

ECM ENGINE CONTROL
AND MONITORING

AFM1000TM

Air-Fuel Ratio Combustion Monitor

Instruction Manual

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Introduction

The Air-Fuel Ratio Combustion Monitor (AFM1000)

The ECM Air-Fuel Ratio Combustion Monitor (AFM1000) was designed for the professional calibration of carburetor or fuel-injection systems. Using a state-of-the-art, wide-range UEGO (Universal Exhaust Gas Oxygen) sensor, the AFM1000 provides unmatched measurement range, accuracy, and speed-of-response in a compact, lightweight package. Suitable for dynamometer or in-vehicle applications, the AFM1000 is an essential tool for any engine development program.

AFM1000 features:

- Measurement range of 8 to 18 AFR (gasoline¹)
- Easy calibration in air
- 0 to 5 volt linearized output for use with data acquisition or engine control systems
- 11 to 28 VDC operation²

AFM1000 Components List

The following items are included with the AFM1000:

Item No.	Description	Part Number
1.	Control Module	1000A-1
2.	UEGO Sensor	1000A-2
3.	Wiring Harness, 20' or Wiring Harness, 10' or Wiring Harness, 3'	1000A-3a 1000A-3b 1000A-3c
4.	Calibration Screwdriver	1000A-4
5.	Sensor Mounting Boss and Plug (M18X1.5mm)	1000A-5
6.	Instruction Manual	1000A-6

¹ Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.

² An AC/DC Power Supply (P/N 1000A-7) is available.

Important Operation Notes

1. Before installing the UEGO sensor, apply a small amount of non-lead containing antiseize compound to its threads. Do not get the compound on the sensor's tip.
2. **Do not operate an engine for more than three minutes with the UEGO sensor in the exhaust and the control module's power off. If the sensor is off in a running engine for a longer period, soot and water will condense in the sensor and may reduce its sensitivity.**
3. Do not use the UEGO sensor in exhaust systems in which water is sprayed into the exhaust. Water striking the sensor may cause permanent sensor damage.
4. Do not put the UEGO sensor in a heavily sooting or oil-burning engine.
5. Use of the UEGO sensor with leaded fuels may reduce the sensitivity of the sensor.
6. Do not put the UEGO sensor in exhausts in which the temperature is greater than 950 deg. C (1742 deg. F) or the pressure is not between 0.8 to 1.3 atm.
7. Route and cable-tie the wiring harness away from hot or moving objects and ignition wires.
8. Do not remove or attach the UEGO sensor from the instrument harness with the control module on.
9. Do not drop the UEGO sensor onto a hard surface.
10. Do not expose the UEGO sensor to flammable substances.
11. Do not attempt to wash the UEGO sensor with any solvent or compressed air.

How to Use

Hooking-up the AFM1000

Location of the UEGO Sensor

The UEGO sensor should be located approximately 12" from the exhaust valve(s) of the engine. A location further from the engine may be used as long as it is at least ten times the exhaust pipe diameter upstream of the end of the exhaust system. For example, with a 2 1/2" diameter exhaust pipe, the sensor should be at least 25" upstream of the end of the exhaust. The problem with locations further downstream than ten diameters is that air may be trapped in the exhaust giving leaner than actual readings. This especially occurs at low exhaust flowrates. UEGO sensor mounting locations far from the engine expose the sensor to more liquid water during start-up and should be avoided.

When choosing a UEGO sensor location, take into consideration engine movement, ground clearance, and wire harness routing.

Install the UEGO sensor by lightly coating its threads with a non-lead containing antiseize compound and tighten it to 30 ± 3 ft-lbf (40 ± 4 Nm). Attach the sensor to the wiring harness and route the harness to the control module. Use cable ties to keep the harness away from hot or moving objects and ignition wires.

Do not modify the wiring harness and replace it if it is damaged.

Installation of the Sensor Mounting Boss

The UEGO sensor is mounted in the engine's exhaust by threading it into a M18X1.5mm boss that is cast, welded, or brazed onto the engine's exhaust pipe. This thread size is identical to that of most exhaust oxygen sensors (O₂ sensors) used in production automobiles with 3-way exhaust catalysts.

The sensor boss provided has a M18X1.5mm thread. To mount the boss, first drill a 3/4" diameter hole in the desired location. Wire-brush the area around the hole and clamp the boss over the hole. Do not mount the sensor where liquid inside the exhaust may collect in the sensor or its threads. Weld or braze the boss to the exhaust pipe. After the boss is attached to the exhaust, tap the treads to clean them and file the top of the boss to provide a flat surface for sealing. When the UEGO sensor is not being used, use the supplied plug (with some anti-seize) to plug the hole. Do not use the UEGO sensor to plug the hole when the control module is not being used.

Power

The AFM1000 requires clean DC power of 11 to 28V at 1.4A (steady-state). During sensor warm-up, the requirements are approximately 5A for a period of up to 1 minute. A good car or motorcycle 12V battery can meet these specifications. An AC/DC power supply is available (P/N 1000A-7). The supplied wiring harness must be connected directly to the power source. Do not modify the wiring harness.

Warm-up

After powering-up the AFM1000, it will take less than one minute for the control module to bring the UEGO sensor to its operating temperature. It is okay to have the engine running during this period. In fact it is recommended that a cold engine be started before the AFM1000 is powered-up. The reason for this is to allow any condensed water to be cleared from the exhaust system. Water can thermally shock the UEGO sensor.

Analog Output

The AFM1000 has a 0V to 5V linearized output suitable for input into a data acquisition or engine control system.

The relationship between the analog output (V_{out}) and the AFR for gasoline¹ is:

$$\text{AFR} = 2.0 \times V_{out} + 8.0 \text{ (for gasoline only)}$$

For example, if V_{out} is 1 V then the AFR is 10:1.

The analog output is available from the female BNC connector on the wiring harness. The shell of the connector is signal ground and it is electrically connected to the power source ground.

When the AFM1000 is first turned on, the output passes through a sequence of three voltages (0.0V (8.0 AFR), 3.28V (14.56 AFR), 5.00V (18.0 AFR)). Each voltage is held for five seconds. The purpose of this sequence is to verify correct electrical connection and signal conversion with the AFM1000 and the data receiving device.

Calibration

Calibration of the AFM1000 and the UEGO sensor requires that the sensor be held in air (not in the exhaust even with the engine off) for 3 minutes following power-up. To bring the unit into calibration, adjust the calibration potentiometer (CAL POT) on the top of the control module using the calibration screwdriver provided. The screwdriver must be inserted approximately ½" inside the unit to reach the potentiometer. First turn the potentiometer to

¹ Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.

counter-clockwise until the CAL LED (orange) is off, then turn the potentiometer slowly clockwise until the CAL LED just lights. If the CAL POT cannot be turned to where the CAL LED is off then the sensor is bad.

Fuel Type Compensation

The AFM1000 assumes a fuel H:C ratio of 1.85 and an O:C ratio of zero. If a fuel of a different composition (H:C=m, O:C=p) is used, Equation 2 can be used to compensate (i.e. correct) the AFM1000's output.

$$\text{AFR}_{\text{corr}} = [(2.368 \times (m - 2p + 4)) / (m + 16p + 12)] \times \text{AFR} \quad [\text{Equation 2}]$$

where: AFR_{corr} is the AFR for the fuel of H:C=m and O:C=p composition.
AFR is the AFR output by the AFM1000.

The relationship between the analog output (V_{out}) and the AFR for methanol (race car "alcohol") is:

$$\text{AFR} = 0.888 \times \text{Vout} + 3.55 \quad (\text{methanol only}) \quad [\text{Equation 3}]$$

The relationship between the analog output (V_{out}) and the AFR for ethanol (corn alcohol) is:

$$\text{AFR} = 1.235 \times \text{Vout} + 4.94 \quad (\text{ethanol only}) \quad [\text{Equation 4}]$$

The relationship between the analog output (V_{out}) and the AFR for M85 is:

$$\text{AFR} = 1.050 \times \text{Vout} + 4.22 \quad (\text{M85 only}) \quad [\text{Equation 5}]$$

The relationship between the analog output (V_{out}) and the AFR for CH₄ (natural gas) is:

$$\text{AFR} = 2.366 \times \text{Vout} + 9.46 \quad (\text{natural gas only}) \quad [\text{Equation 6}]$$

Pressure Compensation

All wide-range exhaust sensors have a pressure sensitivity. Errors occur when the sensor is operated at pressures different from the pressure at which it was calibrated. Changes in pressure come about from changes in weather, altitude changes, and engine backpressure. There is no sensitivity to pressure at stoichiometric (Lambda = 1) conditions. The sensitivity gets greater the further from stoichiometric the engine is operated. Increases in pressure make the sensor read further from stoichiometric (i.e. if lean, reads leaner, if rich, reads richer). For example, an increase in exhaust pressure of 127 mmHg above the calibration pressure (which would result from calibrating at 1 mile above sea level and then driving down to sea level) would make a 12.65 AFR engine read 12.50 or a 16.77 AFR engine read 17.00. To compensate for pressure use Equation 7:

$$\mathbf{AFR_{corrected} = (AFR_{measured} + B \times P) / (1 + C \times P)} \quad \text{[Equation 7]}$$

where: $AFR_{corrected}$ = the AFR corrected for exhaust pressure.

$AFR_{measured}$ = the AFR output by the AFM1000.

$B = 0.009140$ for $AFR < 14.57$ (rich).

$B = 0.012100$ for $AFR \geq 14.57$ (lean).

$C = 0.000627$ for $AFR < 14.57$ (rich).

$C = 0.000830$ for $AFR \geq 14.57$ (lean).

P = the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (using the CAL POT on the AFM1000 while the sensor is held in air).

Specifications and Limits

Measurement Range and Accuracy

- Range: 8 to 18 AFR (gasoline)¹
- Accuracy: 1.5%

Exhaust Operating Limits

Maximum Exhaust Gas Temperature: 950 deg. C, 1742 deg. F.
Exhaust Gas Pressure Range: 0.8 - 1.3 atm.

Sensor Installation

Thread Size: M18X1.5mm. Lightly coat with non-lead containing antiseize.
Hex Size: 22mm.
Tightening Torque: 30 ±3 ft-lbf, 40 ±4 Nm.

The UEGO sensor's thread size is identical to that of most O₂ sensors used in production vehicles.

Output Specifications and Limits

Analog Output:

- 0V at 8.0:1 AFR (gasoline)
- 5V at 18.0:1 AFR (gasoline)
- $AFR = 2.0 \times V + 8.0$
- Output Impedance: 500 Ohm
- Output Connector: Female BNC, Signal = Center, Ground = Shell

General Information

Power: 11 to 28 VDC at 5A (surge), 1.4A (continuous)

Fuse: Internal, automatically resettable

Dimensions: 4" x 3.5" x 1",
102mm x 89mm x 25mm (W x H x D)

Weight: 5.6 oz., 160 gm.

¹ Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.

Troubleshooting

If the Green LED on the side of the unit is on, all is okay.

If the Green LED on the side of the unit is flashing continuously, the unit is warming up. The sensor requires 30 seconds of warm-up time after the unit is turned on.

If the Red LED is flashing 1, 2, 4, 5, or 6 times per second, the UEGO sensor is broken. Of course, this will also occur if the sensor is not connected.

Sometimes one or more of these codes will occur within 1 minute of power-up. This is okay as long as they do not remain active.

If the Red LED is flashing 3 times per second, the battery voltage is either too low (less than 11 V) or too high (greater than 28 V). If this occurs, immediately stop the engine and supply the correct battery voltage to the control module.

If the CAL POT cannot be turned to where the CAL LED is off then the sensor is bad.

If the AFM1000 outputs erroneous values, one of two conditions exists:

1. The unit is being confused by noisy power or operating in an electrically noisy environment. In some situations, a timing light might create a noise problem. Keeping the control module and its wiring harness away from the engine's ignition wires will help avoid this source of electrical noise.
2. The ground wire on the wiring harness is not attached directly to the ground at the vehicle's battery. If you connect a single wire from the wiring harness ground to the vehicle's battery, a large voltage drop will occur across that wire and cause the analog output ground at the BNC connector to be elevated above battery ground. And since battery ground is often the engine's data acquisition ground, if you hook the analog output ground at the BNC connector to the ground at the data acquisition system then you will cause a current loop through the ground of the data acquisition system to the vehicle battery.
3. The AFM1000 must be returned to the factory for repair. There are no user-repairable components inside the control module. The warranty is void if the control module is opened or wiring harness is modified. Contact ECM before returning the AFM1000 to the factory.

Safety Warnings

In installation and use of this product, comply with the National Electrical Code and any other applicable Federal, State, or local safety codes.

Always wear eye protection when working near engines, vehicles, or machinery.

During installation, turn off the power and take all other necessary precautions to prevent injury, property loss, and equipment damage. Do not apply power until all wiring is completed.

Never work on a running engine.

When installing the AFM1000's cabling and sensor on a stopped engine, it is best to think-out your moves before you make them.

Route and cable-tie all cables away from hot, moving, sharp, high energy (spark), and caustic objects.

Take into consideration the movement of the engine, chassis, and wind buffeting when instrumenting the engine.

Clear tools away from the engine before starting.

Operate the engine only in a well ventilated area and never when you or one of your co-workers is tired.

When operating the AFM1000 in a moving vehicle, the operator should keep his or her eyes on the road.

One measure of professionalism is how much you and your co-workers can accomplish without an injury. Always be at your professional best. Think and act with safety in mind.

Warranty and Disclaimers

WARRANTY

The products described in this manual, with the exception of the UEGO sensor, are warranted to be free from defects in material and workmanship for a period of 365 days from the date of shipment to the buyer. Within the 365 day warranty period, we shall at our option replace such items or reimburse the customer the original price of such items which are returned to us with shipping charges prepaid and which are determined by us to be defective. This warranty does not apply to any item which has been subjected to misuse, negligence or accident; or misapplied; or modified; or improperly installed.

The UEGO sensor is considered an expendable part and as such cannot be covered by a warranty.

This warranty comprises the sole and entire warranty pertaining to the items provided hereunder. Seller makes no other warranty, guarantee, or representation of any kind whatsoever. All other warranties, including but not limited to merchantability and fitness for purpose, whether express, implied, or arising by operation of law, trade usage, or course of dealing are hereby disclaimed.

The warranty is void if the control module is opened or the wiring harness is modified.

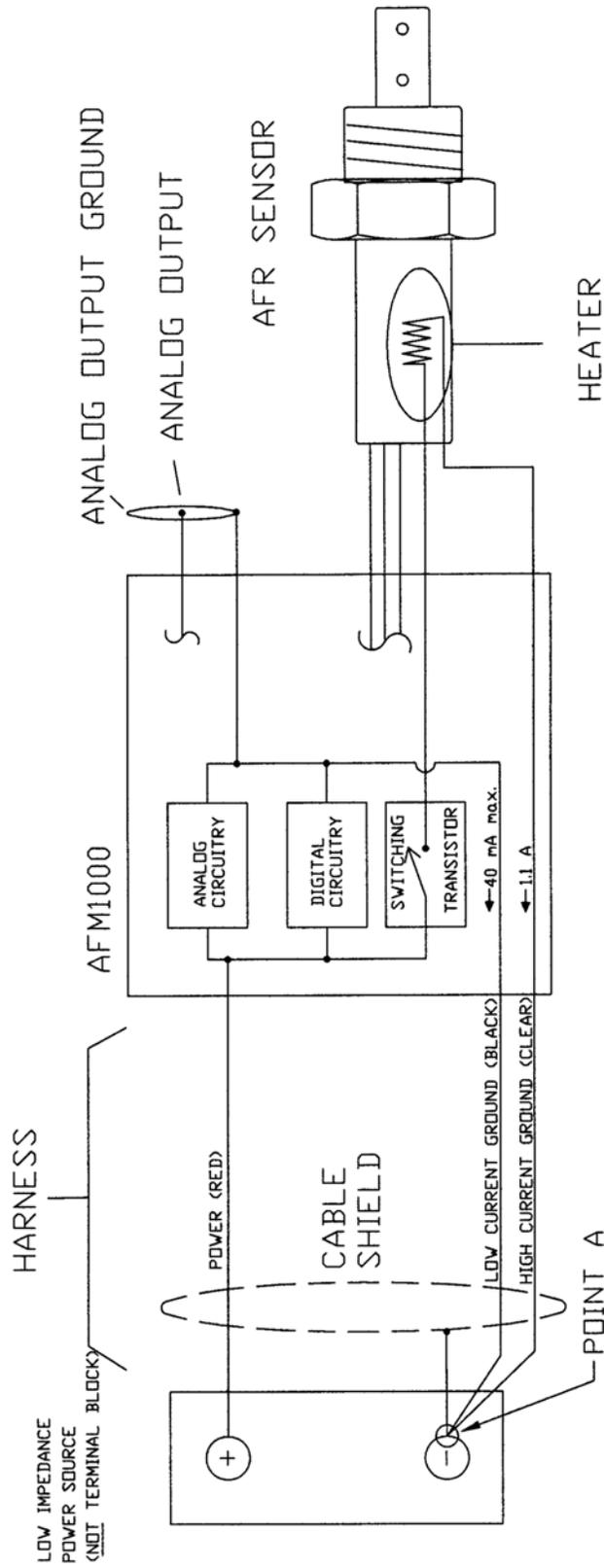
LIMITATION OF REMEDY

Seller's liability arising from or in any way connected with the items sold and/or services provided shall be limited exclusively to repair or replacement of the items sold or refund of the purchase price paid by buyer, at seller's sole option. In no event shall seller be liable for any incidental, consequential or special damages of any kind or nature whatsoever, including but not limited to lost profits arising from or in any way connected with items sold and/or services provided to buyer, whether alleged to arise from breach of contract, express or implied warranty, or in tort, including without limitation, negligence, failure to warn or strict liability. In no event shall the company's liability to buyer arising out of or relating to the sale of any product or service exceed the purchase price paid by buyer to the company for such product or service.

PRODUCT CHANGES

We reserve the right to discontinue a particular product or to make technical design changes at any time without notice.

POWER WIRING IN AFM1000



NOTES:

1. TWO GROUND WIRES ARE USED. ONE TO CLOSE THE CURRENT LOOP ON THE SENSOR HEATER AND ONE TO CLOSE THE LOOP ON THE ELECTRONIC CIRCUITRY. IF YOU RUN GROUNDS ON SAME WIRE, YOU WILL GET NOISE IN OUTPUT.
2. DO NOT REWIRE TO MAKE SINGLE WIRE FROM POINT A TO ACTUAL BATTERY. IF YOU DO THEN YOU WILL GET A LARGE VOLTAGE POTENTIAL BETWEEN THE ANALOG OUTPUT GROUND AND BATTERY.
3. IF YOU WIRE AS SHOWN ABOVE, VOLTAGE POTENTIAL BETWEEN ANALOG OUTPUT GROUND AND BATTERY GROUND WILL BE SMALL (<<0.002 VOLTS).
4. IN SOME APPLICATIONS, CUTTING LOW CURRENT GROUND (BLACK) AT GROUND RING AND CLOSING GROUND VIA ANALOG OUTPUT GROUND MAY IMPROVE NOISE IMMUNITY OF SYSTEM. FOR THIS CASE, THE GROUND OF THE EQUIPMENT ATTACHED TO THE ANALOG OUTPUT MUST ITSELF BE CONNECTED TO BATTERY GROUND.

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