Spitronics ECU - Lambda Sensor - Guide

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The Lambda Sensor measures oxygen content in the exhaust and provides information about the engine air-fuel mixture.

Depending on the sensor and ECU configuration, the Lambda signal can be used for:

- Monitoring mixture.
- Tuning assistance.
- Fuel-economy optimisation.

- Closed-loop fuel correction.
- Detecting mixture changes caused by operating conditions.

Where closed-loop Lambda Control is supported, the ECU can use the sensor signal to make small corrections to the calculated fuel delivery.

Important

The engine must first be tuned correctly in **open loop**.

Lambda Control should maintain and fine-correct a good base Tune. It should not be used to create the base Tune or hide incorrect fuel calibration.

Lambda and AFR

Lambda and AFR both describe air-fuel mixture, but they are not exactly the same quantity.

AFR

AFR means:

Air-Fuel Ratio

For petrol, a commonly used stoichiometric reference is approximately:

14.7:1

Lambda

Lambda expresses mixture relative to the stoichiometric point.

- Lambda 1.00 = stoichiometric.
- Lambda below 1.00 = richer than stoichiometric.
- Lambda above 1.00 = leaner than stoichiometric.

Some Spitronics software generations work primarily with the sensor voltage or a percentage derived from that voltage rather than displaying calculated AFR.

The exact display depends on the sensor type and firmware generation.

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Sensor Types

The ECU may receive Lambda information from different sensor systems.

The two main types covered by the current software are:

- Narrowband Lambda Sensor.
- Wideband Lambda Controller output.

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Narrowband Sensor

A conventional narrowband oxygen sensor produces a small voltage that changes sharply around the stoichiometric mixture point.

Typical output range is approximately:

0.1-0.9 V

A typical stoichiometric switching point is approximately:

0.45 V

The current software may represent this as approximately:

45%

Narrowband sensors are very useful for determining whether the mixture is richer or leaner than stoichiometric.

They are not suitable for accurately measuring a wide range of AFR values.

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Wideband Sensor

A wideband Lambda Sensor requires a dedicated electronic controller.

The wideband controller operates the sensor and provides an analogue output signal to the ECU.

A common output range is:

0-5 V

The relationship between voltage and AFR or Lambda depends on the wideband controller.

For this reason, do not assume that every 0-5 V wideband system uses the same calibration.

Use the output specification supplied with the wideband controller.

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Wideband Controller

The ECU Lambda input reads the analogue output from the wideband controller.

The ECU does not directly operate the wideband sensor element in this configuration.

Typical arrangement:

Wideband Sensor → Wideband Controller → Analogue Output → ECU Lambda Input

[Insert Generic Diagram - Wideband Sensor and Controller]

Product-specific connection details belong under the applicable Product information.

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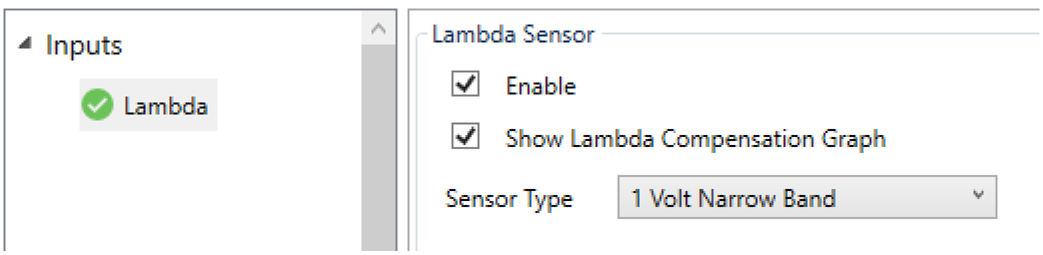
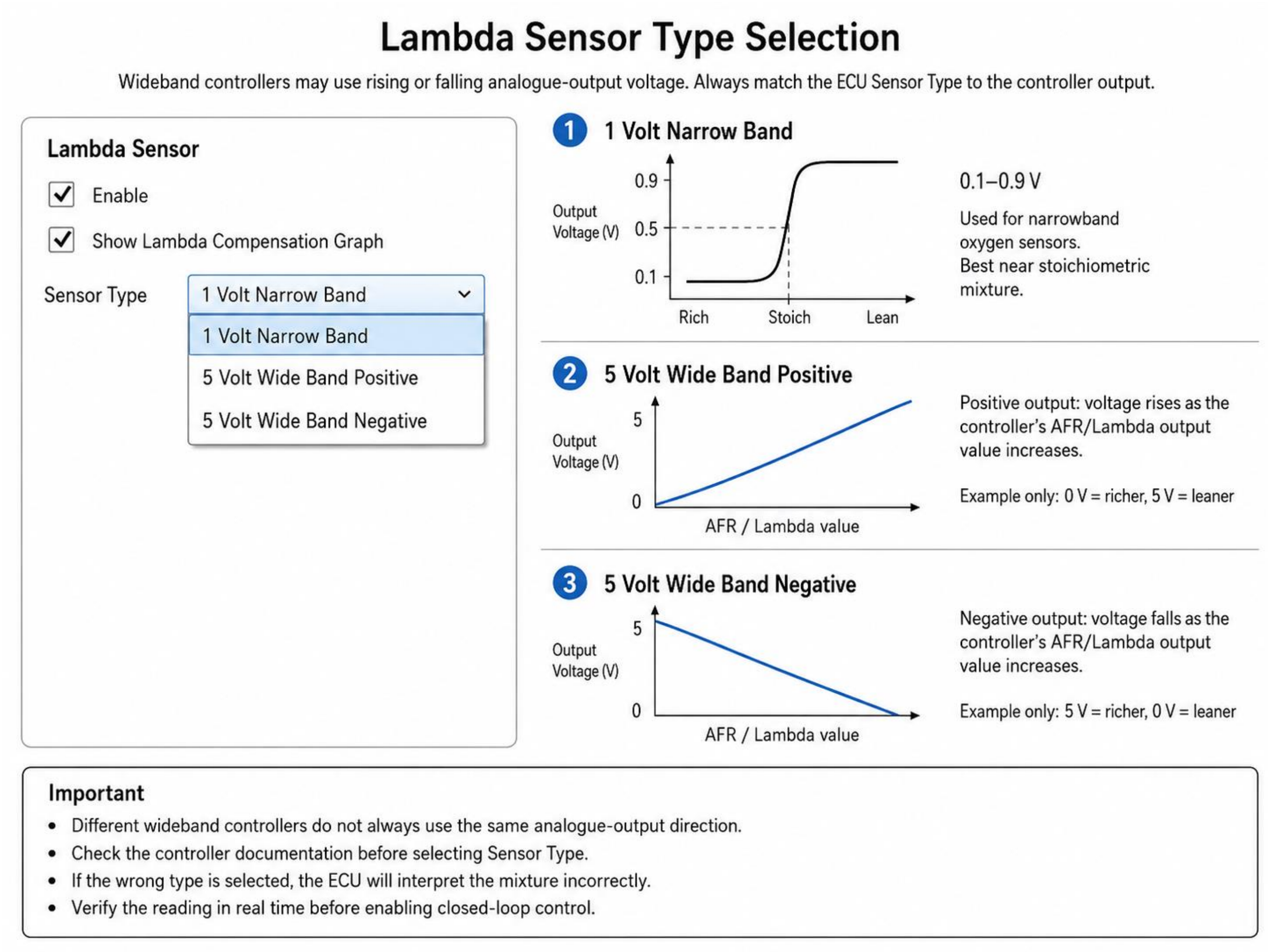
Software Setup

Enable the Lambda Sensor under the applicable ECU Inputs section.



Typical selections may include:

- Enable.
- Show Lambda Compensation Graph.
- Sensor Type.



The exact terminology and available options depend on the Device and firmware generation.

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Monitor Only

The Lambda Input can be used for monitoring without enabling closed-loop fuel correction.

This is the preferred mode while establishing the base fuel Tune.

Use the Lambda reading together with:

- AFR gauge.
- Realtime Data.
- Data Logging.
- Dyno measurements.

to determine the required base fuel calibration.

The software separates Lambda display from active control through the Lambda and Graph selections.

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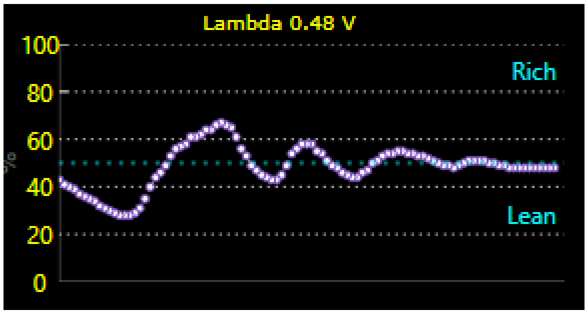
Lambda Realtime Display

The Lambda Realtime display can be viewed in two different modes:

- Bar display.
- Graph display.

Double-click the Lambda display to toggle between the two modes.



Bar Display

The Bar display provides a simple indication of the current Lambda input value.

The value is shown as a percentage according to the configured Lambda input.

Example:
Lambda 48%

This view is useful when:

- Monitoring the mixture quickly.
- Checking that the Lambda signal is active.
- Comparing the current signal with the Lambda Target.
- Working on another tuning page where a compact display is preferred.

Graph Display

Double-click the Lambda Bar to change to the Graph display.

The Graph shows the recent Lambda signal over time.

This makes it easier to see:

- Rich and lean movement.
- Sensor response.
- Mixture oscillation.
- Closed-loop correction activity.
- Whether the signal is stable or erratic.

The current Lambda voltage is displayed at the top of the Graph.

For example:
Lambda 0.48 V
The Graph also indicates the Rich and Lean directions for the selected sensor configuration.

Why the Graph View Is Useful

A single numerical value only shows what the Lambda signal is doing at that instant.

The Graph view shows the behaviour over time.

This can help identify:
- A narrowband sensor switching around stoichiometric.
- Slow Lambda response.
- Excessive closed-loop hunting.
- A signal that is stuck rich or lean.
- Rapid mixture changes during throttle movement.

Sensor Type Affects Direction

The Rich and Lean direction depends on the selected Lambda Sensor Type.

Different sensor systems may have different voltage directions.

For example, a wideband controller may use:
- Rising voltage as AFR/Lambda increases.
- Falling voltage as AFR/Lambda increases.

Always select the correct Sensor Type before interpreting the Graph or enabling closed-loop control.

Practical Use

During base tuning:
1. Keep closed-loop Lambda Control disabled.
2. Use the Bar or Graph display to monitor the Lambda signal.
3. Compare the signal with the independent wideband AFR/Lambda instrument where applicable.
4. Confirm that the signal direction and response are correct.
5. Only enable closed-loop Lambda Control once the base Tune and Lambda input have been verified.

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Closed-Loop Lambda Control

Closed-loop Lambda Control compares the measured Lambda signal with a desired target and adjusts fuel accordingly.

The basic control process is:

Target mixture

↓

Measure Lambda signal

↓

Compare actual signal with target

↓

Adjust fuel

↓

Measure again

This correction repeats while Lambda Control is active.

The correction should remain limited so that a sensor fault or poor base Tune cannot make an excessive fuel change.

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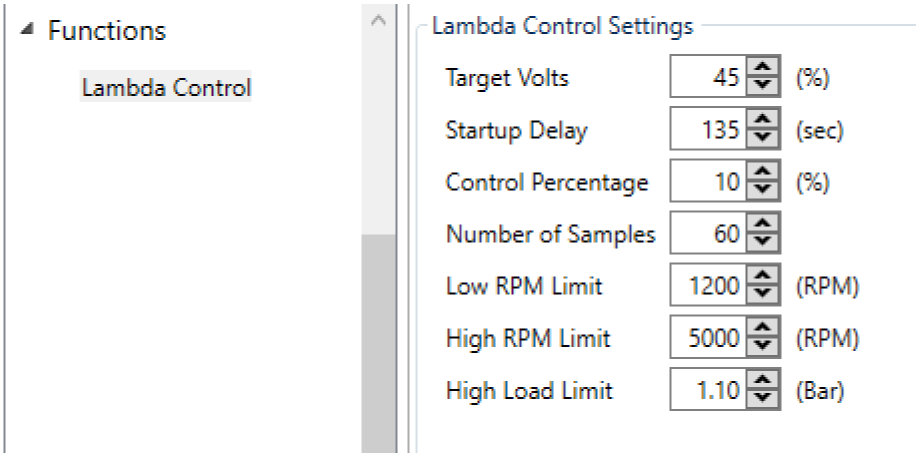
Lambda Control Settings

Typical Lambda Control settings may include:

- Target.
- Startup Delay.
- Control Percentage.
- Number of Samples.
- Low RPM Limit.
- High RPM Limit.
- Load Limit.



The exact available settings and names depend on firmware generation.

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Target

The Target setting defines the Lambda sensor signal that the ECU attempts to maintain.

For a narrowband sensor, the stoichiometric switching region is approximately:

0.45 V

or approximately:

45%

in software using percentage representation.

For a wideband controller, the required target voltage depends on that controller's voltage-to-Lambda or voltage-to-AFR calibration.

Do not copy the target value from another wideband system unless the analogue-output calibration is the same.

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Wideband Target Calibration

Before using closed-loop control with a wideband controller, determine:

- Voltage corresponding to the required Lambda or AFR.
- Whether the output rises or falls as mixture becomes richer.
- Minimum and maximum analogue-output voltage.

The software may provide selections for rising or falling wideband output characteristics.

Use the controller manufacturer's analogue-output information to select the correct configuration.

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Startup Delay

The Lambda Sensor or wideband controller requires time to become operational after startup.

Startup Delay prevents closed-loop fuel correction from becoming active before a reliable Lambda signal is available.

Measure the actual sensor warm-up time rather than assuming that every system behaves identically.

A practical procedure is:

1. Start the engine cold.
2. Observe the Lambda signal.
3. Measure how long it takes to become stable and responsive.
4. Set the Startup Delay so Lambda Control begins only after the sensor is ready.

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Control Percentage

Control Percentage determines the maximum amount of fuel correction that Lambda Control is allowed to apply.

Example:

Control Percentage = 10%

The ECU may correct fuel by approximately:

±10%

according to the Lambda error.

Keep this limit reasonably small.

A large correction range can allow:

- Poor base tuning to remain unnoticed.
- Sensor faults to cause excessive fuel correction.
- Engine behaviour to change dramatically when Lambda Control becomes active.

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Base Tune First

Lambda Control should normally make small corrections around a good base Tune.

A useful diagnostic principle is:

If Lambda Control continually requires a large correction in the same direction, investigate the base Tune.

For example:

Consistent +10% correction

may indicate that the underlying Tune is too lean in that operating region.

The engine may still run correctly because Lambda Control is compensating, but the base calibration should be corrected.

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Number of Samples

The Lambda signal does not respond instantaneously to changes in fuel.

There is delay caused by:

- Combustion.
- Exhaust gas travel.
- Sensor response.
- Controller response.
- ECU sampling.

The Number of Samples setting is used to stabilise closed-loop operation by averaging or delaying the correction response.

In general:

Fewer samples → faster response

More samples → slower but more stable response

Excessively fast correction can cause AFR hunting or oscillation.

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Lambda Control Limits

Closed-loop Lambda Control should operate only in engine regions where the feedback can safely and reliably make corrections.

Typical limits may include:

- Minimum RPM.
- Maximum RPM.
- Maximum load.

The software provides RPM and load limits for Lambda Control.

These limits allow Lambda correction to be disabled in operating areas where rapid or large fuel changes could be undesirable.

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High-Load Operation

For high-performance applications, Lambda correction should be used conservatively at high load.

The general principle is:

Do not depend on closed-loop Lambda correction to make a high-load Tune safe.

The high-load base Tune must already be correct.

Lambda may still be used for monitoring and engine protection where suitable firmware functions are available.

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Lambda Target Graphs

Where supported, Lambda target can be modified according to operating conditions.

Typical Graphs may include:

- Manifold Pressure.
- TPS.
- RPM.

These Graphs modify the basic Lambda target rather than directly tuning the main fuel calculation.

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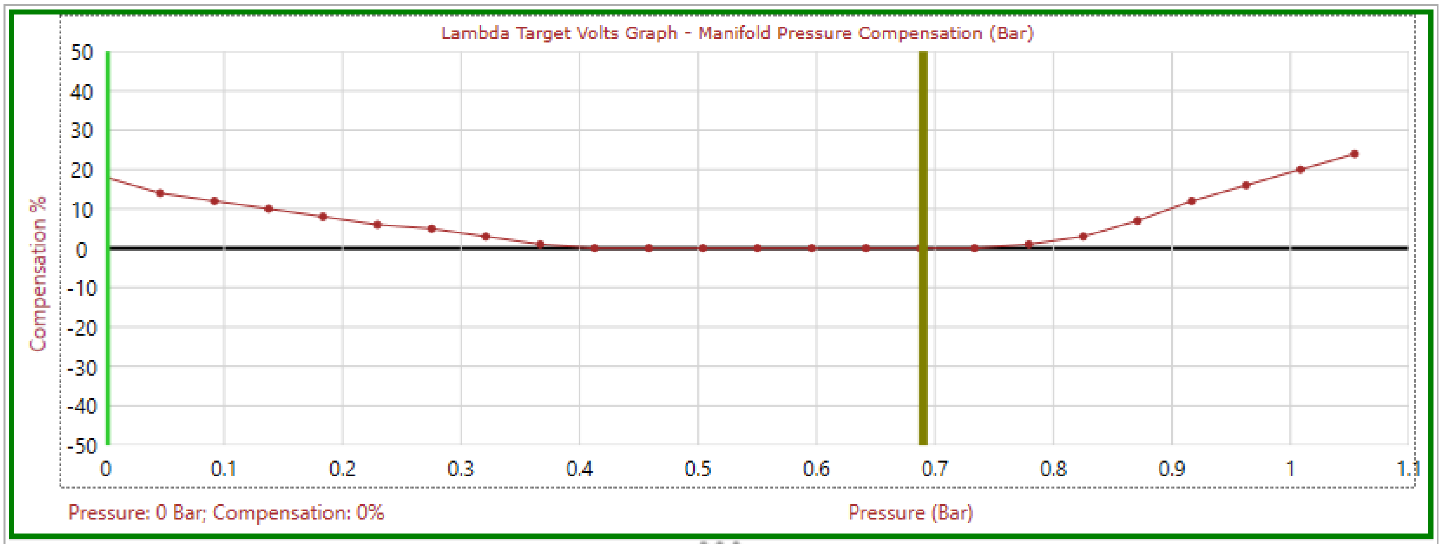
Manifold Pressure Target Compensation

The Manifold Pressure Graph allows Lambda target to change with engine load.



This can be used to request a different mixture under:

- Vacuum.
- Cruise.
- Higher load.
- Naturally aspirated full load.
- Boost where the control strategy permits it.

The target should follow the engine's actual mixture requirement.

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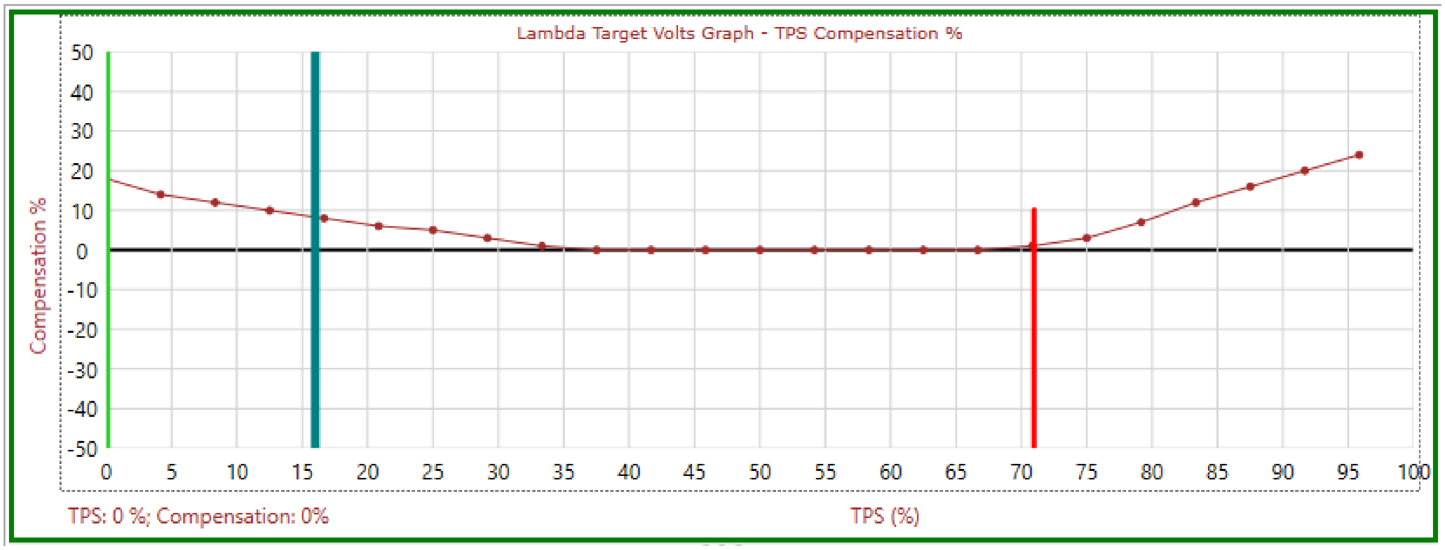
TPS Target Compensation

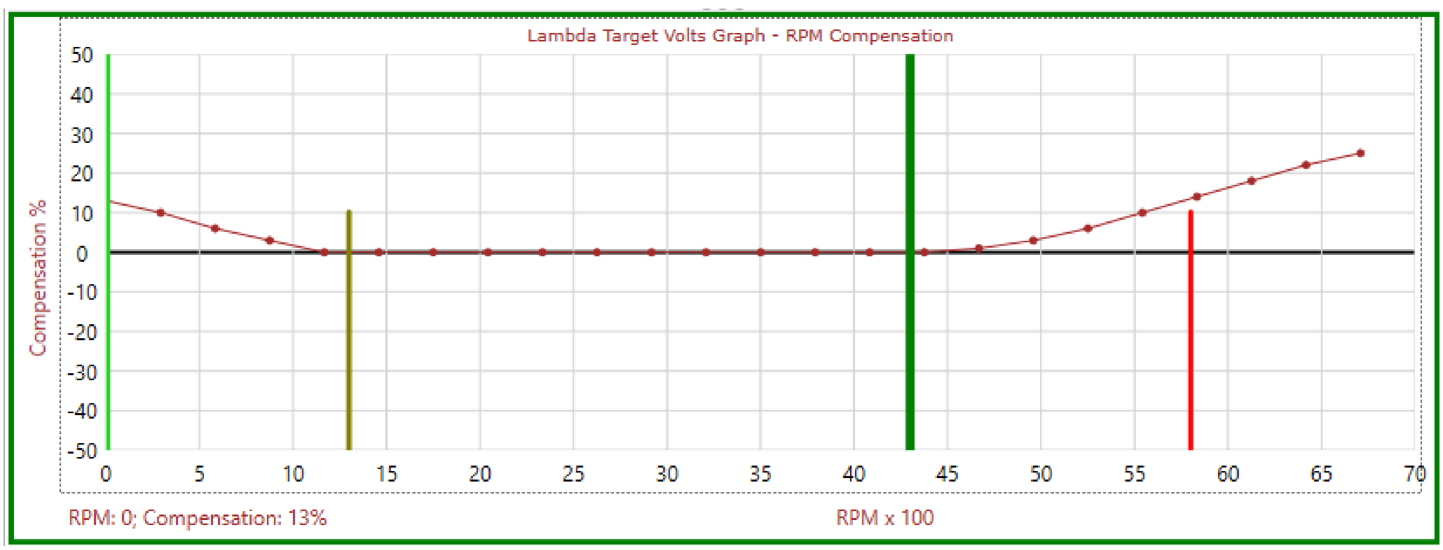
Where MAP is not used as the primary load reference, TPS can be used to modify the Lambda target.



This allows the desired Lambda signal to change as throttle opening changes.

RPM Target Compensation

The RPM Graph allows Lambda target to change across the engine-speed range.



This can be useful where the desired mixture changes with engine speed.

The software interpolates between Graph points.

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Target Compensation Calculation

The existing Lambda Graphs apply a percentage correction to the basic target.

Example:

Basic Target = 45%

Graph Compensation = +10%

Resulting Target:

49.5%

The exact meaning of a higher or lower target depends on the selected sensor type and signal direction.

Always verify whether increasing voltage indicates richer or leaner mixture for the configured Lambda system.

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Tuning Strategy

A good Lambda tuning sequence is:

1. Disable closed-loop Lambda Control.
2. Warm the engine fully.
3. Tune the base fuel calibration.
4. Use a suitable wideband AFR/Lambda instrument for accurate tuning.
5. Verify the Tune throughout the required load and RPM range.
6. Configure the required Lambda target.
7. Set conservative control limits.
8. Enable closed-loop control.
9. Observe the correction being applied.
10. Correct the base Tune where the ECU continually requires large compensation.

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Using Lambda Correction as a Diagnostic Tool

Lambda Control can provide useful information about the quality of the base Tune.

If the engine runs correctly but the ECU continually applies significant Lambda correction, this can indicate that the base Tune is drifting away from the desired mixture.

For example:

- Persistent positive correction → investigate a lean base condition.
- Persistent negative correction → investigate a rich base condition.

Possible causes may include:

- Incorrect Tune.
- Fuel-pressure change.
- Injector change.
- Air leak.
- Sensor calibration.
- Fuel composition.
- Mechanical change.

Feedback should therefore be used not only to correct the mixture, but also to reveal when a problem may be developing.

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Narrowband Sensor Hardware

Conventional narrowband oxygen sensors may use different numbers of wires.

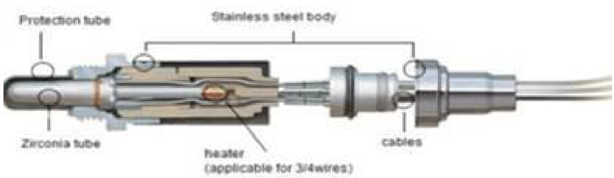
Typical configurations include:

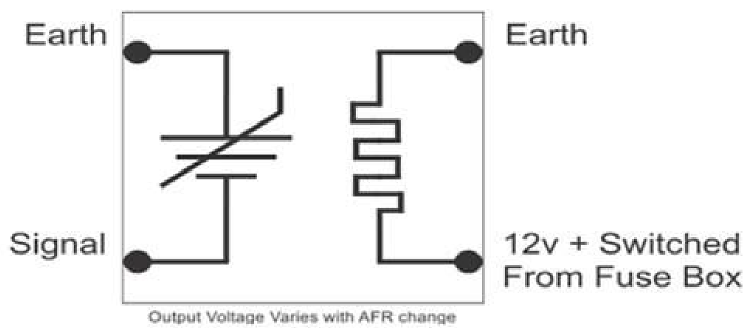
- 1-wire sensor.
- 3-wire heated sensor.
- 4-wire heated sensor.

The additional wires normally provide:

- Heater supply.
- Heater Ground.
- Sensor signal.
- Sensor Ground where provided.

Typical Bosch and Denso narrowband sensor arrangements are shown below.





Do not rely only on wire colour because colours can vary between manufacturers.

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Heater Circuit

Heated narrowband sensors contain a heater element that brings the sensing element up to operating temperature.

A typical heater resistance may be in the region of:

6-12 Ω

This value should be treated as a general check rather than a specification for every Lambda sensor.

Always compare with known sensor information where available.

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Checking an Unknown Narrowband Sensor

For an unknown conventional heated narrowband sensor:

1. Identify possible heater wires using resistance measurement.
2. Verify the heater circuit against expected sensor information.
3. Identify the remaining signal-related wires.
4. Connect according to the applicable sensor information.
5. Warm the sensor before evaluating its output.

A narrowband sensor generally does not provide a useful mixture signal until it has reached operating temperature.

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Wideband Sensor Wiring

Do not attempt to connect the raw sensing wires of a normal wideband Lambda Sensor directly to the ECU analogue Lambda input.

A wideband sensor requires its compatible controller.

Typical arrangement:

Wideband Sensor → Matching Wideband Controller → Analogue Output → ECU Lambda Input

Use the controller documentation for:

- Sensor connection.
- Heater operation.
- Analogue-output calibration.
- Sensor calibration requirements.

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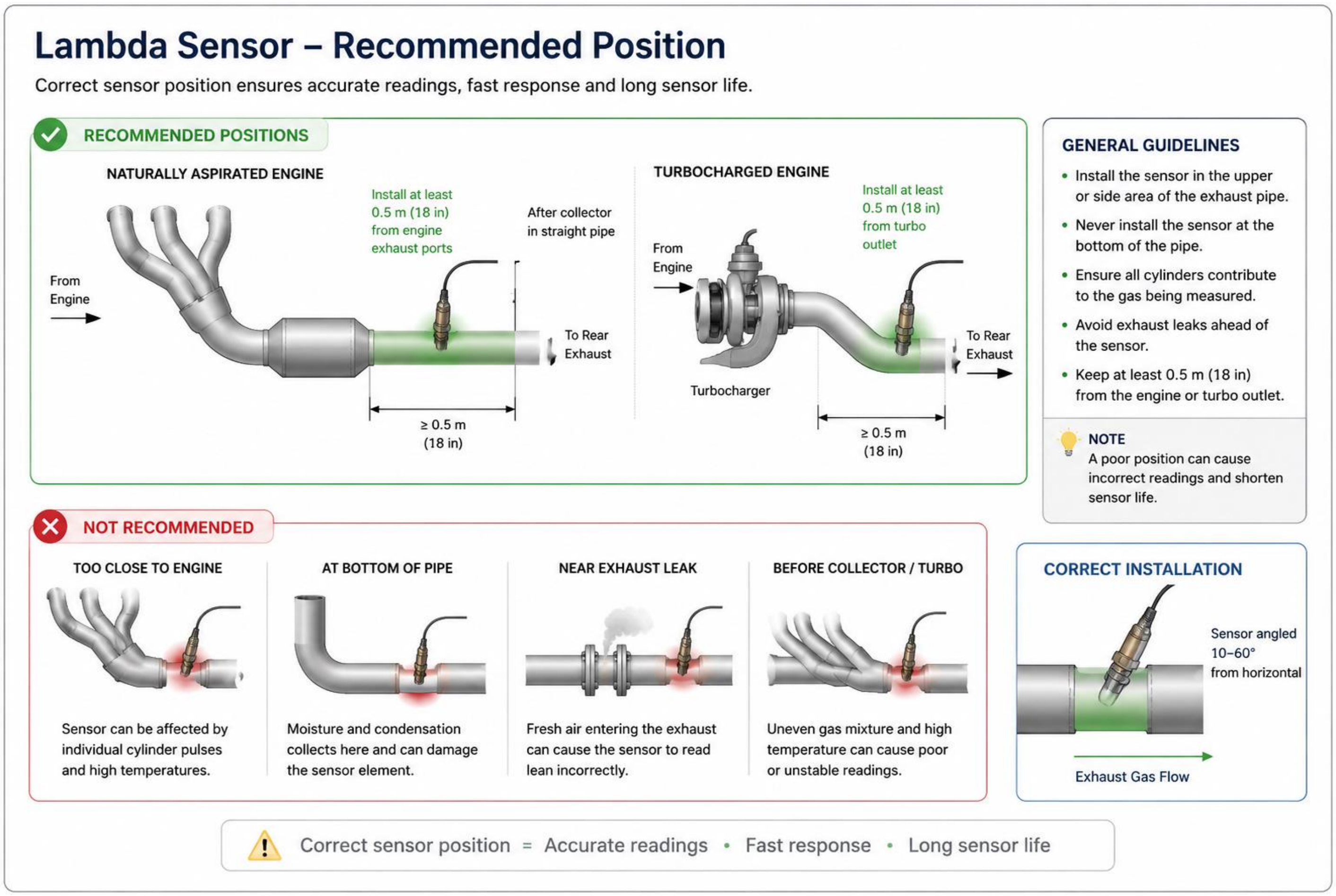
Sensor Position

The Lambda Sensor should be installed where it receives representative exhaust gas from the cylinders being monitored.

Install the sensor after the exhaust collector or turbocharger outlet and avoid the bottom of the pipe where moisture can collect.

As a general rule:

- Mount the sensor in the upper or side area of the exhaust pipe.
- Avoid the lowest point of the pipe.
- Avoid a position where condensation can collect around the sensor element.
- Ensure all required cylinders contribute to the gas being measured.
- Avoid exhaust leaks ahead of the sensor.



Product- or sensor-specific installation requirements should take priority where provided.

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Exhaust Leaks

An exhaust leak upstream of the Lambda Sensor can allow outside oxygen into the exhaust stream.

The sensor may then indicate a mixture leaner than the actual combustion mixture.

This can cause closed-loop control to add unnecessary fuel.

If Lambda readings appear unexpectedly lean, check for:

- Exhaust manifold leaks.
- Collector leaks.
- Sensor bung leaks.
- Cracked exhaust components.

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Sensor Contamination and Life

Lambda Sensor performance can deteriorate with use and contamination.

Rich mixtures, fuel additives and some sealants or anti-seize products may shorten sensor life.

A contaminated or ageing sensor may:

- Respond slowly.
- Read incorrectly.
- Become stuck rich or lean.
- Cause unstable closed-loop correction.

Sensor replacement should be considered when response becomes unreliable.

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Fault Finding

Symptom	Possible Cause	Check
No Lambda signal	Sensor not hot	Check heater and warm-up
No Lambda signal	Wiring fault	Check sensor/controller output and ECU Input
Reading fixed rich or lean	Sensor or controller problem	Verify with independent AFR instrument
AFR correct but ECU Lambda reading incorrect	Wrong input calibration	Check Sensor Type and voltage direction
Lambda correction constantly positive	Base Tune may be lean	Check base fuel Tune and fuel pressure
Lambda correction constantly negative	Base Tune may be rich	Check base Tune
Correction oscillates rapidly	Control too fast	Increase stabilisation / Samples
Correction responds very slowly	Excessive filtering or samples	Review control response
Lean reading unexpectedly	Exhaust leak	Check exhaust before sensor
Reading changes after controller replacement	Different analogue calibration	Verify voltage-to-Lambda specification

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Lambda Sensor Failure

Closed-loop feedback depends on the measurement being correct.
A failed or incorrect Lambda signal can therefore cause the ECU to make the wrong fuel correction.

For this reason:

- Keep Lambda correction limits reasonable.
- Use appropriate control limits.
- Tune the base engine correctly.
- Monitor sensor behaviour.
- Use diagnostics where available.
- Do not depend on Lambda Control as the only engine-protection strategy.

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Setup Check

Before enabling closed-loop Lambda Control, verify:

[ ] Correct sensor or wideband controller is fitted.

[ ] Correct Lambda Sensor Type is selected.

[ ] Wideband analogue-output calibration is known.

[ ] Signal direction is correct.

[ ] Realtime Lambda signal responds correctly.

[ ] Sensor has reached operating temperature.

[ ] Base fuel Tune is correct in open loop.

[ ] Target is appropriate for the sensor system.

[ ] Startup Delay allows reliable sensor operation.

[ ] Control Percentage is conservative.

[ ] Number of Samples provides stable correction.

[ ] RPM and load limits are suitable.

[ ] Target Graphs are configured where required.

[ ] Exhaust system has no significant leaks before the sensor.

[ ] Lambda correction has been observed under normal operation.

[ ] Persistent correction is used to improve the base Tune rather than ignored.

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