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## AFR500 Tuning Manual



### 1. Critical Product Notes

- Do calibrate your AFR500 in free air before first use!
- When powered, the oxygen sensor becomes very hot and will stay very hot for some time after use. Take caution with this heated sensor to avoid burns or ignition of flammable substances.
- Do not leave the sensor in the exhaust stream while disconnected from the controller or unpowered. This will foul an oxygen sensor rapidly.
- Do not open or modify the AFR500 controller.
- Do not apply excessive voltage (more than 28V DC) to the harness.
- Do not allow the sensor to be dropped or be handled roughly; the delicate ceramic internals may be damaged by mishandling.
- Do not modify the wiring harness.
- Do not run the wiring harness near hot or sharp objects. A short in this harness could result in a fire.
- Do not use the wiring harness if it is damaged. Replace it.
- Do not expose the AFR500 to open weather conditions or water as the enclosure is not fully sealed.
- Do not open or modify the oxygen sensor.

**Please read this manual fully to understand the proper use** of the AFR500. Misuse, mishandling and a lack of understanding may cause premature failure or inaccurate readings. We do not take responsibility for and cannot warranty the AFR500 kit in cases of improper use or improper applications.

Ballenger Motorsports does not accept any responsibility for incurred damage as a result of using the AFR500.

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## **2. Introduction**

The AFR500 is a precision oxygen concentration measurement system. Unlike conventional oxygen sensors which only work near a stoichiometric ratio (14.64:1 or 1.00λ), the AFR500 uses unique wideband technology to sense air-fuel ratios in the range of 9.00:1 to 16.00:1 (0.62 to 1.10 λ or lambda). The system is capable of working with many fuel types.

## **3. Kit Contents**

- AFR500 Controller
- Wideband oxygen sensor (Bosch LSU 4.2, or NTK Sensors)
- 13ft (standard), 7ft, or 24ft wiring harness
- AFR500 Tuning Manual
- Weld-in sensor bung
- Screw-in sensor plug
- Adhesive backed hook & loop pair

## **4. Functional Description**

The wideband sensor infers an air fuel ratio relative to the stoichiometric (chemically balanced) air fuel ratio by balancing the amount of oxygen pumped in or out of a measurement chamber. As the exhaust gasses get richer or leaner, the amount of oxygen that must be pumped in or out to maintain a stoichiometric air fuel ratio in the measurement chamber varies in proportion to the air fuel ratio. By measuring the current required to pump the oxygen in or out, the air fuel ratio (lambda) can be estimated. Note that the measured air fuel ratio is actually the output from the AFR500 pumping current controller and not a signal that comes directly from the sensor. Wideband sensors DO NOT output a voltage that can be directly measured as conventional oxygen sensors do.

## **5. Wiring Installation**

Black – Primary Ground

Red – Primary Power

Orange, White, Blue, Pink – Sensor Specific wires

Yellow – Analog Output

Black with white stripe – Analog Ground

The Yellow & Black/White Analog wires are unterminated and wrapped under tape in the harness. Follow these wires from the AFR500v2 connector and remove the tape holding the ends in place. Once exposed, the analog wires may be used as-is or extended with high quality butt connectors to another device.

A fused, red wire with a #8 spade connection is provided to connect to a switched power source. This power source should be capable of supplying 3A and should operate between 11v – 28v. Ideally this source will be above 13v during operation.

A black wire with a #8 spade connection is provided to connect to a reliable ground source, ideally the battery. If the analog output is used, the analog ground and main ground should be connected to the same location to avoid a ground loop or offset. Modifying or lengthening the ground may cause the ground level to shift, leading to erroneous analog output values.

Avoid high temperature, high vibration, sharp objects and ignition components when routing the wiring harness.

If you wish to install the AFR500 across a firewall, it is relatively simple to de-pin the Deutsch connector at the AFR500 controller. If the numbers on the back of the Deutsch connector are unreadable, TAKE PICTURES and NOTE THE WIRING POSITIONS. The orange wedgelock can be removed from the front of the connector and the terminals de-pinned with a small screwdriver. Be sure power is disconnected when doing this and take care not to bend any wires.

The Deutsch wiring pinout follows:

1. Orange wire
2. Red wire
3. Yellow wire
4. Black wire with white stripe
5. Blue wire
6. White wire
7. Pink wire
8. Black wire

## **6. Sensor Installation**

Oxygen sensors are sensitive to temperature, pressure and contaminants. A non-ideal sensor installation may dramatically reduce your sensor life.

Ensure that there are no leaks in the exhaust system as this will falsely indicate lean or high air fuel ratio values. The sensor should be installed upstream of any air-injection equipment.

The sensor should not be installed in a pressurized environment and therefore should be installed downstream of any turbochargers or similar systems causing exhaust pressure.

The sensor should be installed upstream of any emissions systems and catalytic converters.

Typically, the oxygen sensor should be installed 1ft to 4ft from the exhaust ports. A sensor that is too close will receive frequent thermal variations, leading to a reduced sensor life. A sensor that is too far away may run too cold and risk condensate leading to reduced sensor life.

The sensor should be installed at least 10° above horizontal to avoid condensation and water pooling in the sensing element. Ideally the sensor is installed just off vertical between the 10 and 2 clock positions (see Fig 4).

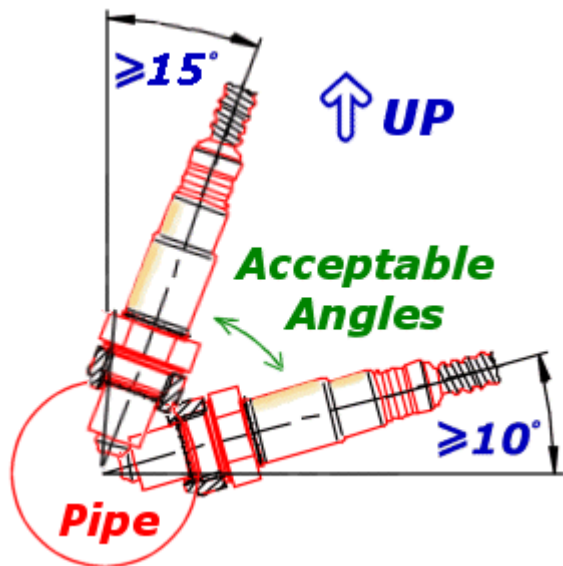


Fig 1. Minimum installation angle above horizontal

## 7. Calibration

Sensor calibration is an absolutely **critical** step in setting up your AFR500 wideband system. Follow the steps below to reliably calibrate your AFR500:

1. Connect the wiring harness to the AFR500 controller and to the oxygen sensor without power and ground. Hold the sensor in FREE AIR by the wires or on a safe, non-reactive surface that will not melt. Performing a calibration with the sensor in the exhaust is unreliable even if the engine has been off for days.
2. Connect power and ground to the AFR500. The sensor will rapidly heat up. Take care not to touch this sensor directly!
3. Wait 5 - 15 minutes while the sensor saturates.
4. Turn the calibration knob until the AFR500 reads "CAL-". If it reads "Air\_", turn clockwise. If it reads "Air-", turn counterclockwise. When the AFR500 reads "CAL-", your sensor calibration is complete.

5. Your AFR500 may read 16.00, Air-, Air\_, or CAL- before engine startup or when letting off the throttle of a fuel injected vehicle, this is normal.
6. Recheck the sensor periodically. Sensor drift will depend on use where a well tuned street vehicle will need rechecking less often than a leaded fuel dragster.
7. Disconnect power from the AFR500 harness. Once the sensor cools down, install the oxygen sensor. Take care, it will be hot for a long time! Take care not to bump or knock the calibration knob on the AFR500 until your next calibration!

## 8. Analog Output

The AFR500 has a 0v to 5v linear voltage output where 0v is equal to 9:1 air-fuel ratio for gasoline and 5v is equal to 16:1 air-fuel ratio for gasoline. Take care to wire the analog output and ground. The main ground and analog ground should be connected to the same location to avoid a ground loop or shift.

## 9. Analog Output Values

$$\begin{aligned} \text{Gasoline AFR} &= 9.00 + V_{out} \times 1.400 \\ \text{Methanol AFR} &= 3.96 + V_{out} \times 0.616 \\ \text{Lambda} &= 0.62 + V_{out} \times 0.096 \end{aligned}$$

It is important to observe any analog offsets. Any analog input in a logging system may suffer from a voltage offset, requiring that you always check your analog values against a known reference. In the case of the AFR500, there is a special provision for this.

During startup, the AFR500 will output 1 volt (10.4 AFR) until the countdown timer reaches 15 seconds. At 14 seconds until 5 seconds, the countdown timer will output 4 volts (14.6AFR). During the final 5 seconds, the AFR500 will output 0v. Using these values, expect to correct within a variation of +/- 0.08 volts

## 10. Display

The AFR500 only displays air fuel ratio in Gasoline AFR. When tuning other fuels, you will need to understand the Gasoline AFR scale or use the analog output.

## **11. Compatible Fuels**

The AFR500 is widely fuel compatible. Many are listed below:

Gasoline / Petrol (leaded or unleaded)

Alcohol (Methanol)

Ethanol

Compressed Natural Gas (CNG)

Liquefied Petroleum Gas (LPG)

Propane

Many other combustible fuels

## **12. Troubleshooting**

Error codes will be displayed on the AFR500 screen if there is a problem. “Bat” indicates a voltage out of range. “SEn” indicates a problem as indicated in the chart below:

Error Code	Description
SEn 1	Heater open (wire open or sensing element cracked) or no sensor connected
SEn 2	Heater shorted (wiring problem, H+ wire connected to GND)
SEn 3	Supply voltage out of range (28V)
SEn 4	Vs voltage > 1.7V (sensor too cold/not ready for measurement or Vs+ electrode cracked or Vs+ wire open)
SEn 5	(not used)
SEn 6	Ip+ voltage out of range ( sensing element cracked or IP+ wire open )
BAT_	The supply voltage is too low (<11 VDC)
BAT <sup>-</sup>	The supply voltage is too high

Top causes for an error:

1. Bad Sensor due to rich misfiring or backfiring (tuning far too rich and/or raw fuel hitting the sensor possibly leading to a cracked ceramic or contaminated ceramic element).
2. Bad Sensor due to having the sensor in the exhaust stream with no control and no heating which almost immediately foul a sensor.
3. Bad Sensor due to bad manufacturing or damage in transit or improper installation (sensor is at the bottom of the pipe, etc).
4. Bad Sensor due to mechanical damage (dropped or hit).
5. Sensor not reading within range due to being too hot or cold (ie right next to the port or far down the exhaust stream).
6. Wiring in harness is loose; pull each wire individually on each connector to validate fully seated terminals.
7. Wiring is improperly populated (crossed), send customer images and make sure to tell them to validate direction using keyways.
8. Bad ground connection to the controller or bad power connection. The voltage should be a DC supply voltage between 11 and 28 volts. If the voltage drops below 11 it will reset itself (sometimes this happens during cranking). We have seen bad wiring contribute to sensor problems often. Try connecting your power and ground directly to a good battery and see if your issue remains.

## **13. How to maximize sensor life**

1. Get a baseline tune before installing a sensor. You don't need the sensor in most cases to get your baseline timing and fuel settings.
2. NEVER leave a sensor in an exhaust unheated (disconnected).
3. Don't leave the sensor in continuously, only use for tuning and specific monitoring periods.

4. Limit your use of the sensor with leaded, race, or oil mixed fuels.
5. Limit time in water cooled exhausts and avoid this where possible.
6. Always let the sensor warm up before firing the engine. The AFR500v2 has a 20 second countdown timer. If you can wait longer, this will increase the sensor life (to a point).
7. Handle the sensor with extreme care. The sensing element is a delicate ceramic. Rough handling or drops may destroy the sensor.

#### **14. Spare Parts**

Spare parts may be purchased from your preferred dealer or Ballenger Motorsports directly at [www.bmotorsports.com](http://www.bmotorsports.com) . All parts work with the AFR500, AFR500v2, & NGK Powerdex AFX except where noted.

<b>Part Number</b>	<b>Description</b>
SNSR-00990	AFR500v2 Air Fuel Ratio Monitor Kit
SNSR-00980	AFR500v2 control unit only
SNSR-01001	13ft harness
SNSR-00999	7ft harness
SNSR-00998	24ft harness (typically for dyno rooms)
SNSR-01012	Bosch LSU 4.2 Sensor
SNSR-01043*	Bosch LSU 4.9 Sensor for AFR500v2 only
SNSR-01010	Production Grade NTK Sensor
SNSR-01016	Calibration Grade NTK Sensor
SNSR-01020	Lab Grade NTK Sensor (request for AFR500!)
SNSR-01061	Steel oxygen sensor boss / bung
SNSR-01062	Steel oxygen sensor plug / screw
SNSR-01051	Stainless Steel oxygen sensor boss / bung
SNSR-01052	Stainless Steel oxygen sensor plug / screw
TOOL-07557	High temperature mounting Velcro hook
TOOL-07558	High temperature mounting Velcro loop
TOOL-06736	AFR500 Cigarette / Lighter fused power
CONN-100111	AFR500 Deutsch 8 way connector
CONN-100025	AFR500 Deutsch Terminals
CONN-00121	AFR500 Harness side connector to sensor
CONN-00124	AFR500 Harness side connector kit to sensor
CONN-85588	AFR500 Harness side connector pigtail to sensor
CONN-00110	AFR500 Sensor side connector to sensor
CONN-00135	AFR500 Sensor side connector kit to sensor
CONN-85590	AFR500 Sensor side connector pigtail to sensor
CONN-100810*	AFR500v2 Header Jumpers with Ergo Handle

\* = AFR500v2 only