Instead, the resistance of the sensing element changes in response to the Oxygen present in the exhaust gases. And in simple terms the sensor has a voltage supply into the sensor and this voltage flows through the sensor and out in the signal wire back to the ECU but the output from the signal wire will vary depending on the resistance of the sensing element which depends on the oxygen in the exhaust and the ECU uses this voltage signal to calculate the amount fuel supplied to the engine. The supply voltage to this type of sensor is normally 5 volts and the output signal normally varies from 0 to 5 volts about once a second .The heater element works in the same way as a Zirconia sensor.

There is no need for a pocket of atmospheric reference gas with this type of sensor, hence the absence of a vent. This is important for off-road vehicles where mud and other debris may splash the exhaust system. The sensor casing can be physically smaller, stronger, and it has a faster reaction time than the Zirconia type, which is why it is a functionally superior sensor. However, it is still a narrowband type of sensor.

Titania sensors were initially used because they are less susceptible to lead poisoning than the Zirconia types. They are, however, more susceptible to anti-freeze poisoning than the Zirconia types. However the other advantages of the sensor (faster response times, more efficient packaging) led some ECU designers to use this type of sensor.

Some Opels, BMWs, and Volvos that had Siemens engine management system used Titania O2 sensors the colours of the wires on the Titania sensors are as follows

Heater circuit positive = Red
Heater circuit negative = White
Voltage supply in = Yellow
Voltage output signal = Black

Wideband sensor or AFR air fuel ratio sensors

The current generation of sensors are termed Wideband, Planar, UEGO or 'A/F ratio sensors' (Air/Fuel ratio sensors). They are much better at gauging exactly how much Oxygen is in the exhaust stream, rather than the simple switching action from rich to lean of the narrowband sensors. The term 'planar' comes from the shape of the sensing element which is a flat strip (plane), rather than the thimble shape of traditional sensors.

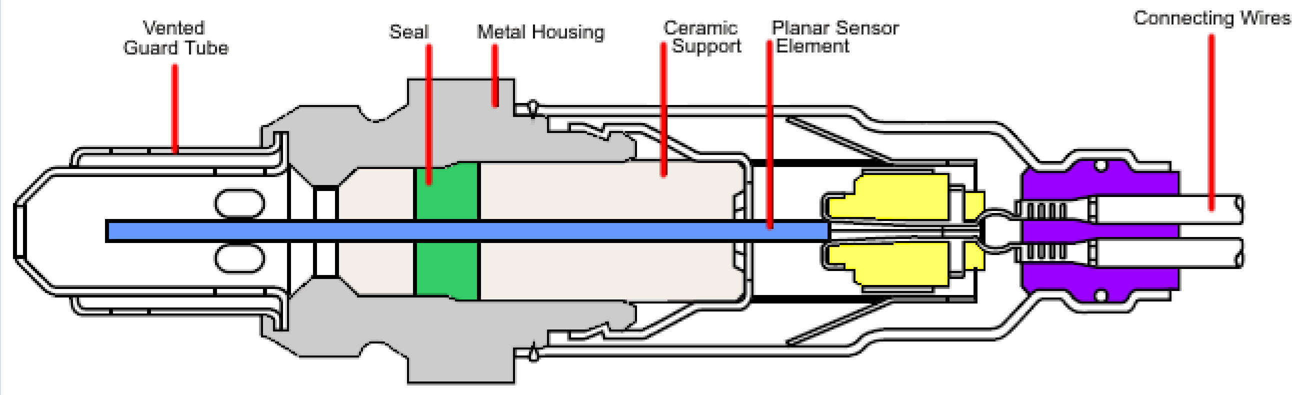


Figure 11 - Cutaway view of a planar wideband sensor

Wideband sensors have only become necessary as engine management systems have evolved to the point where a more accurate sensor is required to meet low-emission vehicle targets - the old style of sensors had their characteristic 'switching point' for various historical reasons. The wideband sensor is an absolute requirement for lean-burn and fuel ionising mixture control strategies (EG.Volkswagen FSI) as well as diesel vehicles. The wideband sensor allows the ECU to gauge how well combustion is occurring right down to very lean mixtures.

The sensor works on broadly the same principle as an ordinary sensor (Nernst cell) but with an added internal system (a device called an oxygen pump), and the output current varies in proportion to the Oxygen present in the exhaust. it can measure a far wider range than a traditional sensor, but more importantly when it is within the range that we are most interested in (from Lambda=0.9 to Lambda=1.1) the response graph is fairly linear, meaning that we can determine the exact oxygen content of the exhaust gas, rather than a steep switching point around the central area. Under cruising conditions in a modern engine, the AF ratio can extend to about 20:1 and the wideband lets us measure accurately at these lean mixtures.

Wideband sensors can be identified by their multi-wire harness (five, six or more wires), and are generally fitted to:

- Any recent car utilising lean-burn or direct-injection engine technology
- Diesel engine vehicles equipped with lambda sensors
- VAG group vehicles from approx 2000 on
- BMW , Mercedes and Volvo from approx 2000 on
- Volkswagen FSI systems, and other stratified charge systems

Note that on vehicles that use a wide band sensors in front of the cat it is still nearly always a normal 4 wire Zirconia sensor after the Cat

Due to the complexed design of the wide band sensor it is much more difficult to test than the other types and we will be doing a separate article on the wideband sensor later on

Lambda sensors fitting positions

Sometimes it is difficult to know which sensor the diagnostic tool is talking about when it shows a fault. Below is a brief description on sensor fitting positions

In line engines

On any in line engine that has just one front and one rear sensor it will normally be worded like this

The front sensor e.g. pre cat lambda sensor = bank 1 - sensor 1

The rear sensor e.g. post cat lambda sensor = bank 1 - sensor 2

And if the vehicle has 2 cats it may have a 3rd sensor after the 2nd cat which will be called = bank1 - sensor 3

And some in line engines may have 2 front sensors for example a 6 CYL engine may have one sensor doing cylinders 1, 2 & 3 this sensor may be called = front bank sensor 1 and the sensor doing cylinders 4, 5 & 6 this sensor may be called = rear bank sensor 2

V type engines

On any V engine bank one is always the bank that has no one cylinder so bank 2 will be the opposite bank on the V so the sensors will normally be worded like this

The front sensor on bank one e.g. pre cat lambda sensor = bank 1 - sensor 1

The rear sensor on bank one e.g. post cat lambda sensor = bank 1 - sensor 2

The front sensor on bank two e.g. pre cat lambda sensor = bank 2 - sensor 1

The rear sensor on bank two e.g. post cat lambda sensor = bank 2 - sensor 2

And if the vehicle has 4 cats it may have a 3rd sensor after the 2nd cat on each bank which will be called = bank 1 - sensor 3   and = bank 2 - sensor 3

Testing lambda sensors

Some times when a lambda sensor is faulty is will give a fault code on the diagnostic tool but not always e.g. if the heater circuit is faulty or there is a complete failure of the sensor it will log a fault but if the sensor is only gone slow to switch it may not log a fault. You will often see this where a vehicle is falling on its emissions but there is no fault codes stored, this may be because the sensor is gone very slow to switch or may not be switching at all but some more modern vehicles can log a fault when the sensor is like this and may show a fault like p0134 O2 sensor circuit no activity detected bank 1 sensor 1 or p0133 O2 sensor circuit slow response bank 1 sensor 1

When you get a lambda sensor fault on the diagnostic tool or you are suspect of the lambda sensor never replace the sensor based on the fault code see below examples

For example a heater circuit fault may be caused by a wiring fault or heater circuit voltage supply problem e.g. fuse gone or ECU fault

A sensor activity or slow response fault may not be the fault of the sensor it could be the case that the engine is running too rich caused by many other things e.g. faulty mass air flow meter, fuel pressure to high, carbon canister sonoild valve stuck open, various others things. If the engine is running too rich there will be less oxygen in the exhaust and the sensor will be constantly informing the ECU that the mixture is rich and because the ECU has reached the limit of the amount it can adjust the mixture by it will not be able to lean down the mixture so therefore the sensor will stay stuck signalling the rich mixture and therefore will not be able to switch and may log a sensor activity or slow response fault and the same applies if the mixture is stuck lean caused by a different problem

So remember if the lambda sensor is not switching at all or not switching fast enough it may not be a sensor fault as the sensor may be signalling what is sees, a permanently rich or lean mixture .and many different things can cause a rich or lean mixture.

If the sensor is stuck signalling a weak or lean mixture and you what to check is the sensor capable of switching you can do this by forcing the engine to go rich by various methods like restricting the air supply or increasing fuel pressure by restricting the fuel return and if the sensor then starts switching you know the sensor is probably not the fault

If the sensor is stuck signalling a rich mixture and you what to check is the sensor capable of switching you can do this by forcing the engine to go lean by various methods like inducing and air leak by disconnecting a vacuum pipe or by decreasing the fuel pressure by restricting the fuel supply if the sensor then starts switching you know the sensor is probably not the fault

On most diagnostic tools as well as reading the fault code you can view live readings or parameters and this is useful to check the lambda sensor switching speed or whether the mixture is stuck rich or lean but along with this it is recommend to test the sensors with an oscilloscope.

Checking the signal from a Zirconia lambda sensor

Connect the scope to the sensor signal wire

Start the engine, and let it warm up to normal operating temperature. Adjust the scope to 1s/div (ie. the scale left to right) and 0.2v/div (the scale top to bottom). At idle you should get a waveform a bit like the one below, if the sensor and the mixture is ok . Then increase the engine speed to about 2500 rpm and hold it there and wait for about 10 sec for the mixture to stabilise, note while the mixture is stabilising the sensor will not be switching like the image below instead the voltage may stay at a high voltage EG 0.80v until the mixture settles down then it should start switching again as in the image below

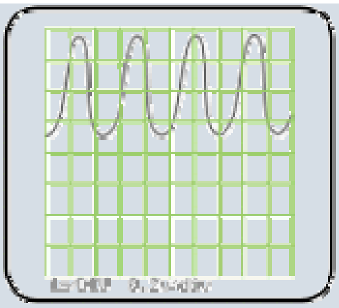


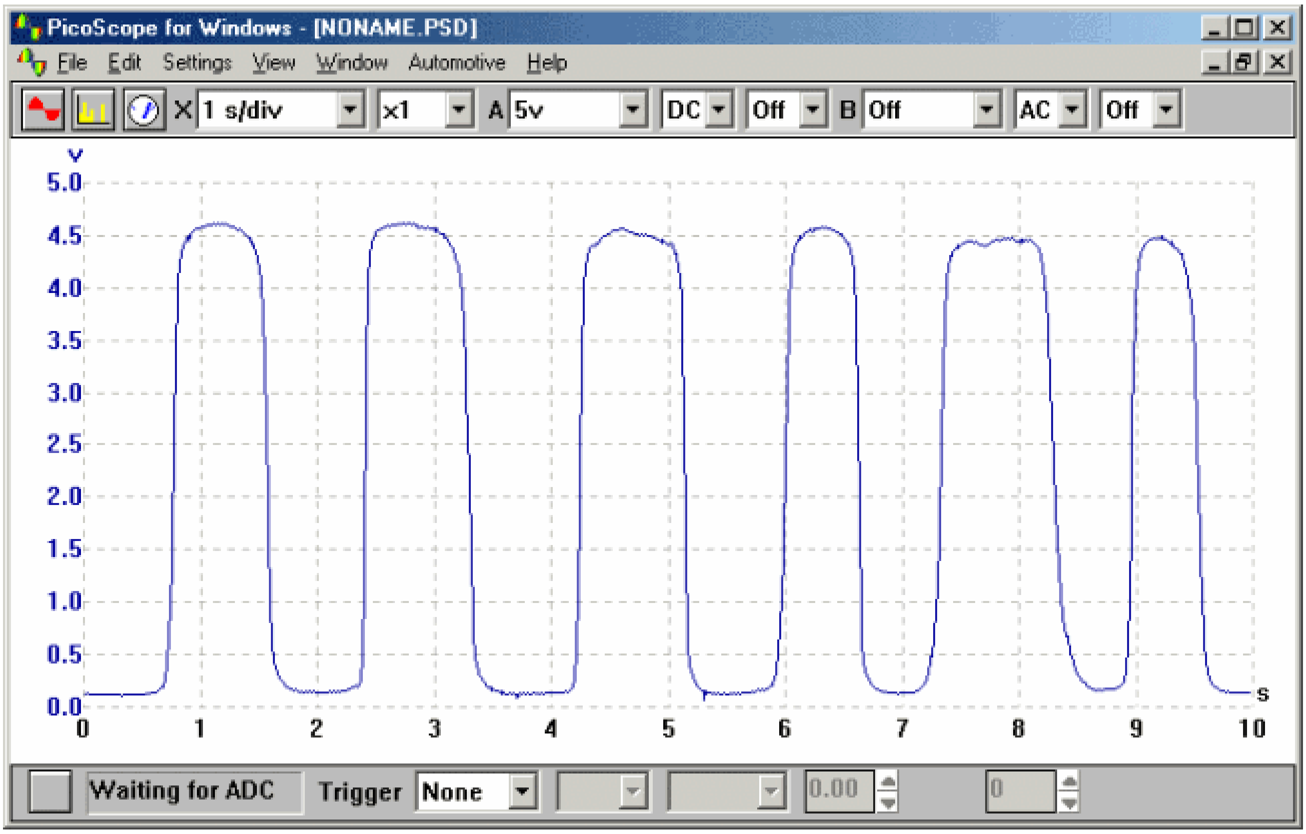
Figure 9 - A typical oscilloscope lambda output graph of a healthy sensor at idle or whilst cruising at constant speed (ie. in closed loop mode) - filtered for clarity

The graph should peak at about 900mV (0.9 Volts), dip to about 100mV (0.1 Volts), and 450mV (0.45 Volts) should be the average centre point of the graph. Over the space of 10 seconds, the graph should cross this central 450mV line 7 or 8 times. This corresponds to the ECU doing its cycling back and forth job effectively, and points to a quick and good condition sensor

Checking the signal from a Titanium lambda sensor

Connect the scope to the sensor signal wire

Start the engine, and let it warm up to normal operating temperature. Adjust the 'scope to 1s/div (ie. the scale left to right) and 0.5v/div (the scale top to bottom). At idle you should get a waveform a bit like the one below, if the sensor and the mixture is ok . Then increase the engine speed to about 2500 rpm and hold it there and wait for about 10 sec for the mixture to stabilise, note while the mixture is stabilising the sensor will not be switching like the image below instead the voltage may stay at a high voltage EG 4.5v until the mixture settles down then it should start switching again as in the image below



Note the signal from the post cat lambda sensor should not be the same as the pre cat signal if the mixture and the cat are ok the rear sensor should read between 0.40 volts and 0.55 volts if all is ok . if the cat is completely gone the rear sensor will be switching between 0.20 volts and 0.90 volts about once a second

Testing the heater circuit on a Zirconia or Titanium lambda sensors

If you are getting heater circuit faults on the diagnostic tool the first thing to do is to see if you have the 12v supply to the heater circuit if not it may be just a fuse but check the applicable wiring diagram for the vehicles.

Next check is the heater circuit ground this is normally grounded back through the ecu and most vehicles this is a permanent ground eg if you put a scope on this wire it should read 0v if the ground is ok but some vehicles use a pulse on this ground to vary the temperature of the heater element.

Then the last check on the heater circuit is to check the resistance of the heater circuit by putting a OMH meter across the 2 heater circuit wires and see what it reads and compare to the specified reading for the vehicle you are working on as there can be many different heater circuit resistances depending on the make and model although the resistance will normally be somewhere between 3 and 20 ohms depending on type.

Due to the complex design of the wide band sensor it is much more difficult to test than the other types and we will be doing a separate article on the wideband sensor later on

Universal lambda sensors

Universal 1,2,3 & 4 wire Zirconia lambda sensors are readily available in the aftermarket and can be used on a huge range of vehicles but not all, see our catalogue on the web to see where they can be used and if your vehicle is not listed there look at the Walker products catalogue on our website for direct fit sensors. We stock a huge range of direct fit lambda sensors made in America by Walker products and for universal sensors we only supply either Bosch or NTK or Walker. We have heard of people claiming universal sensors as not being any good and some people think that you always have to fit the direct fit one in every case this is not true, it is not the case that all universal lambda sensors are no good and if you fit a universal sensor where it is listed to fit and use a quality brand like Walker, Bosch , NTK , Beru or VDO it will be fine but be careful some other manufactures claim that there universal sensors will work in a lot more vehicles than the really can.

Hope this information helps but bear in mind that this is just a brief overview on lambda sensors and there is much more to them than this.

Always heed manufactures testing instructions