Instruction Manual

AEM
PERFORMANCE ELECTRONICS

P/N 30-0310
X-SERIES INLINE WIDEBAND
Bosch LSU4.9

STOP! - READ THIS BEFORE INSTALL OR USE!

WARNING:

THIS INSTALLATION MAY REQUIRE WELDING OR INTEGRATION INTO A VEHICLE'S ELECTRICAL SYSTEM. DAMAGE TO SENSITIVE ELECTRONICS, FIRE, OR EXPLOSION MAY OCCUR IF PROPER PRECAUTION IS NOT TAKEN. IF THERE IS ANY DOUBT, **DO NOT** ATTEMPT THE INSTALLATION AND CONSULT A PROFESSIONAL.

NOTE: IT IS THE RESPONSIBILITY OF THE ENGINE TUNER TO ULTIMATELY CONFIRM THE CALIBRATION USE FOR ANY PARTICULAR ENGINE IS SAFE FOR ITS INTENDED USE. AEM HOLDS NO RESPONSIBILITY FOR ANY ENGINE DAMAGE THAT RESULTS FROM THE MISUSE OF THIS PRODUCT.

The AEM X-Series Inline Wideband Controller features a low-profile weather resistant enclosure with interface options suitable for most data loggers and ECUs. The AEM inline controller is ideal for all vehicles including carbureted applications and engine dynamometers. A 0-5V analog output is included and can be used with data loggers or aftermarket ECUs including the AEM Infinity Engine Management System (EMS). In addition, an AEMnet (CAN bus) and serial data stream are also available for logging or mixture control purposes.

The X-Series Digital Wideband technology is US Patent #9,575,030.
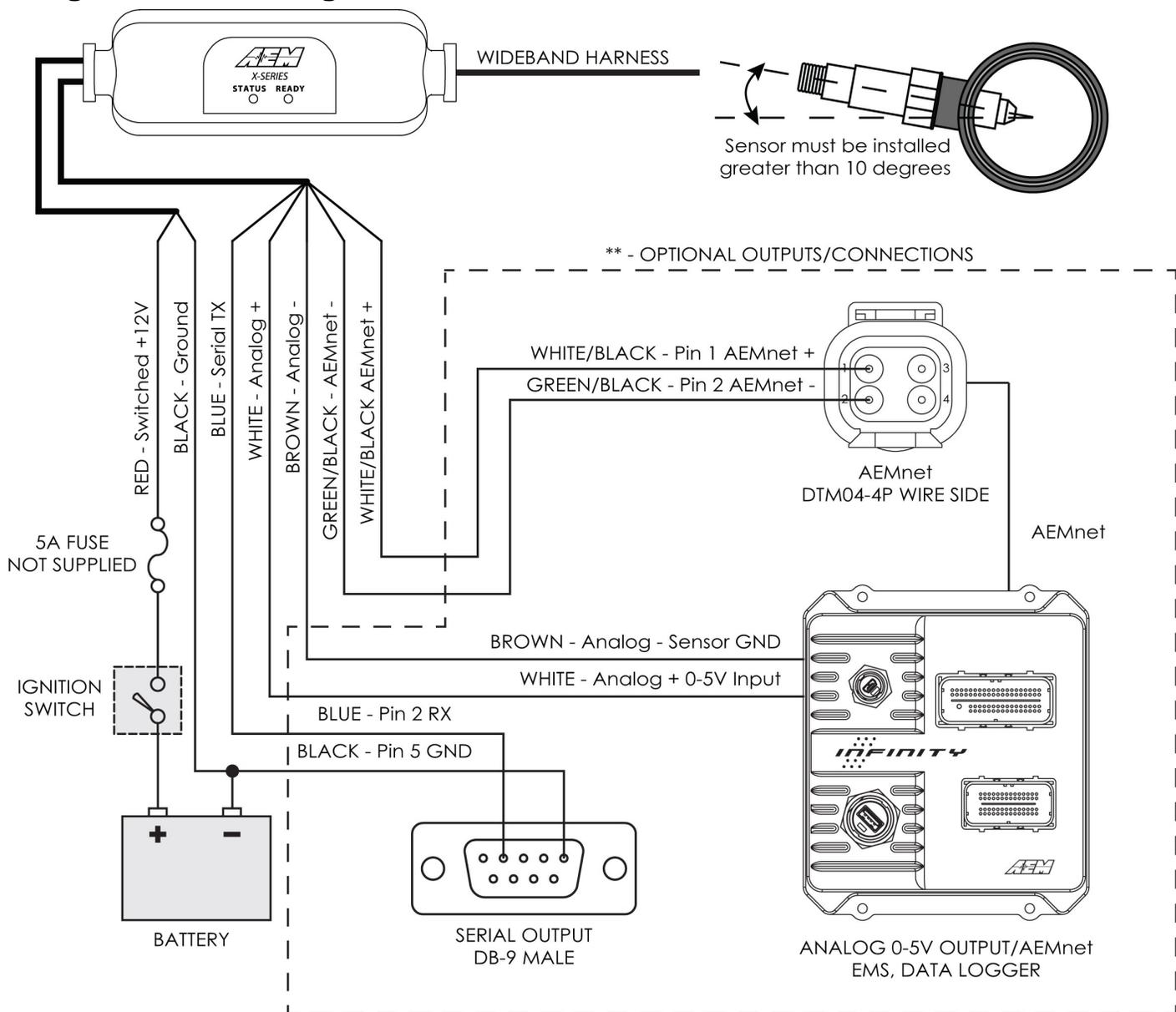
Features

- X-Digital Technology
- Free air or resistor trim calibration modes
- Fast response, 20ms typical
- 8.0:1 to 20.0:1 AFR / 0.55 to 2.00 Lambda
- Supports Bosch LSU4.9 Sensor
- Supports vehicle/system voltages up to 16V
- Low-profile, weather resistant enclosure
- 0-5V Analog Output
- AEMnet (CAN bus) Output
- Serial RS-232 Output

KIT CONTENTS	
PN	**Description**
10-0310	INST, X-SERIES UEGO INLINE
35-0310	ASSY, X-SERIES UEGO INLINE
-	RED INSULATED BUTT CONNECTORS (4)
35-4005	WELD-IN BUNG,02 SENSOR 1214 MILD STEEL
35-2004	SENSOR, WIDEBAND UEGO BOSCH LSU 4.9

OPTIONAL ACCESSORIES	
PN	**Description**
30-2355-200	NO WELD UEGO CLAMP KIT, 1.75" to 2.00"
30-2355-250	NO WELD UEGO CLAMP KIT, 2.25" to 2.50"
30-2355-300	NO WELD UEGO CLAMP KIT, 2.75" to 3.00"
30-2355-350	NO WELD UEGO CLAMP KIT, 3.25" to 3.50"
30-4008	WELD-IN FINNED BUNG, O2 LONG, STAINLESS STEEL
35-4001	BUNG PLUG,02 SENSOR

Wiring Installation Diagram

WIDEBAND HARNESS

Sensor must be installed greater than 10 degrees

** - OPTIONAL OUTPUTS/CONNECTIONS

RED - Switched +12V
BLACK - Ground
BLUE - Serial TX
WHITE - Analog +
BROWN - Analog -
GREEN/BLACK - AEMnet -
WHITE/BLACK AEMnet +

WHITE/BLACK - Pin 1 AEMnet +
GREEN/BLACK - Pin 2 AEMnet -

AEMnet
DTM04-4P WIRE SIDE

AEMnet

5A FUSE
NOT SUPPLIED

BROWN - Analog - Sensor GND
WHITE - Analog + 0-5V Input

IGNITION
SWITCH

BLUE - Pin 2 RX
BLACK - Pin 5 GND

BATTERY

SERIAL OUTPUT
DB-9 MALE

ANALOG 0-5V OUTPUT/AEMnet
EMS, DATA LOGGER

Important Notes on Wiring

• Route harnesses carefully to avoid chafing or undue strain. Apply strain reliefs and wire coverings as necessary.
• Secure wiring to vehicle with wire ties paying special attention to the sensor harness routing beneath the vehicle and/or in the engine compartment.
• Take care when routing sensor harness near hot exhaust components.
• Use a 5A inline fuse on the switched 12V power supply line.
• Avoid cutting or extending the sensor harness. If necessary, use appropriate gauge wire (20 AWG or thicker) when extending wires, especially Switched +12V or Ground.
• Ensure all connections are secure and insulated from shorts to adjacent wires and the vehicle structure. Utilize proper crimping and solder/heatshrink techniques.

| Power / IO	
RED	Switched 12V Power (5A Fuse)
BLACK	Power Ground
GREEN/BLACK	AEMnet- / CANL
WHITE/BLACK	AEMnet+ / CANH
BLUE	Serial / RS-232 Output
WHITE	0-5V Analog Output Positive+
BROWN	0-5V Analog Output Negative-

Bosch LSU4.9 UEGO Sensor	
GREEN	Trim Resistor
WHITE	Heater Negative-
ORANGE	COM
RED	Pump Current
BLACK	Sense
BROWN	Heater Positive+

Operation

The minimum wiring connections required to operate the X-Series UEGO Inline are switched +12V, ground, and one of the outputs: 0-5V Analog, AEMnet / CAN, or Serial. There are two LEDs on the top of the unit which describe the present operating status of the device as follows.

RED Status	*GREEN* Ready	Description
OFF	SOLID ON	Normal Operation
MEDIUM	MEDIUM	(Simultaneous flash) Power up, flash count = AEMnet/CAN ID #
SOLID ON	OFF	Fatal Error, Restart Required
SLOW	OFF	Error, No Sensor Detected
OFF	FAST	Warm Up, Stabilize, Equalize the heater
MEDIUM	MEDIUM	(Simultaneous flash) New Free Air Calibration Required
FAST	FAST	(Simultaneous flash) Free Air Calibration in Progress
ALTERNATING	ALTERNATING	(Alternating Flash) While in AEMnet/CAN Learn Mode

A button is located beneath an access cover on the rear of the unit for the following procedures. Carefully pry the cover off with a small screwdriver or similar and replace when done.

REMOVE COVER TO ACCESS BUTTON
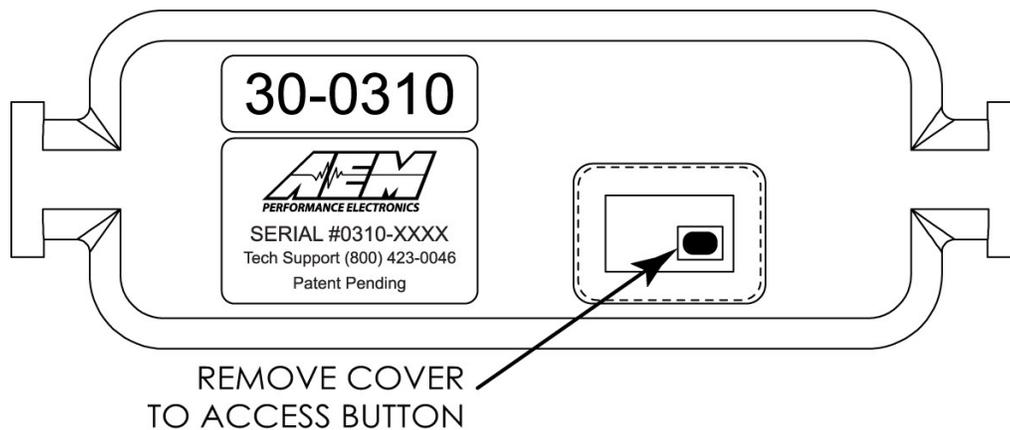
Change to Free Air Calibration Mode

1. Remove oxygen sensor from exhaust but keep it connected to controller.
2. Apply power to controller and wait for the sensor to warm up as indicated by a solid green 'Ready' LED.
3. Press and hold the button until both LEDs begin to flash rapidly in unison.
4. The LEDs will stop flashing once the calibration is complete and the unit will return to Normal Operation mode with only the green 'Ready' LED illuminated solidly.

Change to Resistor Calibration Mode (Default)

This is only necessary if you have already performed a free air calibration and wish to return to resistor calibration mode. The units are shipped from the factory in resistor calibration mode as default - this is the recommended mode for most users.

1. Remove power from the controller and verify that both LEDs are off
2. Press and hold button.
3. Apply power to the controller while holding button.
4. The green 'Ready' LED will flash to confirm resistor calibration mode

AEMnet / CAN bus Learn Mode

If it is desired to use the AEMnet / CAN bus output to send data to your ECU or data logger **AND** you have more than one X-Series UEGO Inline controller then the following learn procedure will have to be performed to assign unique IDs to each controller. Every controller used on the same AEMnet / CAN bus must have its own unique ID. Ensure your CAN bus has proper termination; there must be only two termination resistor (120 Ohm each) located at the physical and opposite end of the bus.

1. Connect the first (and only) inline controller (A) to the AEMnet / CAN bus and apply power.
2. Disconnect the sensor from the next (or second) controller (B) to be added to the bus.
3. Press and hold the button on controller (B) and then apply power.
4. Controller (B) will begin flashing its LEDs in an alternating fashion as it scans the bus and learns its new ID.

5. Once controller (B) has stopped flashing and entered normal mode as indicated by a steady green 'Ready' LED, you may reconnect the sensor.
6. Repeat this process for any additional controllers up to a total of 16.

Calibration

Calibration

The supplied UEGO sensor is factory calibrated via a trim resistor, integral to the sensor connector, and requires no further calibration. The ability to perform a free air calibration is provided for users that wish to do so. A free air calibration can be used as a sensor ages, however, new sensors should use the resistor calibration for best accuracy.

Resistor Trim Calibration Mode

This is the X-Series UEGO controller's default mode as shipped from the factory. It is the recommended calibration mode and, for most users, no further action or calibration is required.

Free Air Calibration Mode

The sensor MUST be removed from the exhaust for this procedure. The calibration will take approximately ten to fifteen seconds during which the sensor must be placed in a "fresh" air environment, i.e. an area without lingering exhaust or chemical fumes. If the sensor detects too low a level of oxygen, which is typically indicative of a sensor being left in the exhaust pipe or in an environment with excess exhaust/chemical fumes, then the process will fail and the calibration will revert to resistor trim calibration mode. The current calibration status may be determined by viewing the AEMnet/CAN output.

What is a UEGO Wideband Sensor?

A Universal Exhaust Gas Oxygen (UEGO) oxygen sensor, also known as a wideband or lambda sensor, measures the proportion of oxygen (O_2) in the exhaust of a running engine. An air to fuel ratio (AFR) or lambda value can be calculated from this measurement. Typically, when calibrating or "tuning" the fuel delivery system of an engine, a specific AFR can be targeted to achieve maximum power, economy, or emissions. The output from a UEGO sensor controller can be used to adjust a carburetor or fuel injection system to reach this target.

UEGO sensors are one of the more sophisticated sensors found in today's vehicles. The sensing element is made of a zirconium dioxide ceramic with a thin platinum coating and has an integrated heating element. An electronic controller, such as is contained in AEM's X-Series UEGO Gauge or Inline Controller, is **required** to use a UEGO oxygen sensor. The controller connects to the sensor via multiple wires (up to 6) carrying sensitive voltages and electrical currents to process and calculate an AFR value. This value may be read directly from a gauge face or data-log as recorded by an ECU or logger via several methods as discussed elsewhere in this manual.

Interpreting Wideband Sensor Readings

An internal combustion engine runs on air (which contains ~20% oxygen) and fuel. The ratio of air to fuel (AFR) that, when combusted, perfectly consumes 100% of both the oxygen and fuel is called the stoichiometric ratio. This ratio is different for every fuel. Ratios lower than stoichiometric have more fuel and are considered "rich"; ratios higher than stoichiometric have less fuel and are considered "lean."

Fuel	Stoichiometric AFR	Lambda
Unleaded Gasoline	14.65 : 1	1.00
Methanol	6.47 : 1	1.00
Ethanol	9.00 : 1	1.00
Propane	15.67 : 1	1.00
CNG	17.20 : 1	1.00

Lambda is a unitless ratio that is fuel agnostic. In other words, a lambda reading of 1.0 is stochiometric for any fuel; AFR = (Stoichiometric AFR * Lambda.)

In general, an engine will have three areas of operation: idle/cruise, wide open throttle, and fuel cut off. The exact AFR value that should be expected (or tuned to) for these areas is very specific to the type and configuration of each individual engine. However, while monitoring your AEM X-Series controller, you should see readings similar to the chart below. Fuel cutoff is generally experienced when completely lifting off the throttle, while decelerating in gear, at high RPM.

Operating Region	WOT	IDLE/CRUISE	FUEL CUTOFF
Approximate AFR	10.5 (RICH)	14.7 (STOICH)	20.0 (LEAN)

IMPORTANT NOTE: Engine tuning should only be performed by experienced individuals as engine damage, or outright failure, can be the result of an improper calibration.

Sensor Placement

The location at which the sensor is installed in the vehicle's exhaust system is critical to its performance and longevity. Please review the following placement guidelines:

- o 18 inches (45cm) downstream of the cylinder head's exhaust port or turbocharger
- o Upstream of any catalytic converters or emission control devices
- o Downstream of any turbochargers or large contributors to exhaust pressure
- o As far as possible from the exhaust exit (tailpipe) to avoid scavenging fresh air in low exhaust flow conditions such as idling
- o AEM's X-Series UEGO controller is a very sensitive device and, thus, it is important to have a completely leak-free exhaust

Sensor Bung

The supplied mild steel sensor bung must be welded into the vehicle's exhaust. An optional stainless steel sensor bung is available for purchase from AEM dealers and may be useful in specific installation scenarios. The taller geometry of this bung helps bring the sensing element further out of the exhaust stream when used in small diameter tubing such as header primaries. In addition, the finned body helps dissipate heat when used in extreme applications. As an alternative to welding, users may purchase a P/N 30-2355-XXX No Weld UEGO Clamp Kit.
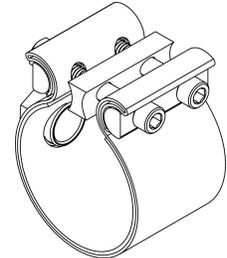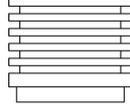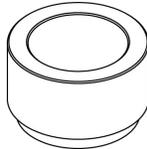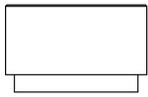
P/N 35-4001 Mild Steel Sensor Bung

P/N 30-4008 Stainless Steel Tall Sensor Bung w/ Fins

P/N 30-2355-XXX No Weld UEGO Clamp Kit
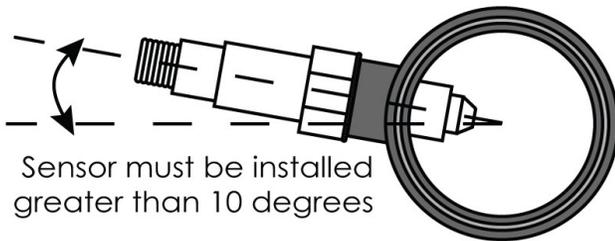
Sensor must be installed greater than 10 degrees

The bung should be welded in such a way that the installed sensor orientation is greater than ten degrees from horizontal to allow any condensation to properly drain from the sensor. In addition, it is recommended to avoid a completely vertical sensor orientation to prevent overheating the sensor. Failure to heed these recommendations may result in premature sensor failure.

Important Notes on Wideband Sensors

The sensor contains an integrated heating element and will become hot enough to produce burns, when powered, even without the presence of exhaust gas. Sensors can remain hot enough to burn or start a fire for quite some time after removing power -- handle with caution.

UEGO sensors are very sensitive devices that must handled and installed with care. Listed below are several contaminants and conditions which will shorten the life of the sensor or result in outright failure. Since AEM is unable to verify the operating conditions under which a sensor is subject, **NO WARRANTY** is provided for the UEGO sensor itself. The gauge/controller is, however subject to AEM's 12 month limited warranty; please see the warranty statement at the end of this document.

The following may damage or destroy oxygen sensors:
- o Leaded (tetraethyl) fuel
- o Silicone
- o Oil
- o Engine coolants
- o Particulates, carbon (e.g. excessively rich mixtures)
- o Mechanical shock (e.g. dropping a sensor on the ground)
- o Thermal shock (e.g. blown head gasket)

- o Extreme exhaust temperatures (Greater than 930 degC/1700 degF)
- o Unheated sensor in exhaust stream. Sensors that are installed in an exhaust must be connected to a properly functioning controller during engine operation.

0-5V Analog Output

WHITE WIRE = Analog Positive +
BROWN WIRE = Analog Negative -

0-5V Analog Output Scaling Formulas		
AFR	=	(2.3750 * Volts) + 7.3125
Lambda	=	(0.1621 * Volts) + 0.4990

The 0-5V analog output is suitable for output to devices such as loggers or ECUs. This differential output requires special care to ensure proper operation.   The WHITE signal wire should be connected to the positive of the analog input of the logging device or ECU; the BROWN wire must be connected to the negative of the analog input of the logging device or ECU. If the logging device or ECU does not have a differential analog input (both a dedicated positive and negative terminal for the analog input) then connect the BROWN wire to the shared signal ground. If the device does not have a dedicated signal ground then as a last course of action, connect it to the power ground of the logging device.

Important Note: If bench testing the analog output outside of a vehicle, a multimeter's positive lead may be connected to the WHITE wire however the BROWN wire must be connected to BOTH the multimeter's negative lead AND power ground going to the X-Series UEGO device. This connection is usually made by the circuitry inside an ECU or data logger.

0-5V Analog Output Scaling Table		
Volts	**Lambda**	**AFR (Gasoline)**
<0.50	SENSOR NOT READY	
0.50	0.58	8.50
0.75	0.62	9.09
1.00	0.66	9.69
1.25	0.70	10.28
1.50	0.74	10.88
1.75	0.78	11.47
2.00	0.82	12.06
2.25	0.86	12.66
2.50	0.90	13.25
2.75	0.94	13.84
3.00	0.99	14.44
3.25	1.03	15.03
3.50	1.07	15.63
3.75	1.11	16.22
4.00	1.15	16.81
4.25	1.19	17.41
4.50	1.23	18.00
>4.50	SENSOR ERROR	

AEMnet (CAN Bus) Output

WHITE WIRE WITH BLACK STRIPE = AEMnet+ / CANH
GREEN WIRE WITH BLACK STRIPE = AEMnet- / CANL

The AEMnet output is suitable for output to AEM devices such as the AQ-1 data logger or Infinity ECU. The following CAN configuration and message definition information is provided below to facilitate interface with third-party devices.

Message ID
If multiple inline controllers are to be connected to the same CAN bus, please reference the Operation section of this manual on how to invoke Learn mode to iterate their message IDs. The IDs will be assigned sequentially as 29-bit identifiers 0x0000180,0x0000181, 0x0000180, ..., 0x000018F.

Bus Termination
All AEMnet/CAN networks must be terminated to have an equivalent of approximately 60 Ohms of resistance. Generally, this means a 120 Ohm resistor connected in parallel to AEMnet+/AEMnet- (or CANH/CANL) at both physical ends of the bus run. The X-Series controller does not have any internal termination and is intended to be connected to a pre-existing, properly terminated network. Please refer to the Bosch CAN2.0B specification for further detail.

bit rate	500	kb/sec
format	29	bit ID
transmit rate	100	hz
terminating resistor	none	
endianness	big / Motorola	
Message/Arbitration ID	0x00000180 to 0x0000018F	
DLC	8	

Byte	Bit	Bitmask	Label	Data Type	Scaling	Offset	Range
0-1			Lambda	16 bit unsigned	.0001 Lambda/bit	0	0 to 6.5535 Lambda
2-3			Oxygen	16 bit signed	0.001%/bit	0	-32.768% to 32.767%
4			System Volts	8 bit unsigned	0.1 V/bit	0	0 to 25.5 Volts
5			Reserved	---	---	---	---
6	0 (lsb)	0	Reserved	---	---	---	---
	1	2	Bosch LSU4.9 Detected	Boolean	0 = false, 1 = true	0	0/1
	2 - 4	4	Reserved	---	---	---	---
	5	32	Free-Air cal in use	Boolean	0 = false, 1 = true	0	0/1
	6	64	Reserved	---	---	---	---
	7 (msb)	128	Lambda Data Valid	Boolean	0 = false, 1 = true	0	0/1
7	0 - 5	0	Reserved	---	---	---	---
	6	64	Sensor Fault	Boolean	0 = false, 1 = true	0	0/1
	7 (msb)	128	Reserved	---	---	---	---

Serial (RS-232) Output

BLUE WIRE = Serial Out

The serial datastream is suitable for output to third party devices such as data loggers, PCs, or reflashed ECUs. The X-Series UEGO serial datastream is designed to match AEM's legacy 30-4100/30-4110 UEGO Digital Gauge for backwards compatibility. The currently selected display mode (lambda or AFR) will dictate what is output via serial. The format is simply the value followed by a carriage return and line feed, e.g. "14.7\r\n"

baud rate	9600 bps
data bits	8
parity	None
stop bits	1

FAQ / Troubleshooting

What are the minimum wiring connections needed to use the gauge/controller?
Switched/fused 12V (RED) and power ground (BLACK) must be supplied; any unused wires may be secured and fastened away for future use. As there is no display, you will also want to connect either the analog, AEMnet, or serial output to your logger or ECU.

When should I use free air calibration mode?
The sensor that is supplied is laboratory calibrated using the integral trim resistor; this is the preferred and recommended calibration mode. If you feel your sensor has been extremely contaminated or damaged and requires re-calibration then it is suggested that you purchase a new sensor. Alternatively, performing a free air calibration may be helpful.

My engine has two banks, can I wire two sensors into one gauge/controller and switch between them?
No, each sensor must have its own dedicated controller/gauge. You may use multiple inline controllers or, alternatively, the AEM P/N 30-2340 4 Channel Wideband UEGO Controller may suit your needs.

Can I extend the wires in my sensor harness?
Yes, but use of at least 20AWG and proper crimping/soldering techniques is required.

My sensor/controller seems bad, how can I test it?
The controller may be powered from a car battery or bench power supply (3A minimum) to perform this test. Once the controller is powered, it should illuminate a red 'Status' LED without a sensor connected. Once the sensor is connected, the green 'Ready' LED should begin to blink and the sensor should begin to get warm. If the sensor is in open air, such as on a workbench, the controller should output a full lean signal (~20:1 AFR) within ~30 seconds. The gas from an unlit butane lighter can be used to simulate a rich condition when introduced to the sensor. A powered sensor will become hot enough to burn and/or ignite anything flammable -- HANDLE WITH CAUTION. The output signal should visibly sweep rich

then lean as the butane is introduced/removed. You may check the output using a voltmeter connected to the white (positive probe) and brown (negative probe.) The voltmeter should read 4.5V with a properly warmed up sensor in free air or something lower if using butane. IMPORTANT, the brown wire must also be connected the power ground (black wire) of the controller for this test to provide useful results.

Is the X-Series UEGO controller/sensor compatible with alternative fuels such as E85, methanol, ethanol, CNG, etc?

Yes. The lambda display mode and faceplate is recommended when using fuels other than gasoline. The AFR display mode uses the gasoline stoichiometric ratio of 14.65 which might be confusing for alternative fuels. Remember that AFR = (lambda * stoichiometric ratio).

For support, contact AEM Technical Support at 1-800-423-0046 or gentech@aemelectronics.com.

12 Month Limited Warranty

Advanced Engine Management Inc. warrants to the consumer that all AEM High Performance products will be free from defects in material and workmanship for a period of twelve (12) months from date of the original purchase. Products that fail within this 12-month warranty period will be repaired or replaced at AEM's option, when determined by AEM that the product failed due to defects in material or workmanship. This warranty is limited to the repair or replacement of the AEM part. In no event shall this warranty exceed the original purchase price of the AEM part nor shall AEM be responsible for special, incidental or consequential damages or cost incurred due to the failure of this product. Warranty claims to AEM must be transportation prepaid and accompanied with dated proof of purchase. This warranty applies only to the original purchaser of product and is non-transferable. All implied warranties shall be limited in duration to the said 12-month warranty period. Improper use or installation, accident, abuse, unauthorized repairs or alterations voids this warranty. AEM disclaims any liability for consequential damages due to breach of any written or implied warranty on all products manufactured by AEM. Warranty returns will only be accepted by AEM when accompanied by a valid Return Merchandise Authorization (RMA) number. Product must be received by AEM within 30 days of the date the RMA is issued.

UEGO oxygen sensors are considered wear items and are not covered under warranty.

Please note that before AEM can issue an RMA for any electronic product, it is first necessary for the installer or end user to contact the EMS tech line at 1-800-423-0046 to discuss the problem. Most issues can be resolved over the phone. Under no circumstances should a system be returned or a RMA requested before the above process transpires.

AEM will not be responsible for electronic products that are installed incorrectly, installed in a non-approved application, misused, or tampered with.

Any AEM electronics product can be returned for repair if it is out of the warranty period. There is a minimum charge of $50.00 for inspection and diagnosis of AEM electronic parts. Parts used in the repair of AEM electronic components will be extra. AEM will provide an estimate of repairs and receive written or electronic authorization before repairs are made to the product.

Specifications

Dimensions	length	4.7 / 120	in / mm
	width	1.4 / 36	in / mm
	height	0.9 / 23	in / mm
Sensor Installation	sensor/bung	M18 x 1.5	thread
	sensor to bung torque	30 / 40.6	ft-lb / N-m
Supply Voltage	min	10	VDC
	max	18	VDC
Supply Current (13.8V)	nominal	1.0	A
	peak	2.0	A
Operating Temperature	min	-4 / -20	degF / degC
	max (16V Supply)	185 / 85	degF / degC
Sensor Temperature	max (sensor element)	1706 / 930	degF / degC
Range	min	0.55	lambda
	max	2.00	lambda
Response Time	typical	20.00	ms
Stoichiometric Constant		14.65	gasoline
Analog Output	resolution	10	bit
	update rate	500	hz
CAN 2.0B Output	bit rate	500	kb/sec
	format	29	bit ID
	transmit rate	100	hz
	terminating resistor	none	
	endianness	big / Motorola	
	Message/Arbitration ID	0x00000180-0x0000018F	
	DLC	8	
Serial Output	baud rate	9600	bps
	data bits	8	
	parity	None	
	stop bits	1	