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AFR500v2 Tuning Manual

1. Critical Product Notes

• Do calibrate your AFR500v2 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 take extreme care when changing internal option jumpers in AFR500v2 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 AFR500v2 to open weather conditions or water as the enclosure is not fully sealed (contact us about sealing).
• Do not open or modify the oxygen sensor.

Please read this manual fully to understand the proper use of the AFR500v2. Misuse, mishandling and a lack of understanding may cause premature failure or inaccurate readings. We do not take responsibility for and cannot warranty the AFR500v2 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 AFR500v2.

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2. Introduction

The AFR500v2 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 AFR500v2 uses unique wideband technology to sense gasoline air-fuel ratios in the range of 9:1-16:1 (0.62-1.10 λ [lambda], 4:1-7.1:1 Methanol) or 6:1-20:1 (0.411-1.373 λ, 2.66:1-8.88:1 Methanol). The system is capable of working with most fuel types.

3. New features in the AFR500v2

The AFR500v2 is a major iteration on the AFR500. All features & functions of the original AFR500 remain intact with the added improvements below:

• Lambda & Methanol AFR display options
• Extreme Range option for FI methanol & laboratory applications
     • (0.411-1.373 Lambda)
     • (6-20 Gas AFR)
     • (2.66-8.88 Methanol AFR)
• Increased display speed
• Bosch LSU 4.9 option
• Faster analog output
• All harnesses, control units, accessories, etc (except the LSU 4.9) are backwards and forwards compatible
• Options are selectable at any time via internal jumpers
• NTK Calibration grade sensor highly recommended for low AFR methanol applications

4. Kit Contents

• AFR500v2 Controller
• Wideband oxygen sensor (Bosch LSU 4.2, 4.9, or NTK Sensors)
• 13ft (standard), 7ft, or 24ft wiring harness
• AFR500v2 Tuning Manual
• Weld-in sensor bung
• Screw-in sensor plug
• Adhesive backed hook & loop pair
• 3 red configuration jumper contacts

5. 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 the output from the AFR500v2 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.

6. 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. Any extensions of main power should be 16AWG or larger with a high quality butt connection and properly validated crimp joint.

A good, noise free ground is critical for best performance. 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 with an onboard logger or ECU, the analog ground and main ground should be connected to the same location to avoid a ground loop or offset.

If the analog output is used with a tuning device such as an HP Tuners, EFI Live, or similar system, the analog ground should be connected to the tuning device's analog ground. In cases where the analog ground is connected to a tuning device, ECU, or logger, the main ground should be connected to the battery or chassis. Any

extensions of the main ground should be 14AWG or larger with a high quality butt connection with both AFR500v2 main ground wires and a properly validated crimp joint.

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

If you wish to install the AFR500v2 across a firewall, it is relatively simple to de-pin the Deutsch connector at the AFR500v2 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

6a. Dyno Specific Wiring & Grounding

Improper grounding will cause serious problems, including damage to your AFR500v2. The dyno frame or chassis must be connected to building electrical ground in accordance with National Electrical Code (NEC) requirements.

Vehicles operated on a chassis dyno will generate considerable electrostatic charge. The vehicle must be grounded to the dyno frame while in operation. You can use a length of 16 AWG wire with one end secured to the dyno frame and the other end equipped with a heavy duty alligator clip that is attached to the vehicle frame or other vehicle ground point. Failure to ground the vehicle will lead to

electrostatic discharge (ESD) across the wideband sensor damaging the sensor and AFR500v2.

If you connect the main ground of an AFR500v2 to a vehicle and the analog ground of an AFR500v2 to the analog input of a dyno controller/logger without a dedicated ground path, you will pass this voltage difference through the AFR500v2 and its wideband sensor. This will skew your readings as well as damage the sensor & controller.

7. Setting & Explanation of Options

Three new options have been added to the AFR500v2 which require the installation of red jumper contacts (provided).

The first option is Bosch LSU 4.9 sensor capability. As shipped (unless otherwise specified), this is set for the Bosch LSU 4.2 & NTK Sensors. You must install a red jumper to enable LSU 4.9 ONLY mode.

The second option is for fuel measurement range. As shipped (unless otherwise specified), this is set for the Wideband (Standard) range of 9:1-16:1 for gasoline. Most customers should keep the standard range setting. Only use the Extreme (FI Methanol/Lab) range setting if you have a specific reason as increased range is traded for resolution. The extreme range is 6:1-20:1 gasoline AFR. You must install a red jumper to enable extreme range measurement.

The third option is for the display. The AFR500v2 can display gasoline AFR, lambda, & methanol AFR. Today's fuels are increasingly complex with mixes and exotic fuel types. Some customers are specifically familiar with methanol AFR rather than gasoline AFR. We've added lambda as it handles fuel based variations and is a better option than gasoline AFR for most modern fuels. Methanol is exclusively for use with race alcohol / methanol fuel. You must install a red jumper to enable lambda or methanol display options.

8. How to set Jumper Configuration Options

See section 9 on how to check your configuration options, you do not need to open the AFR500v2 to check your settings!

CAUTION!
HANDLE WITH EXTREME CARE!!!
HANDLE WITH THE CONNECTOR OR BOARD EDGE
USE RUBBER GLOVES OR CLEAN HANDS
HANDLE ONLY AFTER GROUNDING YOURSELF
HANDLE ONLY ON NON-CONDUCTIVE SURFACES
TAKE EXTREME CARE TO AVOID STATIC DISCHARGE!!!
MISHANDLING WILL VOID YOUR WARRANTY

Before removing the AFR500v2 circuit board, ground yourself and plan a specific work zone that is nonconductive and stable. Do not touch any components.

The AFR500v2 circuit board pulls out from its enclosure with the removal of two external screws and the Deutsch connector. Once removed, jumpers will be visible in the lower left corner of the circuit board when looking in the orientation shown in Fig 1. The provided jumpers are red and have long ergonomic handles to avoid touching any board components directly. If a red contact jumper is installed, then the circuit is closed. If no red contact jumper is installed, then the circuit is open.
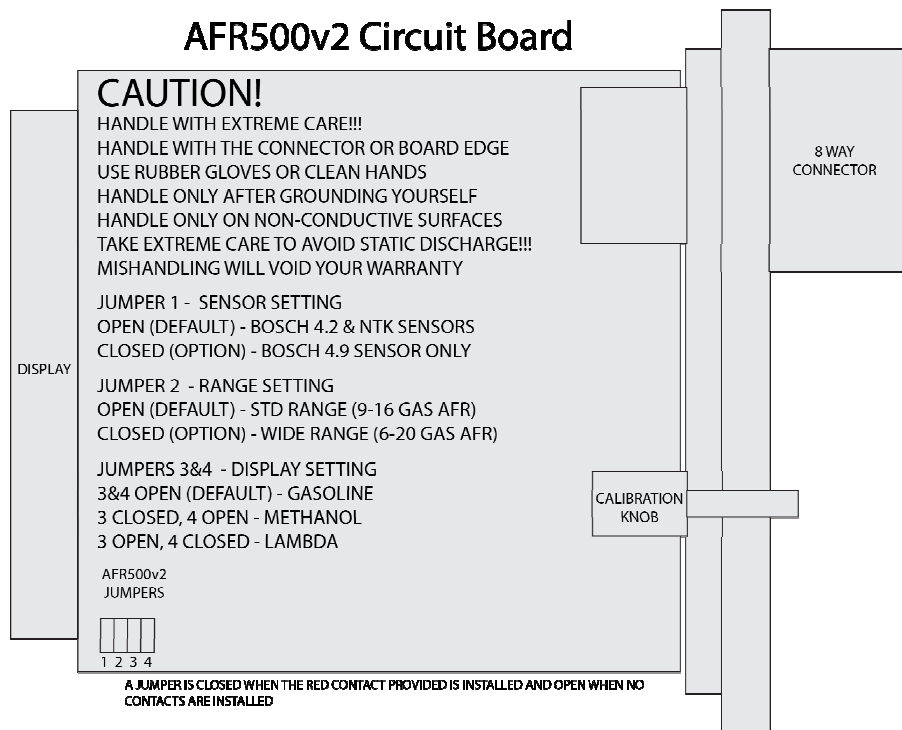
AFR500v2 Circuit Board

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JUMPER 1 - SENSOR SETTING
OPEN (DEFAULT) - BOSCH 4.2 & NTK SENSORS
CLOSED (OPTION) - BOSCH 4.9 SENSOR ONLY

JUMPER 2 - RANGE SETTING
OPEN (DEFAULT) - STD RANGE (9-16 GAS AFR)
CLOSED (OPTION) - WIDE RANGE (6-20 GAS AFR)

JUMPERS 3&4 - DISPLAY SETTING
3&4 OPEN (DEFAULT) - GASOLINE
3 CLOSED, 4 OPEN - METHANOL
3 OPEN, 4 CLOSED - LAMBDA

AFR500v2 JUMPERS

1 2 3 4

8 WAY CONNECTOR

DISPLAY

CALIBRATION KNOB

A JUMPER IS CLOSED WHEN THE RED CONTACT PROVIDED IS INSTALLED AND OPEN WHEN NO CONTACTS ARE INSTALLED

Fig 1. AFR500v2 Circuit Board when removed from case.

AFR500v2 JUMPERS

1 2 3 4

Fig 2. AFR500v2 Jumper Settings Closeup View

Jumper 1 - Sensor Configuration
No Jumper – Bosch LSU 4.2 & NTK Sensors
Jumpered – Bosch LSU 4.9 ONLY!

Jumper 2 - Range Setting
No Jumper – Wideband (Standard) Range (9-16 Gas AFR)
Jumpered – Extreme (FI Methanol/Lab) Range (6-20 Gas AFR)

Jumpers 3&4 – Display Setting

3&4 No Jumper – Gasoline AFR Display
3 Jumpered, 4 No Jumper – Methanol AFR Display
3 No Jumper, 4 Jumpered – Lambda Display
3 Jumpered, 4 Jumpered – No Function

9. Display of Configuration Options (Check Settings)

When power is applied, the AFR500v2 will display your configuration options.

The first two digits on display during boot indicate Sensor configuration.
4.2 Indicates LSU 4.2 / NTK Sensors
4.9 Indicates LSU 4.9 only

The third digit of display indicates range option.
Dash at button is std range, dash at top is extreme range.

The fourth digit of display indicates fuel displayed.
6 indicates gasoline
A indicates methanol
L indicates lambda

Fig 3. Example of default settings on start-up.

10. 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 off vertical between the 10 and 2 clock positions (see Fig 4).

The electrical connector should be installed to maximize strain relief at the sensor and connector, to keep the connector clean and free of contaminants, and to keep the plastic connector away from excessive heat.
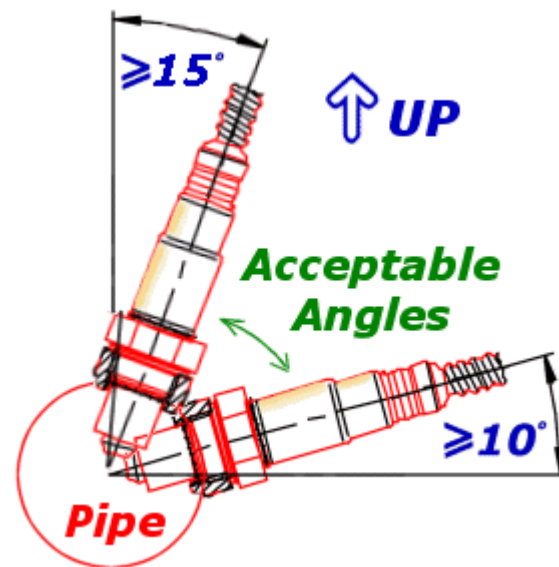

Fig 4. Minimum installation angle above horizontal

11. Calibration

Sensor calibration is a **critical** step in setting up your AFR500v2 wideband system. Follow the steps below to reliably calibrate your AFR500v2:

1. Connect the wiring harness to the AFR500v2 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 AFR500v2. The sensor will rapidly heat up. Take care not to touch this sensor directly!
3. Wait 10 minutes or more while the sensor saturates. The longer, the better.
4. Turn the calibration knob until the AFR500v2 reads "CAL–". If it reads "Air_", turn clockwise. If it reads "Air¯", turn counterclockwise. When the AFR500v2 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 AFR500v2 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 AFR500v2 until your next calibration!

12. Analog Output

The AFR500v2 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. In extreme range mode, 0v is equal to 6:1 for gasoline and 5v is equal to 20:1 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.

13. Analog Output Values

When set to Wideband (Standard) Range:
Gasoline AFR (9:1-16:1)   = $9.00 + V_{out} \times 1.400$
Methanol AFR (4.00-7.10)   = $4.00 + V_{out} \times 0.62$
Lambda (.618-1.098)   = $0.618 + V_{out} \times 0.096$

When set to Extreme (FI Methanol/Lab) Range:
Gasoline AFR (6:1-20:1)   = $6.00 + V_{out} \times 2.800$
Methanol AFR (2.66-8.88)   = $2.66 + V_{out} \times 1.244$
Lambda (.411-1.373)   = $0.411 + V_{out} \times 0.1923$

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 AFR500v2, there is a special provision for this.

During startup, the AFR500v2 will output 1 volt (10.4 AFR or 8.8 AFR in extreme mode) until the countdown timer reaches 15 seconds. At 14 seconds until 5 seconds, the countdown timer will output 4 volts (14.6AFR or 17.2 AFR in extreme mode). During the final 5 seconds, the AFR500v2 will output 0v (9.0AFR or 6.0 AFR in extreme mode). Using these values, expect to correct within a variation of +/- 0.08 volts

14. Display

The AFR500v2 offers display of air fuel ratio in Gasoline AFR (default), Methanol AFR, & Lambda. Lambda provides the most flexible display option for modern mixed fuels, as stoichiometric combustion in all compatible fuels will display as a lambda value of 1. As with AFR, lower lambda values are richer and higher values are leaner.

15. Compatible Fuels

The AFR500v2 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

16. Troubleshooting

Error codes will be displayed on the AFR500v2 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 6	Ip+ voltage out of range (sensing element cracked or IP+ wire open)
SEn 8	Sensor failure or internal component damage. Usually caused by improper grounding.
BAT_	The supply voltage is too low (<11 VDC)
BAT‾	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. Poor wiring & ground problems comprise the overwhelming bulk of the unit & premature sensor failures we see. Dynos must be properly grounded (see section 6a).
9. Damage from improper grounding of Dynos, loggers, ECUs or tuning devices.

17. 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. NTK sensors are significantly more durable than Bosch sensors in such environments.
5. Limit time in water cooled exhausts and avoid this where possible.
6. Handle the sensor with extreme care. The sensing element is a delicate ceramic. Rough handling or drops may destroy the sensor.
7. Never exceed 1700F (930C) EGT at the sensor. In high EGT environments, extended bungs such as SNSR-01064/SNSR-01054 or Heat Sink Bung Extenders such as SNSR-01065 are strongly recommended.

18. Spare Parts

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

Part Number	Description
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