5.2 Lambda probes

Lambda probes measure the oxygen content in the exhaust mixture. They are part of a control loop that continuously ensures that the composition of the fuel/air mix is correct.

The mix ratio of air to fuel in which the maximum conversion of pollutants is reached in the catalyst is (λ) =1 (stoichiometric mix ratio = 14.7 kg air to 1 kg fuel, expressed in volume: 1 litre fuel to approx. 9500 litres air).

Changes in the exhaust gas composition are taken into account by the engine management as it controls numerous functions, and is often the first hint that there may be errors.

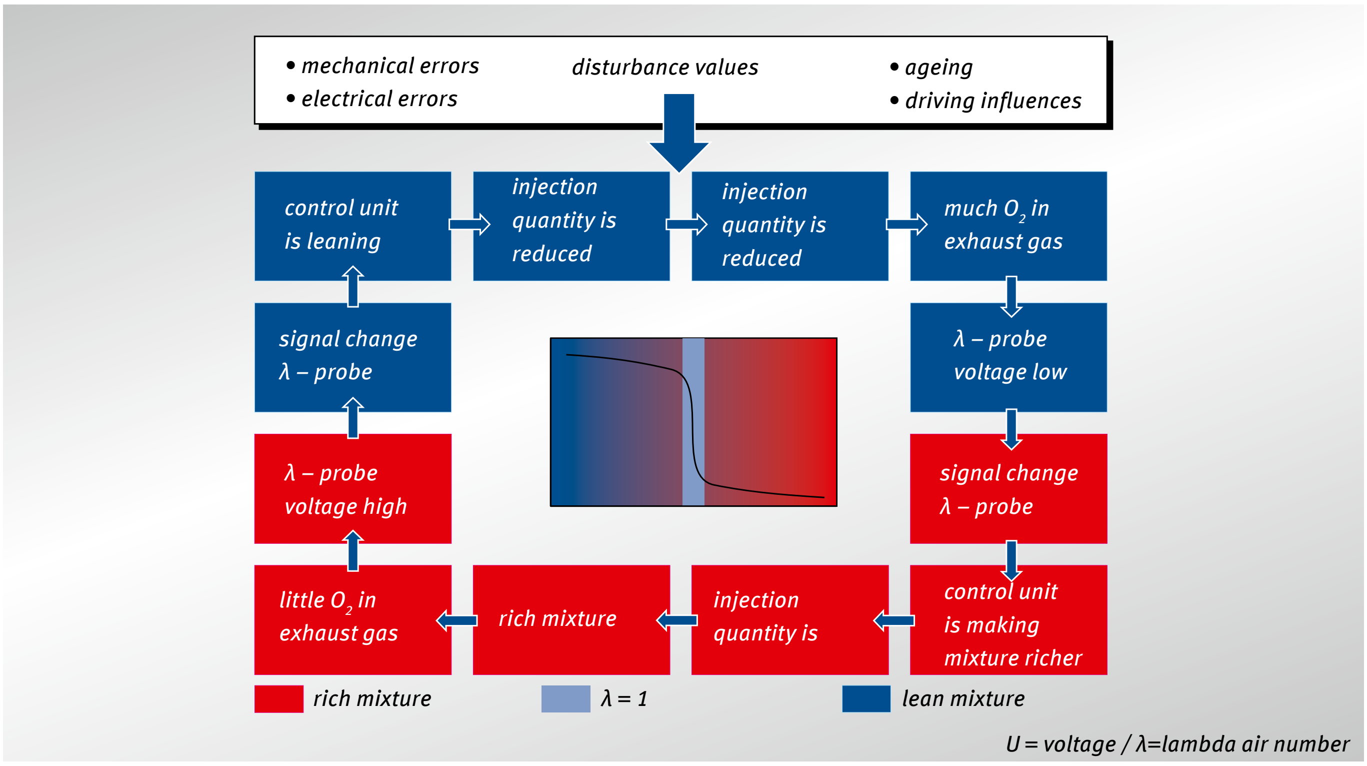

Fig. 46: control loop with lambda jump sensor

The engine control unit uses this signal to control the injection times. For control purposes, only one probe upstream from the catalyst (“pre-cat” or “control” probe) is needed. In OBD II an additional lambda probe that is downstream from the catalyst (“post-cat”, “correction” or “monitor” probe) has been integrated into the system.
It is used to check the catalytic converter and can be constructed the same way as the pre-cat probe.

Accidental mixing up of the plug-in connections of the two probes is usually prevented by different types of plugs and colours.

Lambda probes work starting at a temperature of 350° C. The operating point is at about 600° C. A temperature of 850° C should not be exceeded because damage occurs after 930° C.

A distinction is made between broadband and jump probes.

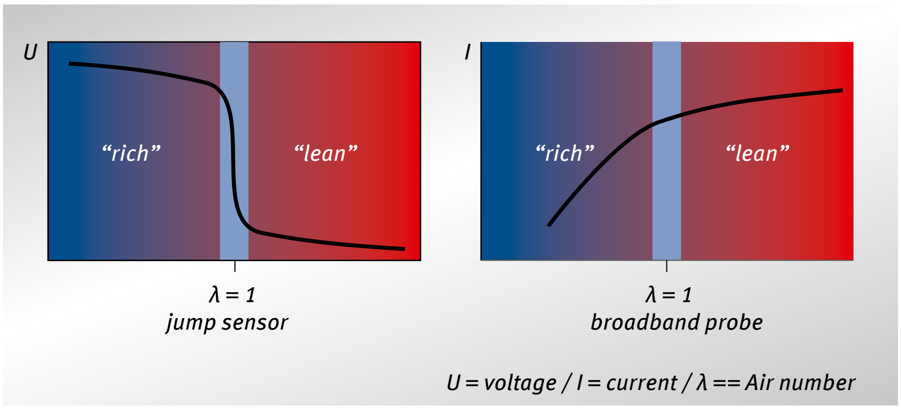

Fig. 47: behaviour of jump and broadband probe control

Jump probes

The output signal of the lambda probe ("probe voltage") is based on the fuel/air ratio.

In the case of a jump probe, the voltage changes abruptly at λ = 1. For this reason the signal can be used only in a range of λ = 1 ± 0.03. In engines in a lean range of λ > 1.03, the signal cannot be processed. Therefore with this probe only a two-point control is possible. Pre and post-cat probes have the same construction.

- A rich mixture (λ < 1) creates a probe voltage of approx. 800 mV. For control purposes the injection times are shortened.
- A lean mixture (λ > 1) creates a probe voltage of approx. 20 mV. For control purposes the injection times are extended.
- There are different versions of jump probes.
- The titanium probe (titanium dioxide probe) responds to changes in the mixture composition by a change in the electric resistance. It works with a higher probe voltage of up to 5 volts. With this probe critical exhaust gas temperatures can be detected.
- The potential-free lambda probe has a separate earth cable from the control unit. The voltage of the control range is increased by 700 mV. This produces a control voltage between 700 and 1700 mV (measured against the vehicle weight). This technical change was necessary for self diagnosis and EOBD.

Important note:

A distinguishing characteristic of the potential-free lambda probe is the 4-pin probe line.

But: Not all 4-pin lambda probes are potential-free!

Broadband probes

Contrary to the jump probes, the broadband probe measures across a wide lambda range from rich to lean continuously. There are no abrupt changes at λ = 1. This way lambda control is possible in the case of "rich" as well as "lean" air/fuel mixtures from about lambda = 0.7 to 3.0. It can also be used for direct injection and future "lean concepts".

This process is carried out by a pump cell (miniature pump) that supplies the electrodes on the exhaust gas side with sufficient oxygen that the voltage between both electrodes is constantly 450 mV. The power consumption of the pump is converted to a lambda value by the control unit.

Important note:

Conventional lambda probes are designed as "finger probes".

Newer jump and broadband probes are increasingly being made in planar constructions ("planar probes"). Planar probes are further developed lambda probes that are heated. Heating causes these probes to be functional shortly after a cold start. This way the volume control can start sooner.

5.2.1 Monitoring

Conditions for monitoring lambda probes.

- Lambda control is working in the control range.
- The vehicle is operating at speeds between 5 and 80 km/h.
- The engine has reached operating temperature.
- The catalytic converter has temperatures between 350 and 650° C.
- The engine speed and the accelerator pedal position are basically constant.
- Monitoring occurs whenever there is a constant operation that lasts more than 20 seconds.

Control probe (jump probe)

Ageing or contamination can affect the response of a lambda probe. Deterioration can manifest itself in an increase in the response time (period duration) or a shifting of the measuring range (probe shift). Either will cause the λ window to be smaller, which will produce a deterioration of the exhaust gas conversion by the catalyst.

The post-cat signal is evaluated for monitoring.

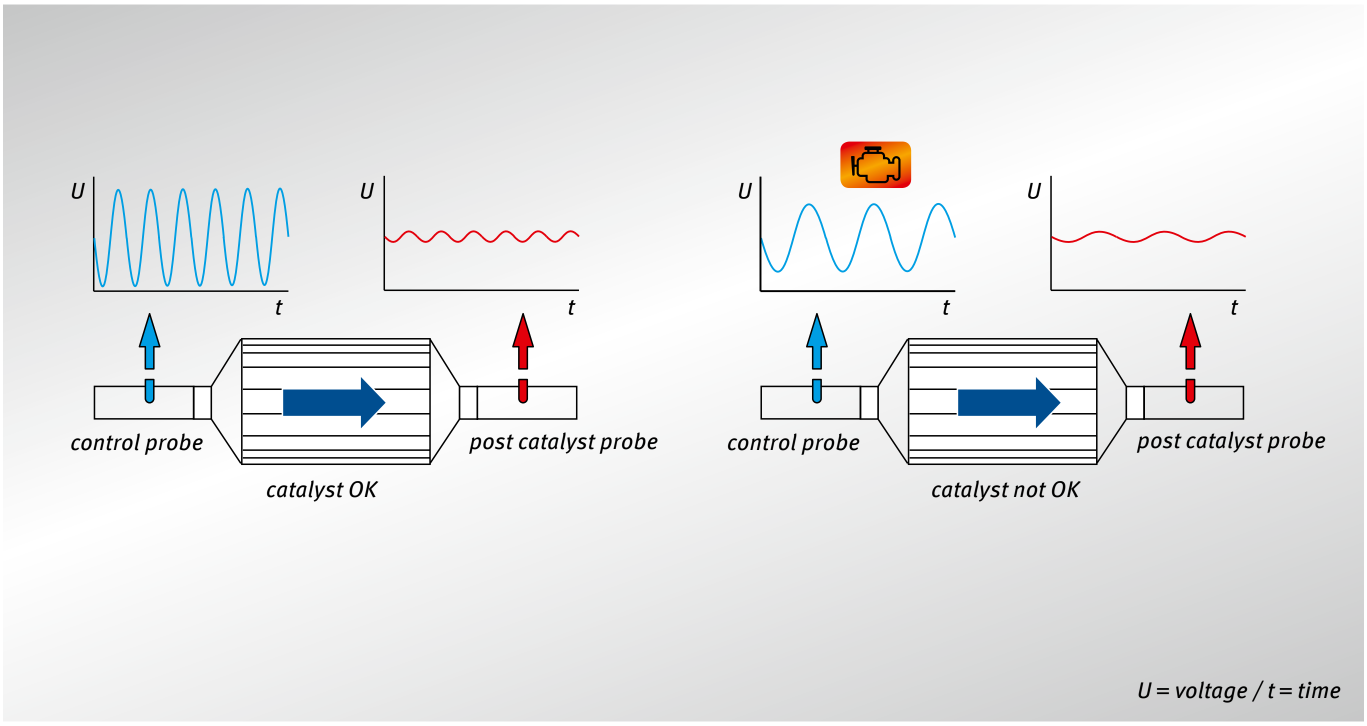

Fig. 48: check of the control frequency (s s of the control probe – jump probe)

Control probe (broadband probe)
Because a broadband probe does not respond with a noticeable jump at λ = 1, the fuel/air mixture has to be "modulated".
A slight switch between lean and rich mixture is created artificially.
The response time of the broadband to these fluctuations created is monitored.
The current actual values are compared with the specified set-point values.

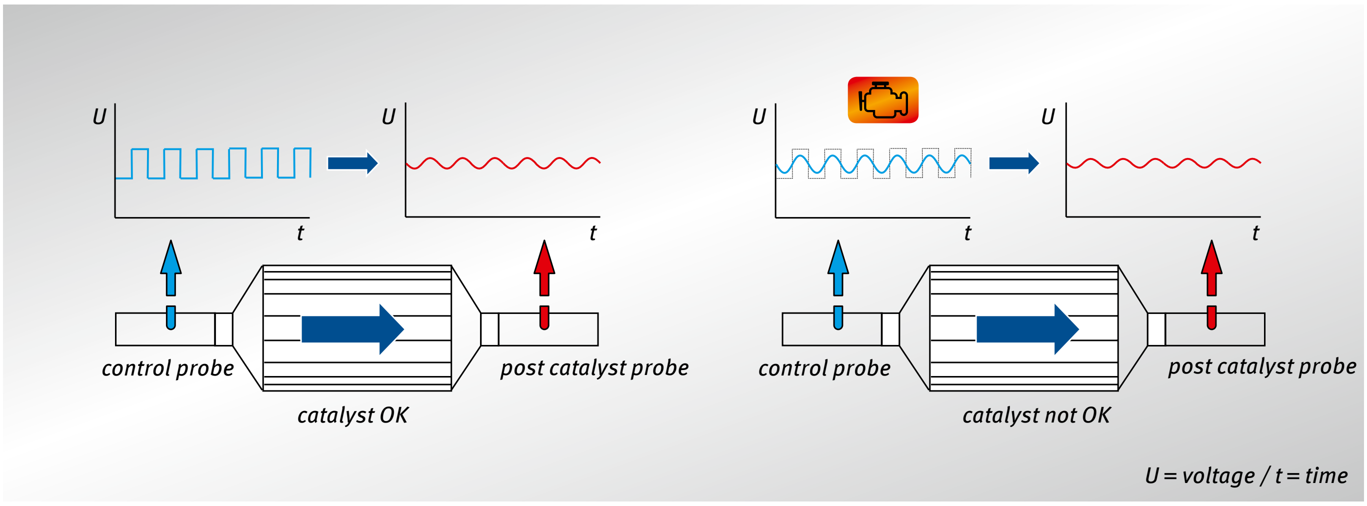

Fig. 49: response time of the control probe (broadband probe)

Post catalyst probe
The lambda control value is monitored for compliance with the specified control limits.
For example, if the air/fuel ratio changes in the "lean" direction during operation, the post catalyst probe will report an increase in the oxygen content of the exhaust gas to the control unit by lowering the voltage. The mixture will be made richer again by the lambda control. The post catalyst probe voltage will rise and the control unit will be able to lower the lambda control value again.
If the probe voltage remains low in spite of the fact that the mixture was made richer, it will continue to be made richer until the control limit is exceeded. This will be detected as an error.
This control will extend over a longer drive.

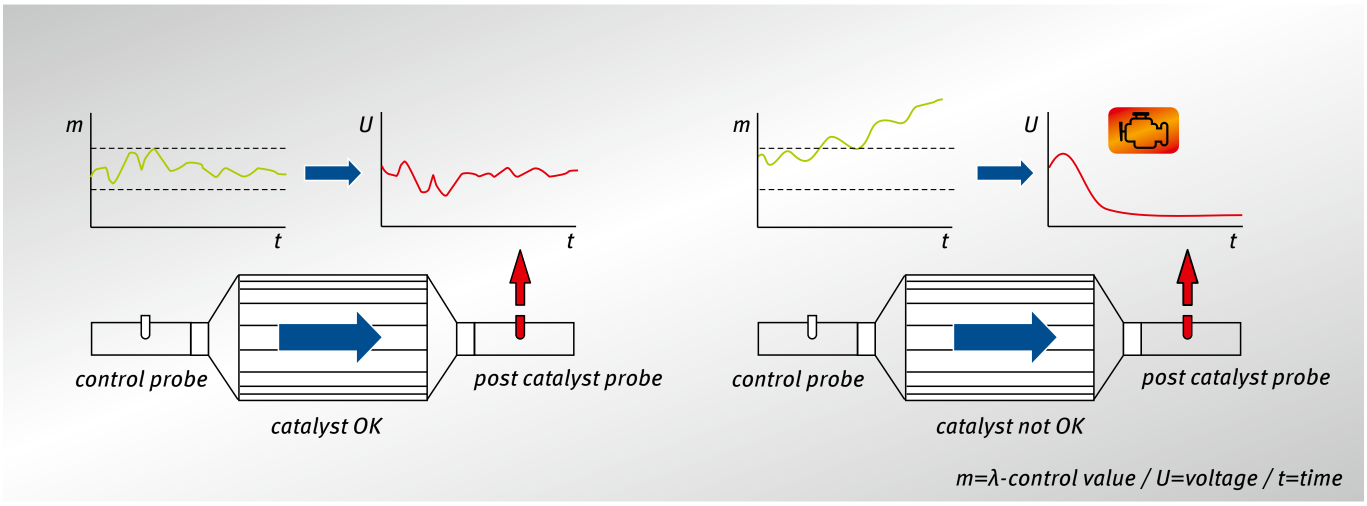

Fig. 50: diagnosis of the post catalyst probe control limit

A further possibility for monitoring is a diagnosis of the control behaviour during acceleration or deceleration. Here as well the effects of the "richer" mixture during acceleration and "leaner" mixture during deceleration are used to evaluate the probe.

Possible fault codes

P0036	HO_2S heater control circuit (bank 1 sensor 2)	malfunction
P0037	HO_2S heater control circuit (bank 1 sensor 2)	low
P0038	HO_2S heater control circuit (bank 1 sensor 2)	high
P0042	HO_2S heater control circuit (bank 1 sensor 3)	malfunction
P0043	HO_2S heater control circuit (bank 1 sensor 3)	low
P0044	HO_2S heater control circuit (bank 1 sensor 3)	high
⋮		
P0064	HO_2S heater control circuit (bank 2 sensor 3)	high
P0130	O_2 sensor circuit (bank 1 sensor 1)	malfunction
P0131	O_2 sensor circuit (bank 1 sensor 1)	low voltage
P0132	O_2 sensor circuit (bank 1 sensor 1)	high voltage
P0133	O_2 sensor circuit (bank 1 sensor 1)	slow response
P0134	O_2 sensor circuit (bank 1 sensor 1)	no activity detected
P0135	O_2 sensor heater circuit (bank 1 sensor 1)	fault in heater circuit
⋮		
P0167	O_2 sensor heater circuit (bank 2 sensor 3)	fault in heater circuit

Diagnostic instructions

Error	Causes
• increased fuel consumption • jerking during deceleration • engine “saws” during idling	• The lambda probe is soiled or has deposits due to bad combustion or leaded fuel. • The lambda probe responds too sluggishly, i.e., the lambda control tends to be too “rich”. • The lambda probe is damaged by exhaust gas temperatures that are too high as a result of a faulty mixture formation or ignition misfires. • The electric earth connection is not OK.

Important note:
Please observe the general instructions in Section 3.
For the error diagnosis, check the
- voltage signal
- earth connection
- heater (if present).

Then read the fault code memory and compare the actual values with the set-point values. If the set-point values are not available, it could be of assistance to read the values from a vehicle of a similar model that doesn’t have any errors.