MTX-L
Digital Air/Fuel Ratio Gauge
User Manual

⚠️ Warning! ⚠️

The Oxygen Sensor used in this device gets very hot in operation.
Do not touch a hot sensor. Do not let a hot sensor touch a combustible surface.
Do not use the sensor with or near flammable liquids or gases. Failure to heed
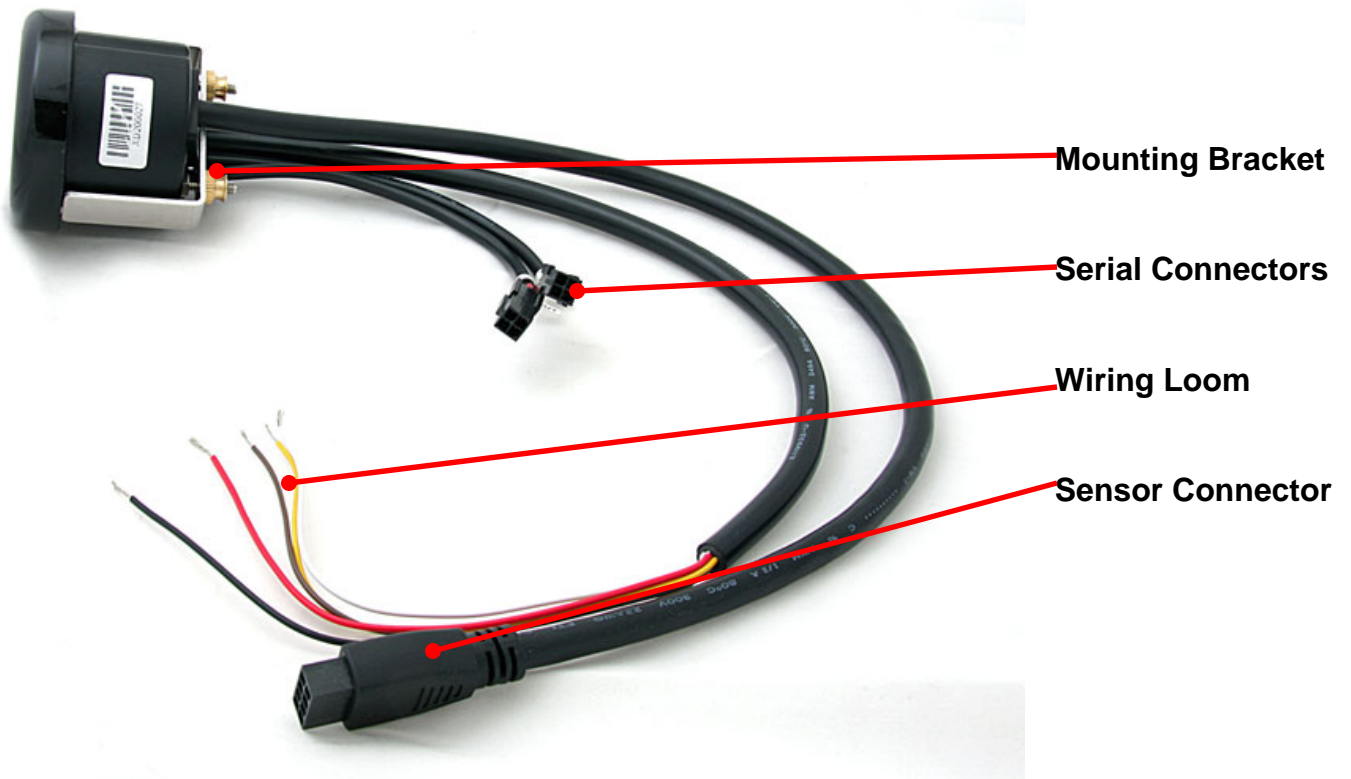these warnings may result in severe burns, explosions, fires, or other dangerous
events.

When installed in the exhaust, the oxygen sensor MUST be connected and
operating with the MTX-L whenever the car is running. An un-powered oxygen
sensor can be quickly damaged when exposed to hot exhaust gases.

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1 MTX-L

The MTX-L is an integrated gauge and controller for wideband AFR (lambda) measurements. Although it can be operated stand alone, it has digital I/O for integration with other MTS compatible products and two configurable analog outputs for integration with ECU's and 3rd party data loggers. The following views will help you get familiar with the unit.

Needle Bar

Status Light

Numeric Display

Mounting Bracket

Serial Connectors

Wiring Loom

Sensor Connector

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2 Installation

2.1 *Wiring*

The MTX-L has 5 stripped wire ends.

1. Connect the **RED** wire to a switched 12V source. A switched 12V source goes on as soon as the ignition on the car is on. Make sure the connection is fused with a minimum fuse size of 3A.

2. Connect the **BLACK** wire to a ground source. Avoid noisy ground sources, such as grounds used for radio and or ignition sources.

3. Connect the **WHITE** wire to a headlight power wire (a wire that supplies current to the headlights). This enables the display to dim for better nighttime viewing. DO NOT CONNECT THIS WIRE TO THE HEADLIGHT DIMMING WIRE. Connection to this rheostat type of switch will cause the gauge to malfunction. If you chose not to utilize the dimming feature, connect the WHITE wire to ground.

4. *Optionally*, the **YELLOW** (Analog out 1) and/or **BROWN** (Analog out 2) can be connected to the analog inputs of other devices such as data loggers or ECUs. If either one or both of these wires are not being used isolate and tape the wire(s) out of the way. The default analog outputs are as follows: Analog output one (yellow) is 0V = 7.35 AFR and 5V = 22.39 AFR. Analog output two (brown) is 1.1V = 14 AFR and .1V = 15 AFR. This is a simulated narrowband signal.

2.2 *Mounting and Routing*

The MTX-L gauge fits in any standard 2 1/16" (52mm) gauge pod. Mounting of the gauge should be done in such a manner that the cables are not being forcefully pulled from the gauge itself. Route the sensor cable avoiding contact with the exhaust pipe and other hot sources that could melt the cable. Also avoid routing the sensor cable near ignition components or other sources of RF (radio frequency) and EMI (Electromagnetic interference) noise.

⚠ The MTX-L gauge is splash resistant (not water proof) and can be mounted so that it is exposed to the outdoor elements. The MTX-L should not be submerged and special consideration should be taken to protect the gauge from direct water spray (water coming from a pressurized source.) When replacing the bezel and/or gauge face verify that the o-ring is properly seated.

2.3 *Sensor Placement*

Your MTX-L gauge kit includes a 1" bung. This bung is supplied to best prolong the life of your sensor since it will allow the sensor to sit flush with the exhaust pipe. Using a bung is the preferred method for mounting the O^2 sensor for both catalytic and non-catalytic cars.

On CATALYTIC CONVERTER equipped vehicles:

Install the oxygen sensor's bung upstream from the catalytic converter (a bung is included in the MTX-L kit). The bung must be installed in the exhaust pipe *at the side or on top, NOT on the bottom* of the exhaust pipe. Any decent muffler or exhaust shop can do this for you. The wide-band oxygen sensor is then installed into the bung to take a reading. The ideal position is between 10:00 and 2:00 position.

On NON-CATALYTIC converter vehicles:

You have the option with non-catalytic cars to also use an exhaust clamp as described below. Use of a bung is the preferred method for mounting the 0^2 sensor for both catalytic and non-catalytic cars.

On TURBO CHARGED vehicles:

Install the bung downstream from the turbo but before the catalytic converter. The high exhaust pressure before the turbo interferes with the lambda measurement and the high exhaust temperatures encountered there can damage the sensor.

Alternatively you can also use the optional exhaust clamp (part number 3728) to sample exhaust gases at the end of the tail pipe.

⚠ Do NOT install the Bung below the 3 o'clock or 9 o'clock position. Condensation can form in the exhaust pipe and permanently damage the sensor. 6 o'clock is the absolute worst position to mount the sensor.

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⚠ Wide band oxygen sensors, like the one shipped with the MTX-L, are designed to work with unleaded gasoline. Use with leaded gasoline will significantly reduce the lifespan of the sensor. The reduction is directly proportional to the metal content of the fuel and the tune of the engine.

⚠ WHEN INSTALLED IN THE EXHAUST, THE OXYGEN SENSOR MUST BE CONNECTED AND OPERATING WITH THE MTX-L WHENEVER THE CAR IS RUNNING. AN UN-POWERED OXYGEN SENSOR WILL BE DAMAGED WHEN EXPOSED TO EXHAUST GAS IF NOT PROPERLY POWERED.

⚠ The maximum temperature of the sensor at the bung (the sensor hexagon) should not exceed 500 ^{o}C or 900 ^{o}F. If these temperatures are exceeded in your application you should install the Innovate Motorsports Heat-Sink Bung extender (P/N 3729 HBX-1).

⚠ It is NOT a good idea to do a sensor prewarm-up prior to starting the engine. Depending on the climate and the sensor position in the exhaust, condensation can form in the exhaust pipes. This condensation could then be blown by the exhaust stream against the hot sensor when the car is started. The resulting heat shock can permanently damage the sensor.

2.4 *Sensor Calibration*

Once the unit has been wired and a suitable location has been found for both the gauge and the sensor it is time to do the sensor calibration. Innovate Motorsports' 'Direct Digital' wideband measurement principal allows you to calibrate the sensor to compensate for sensor wear. This procedure takes just a few moments and it will insure the most accurate readings throughout the oxygen sensor's life. This procedure is required anytime a NEW oxygen sensor is installed.

The calibration procedure requires that the oxygen sensor be in **free air**, not in the exhaust. Important: Just because a vehicle is not running does not mean that the exhaust system is free of gases.

1. With the **sensor disconnected**, apply power to the MTX-L.

When power is applied, all three digits will light up and the needle bar will sweep once through all LEDs. Then the status light will turn red and the numeric display will read "E2". This is an error code, indicating that no sensor is detected. Leave unit powered on for minimum 30 seconds.

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2. **Power down** the MTX-L and attach the oxygen sensor using the cable provided. Again, make sure that the sensor is in **free air (not in the exhaust).**

3. **Power up** the MTX-L.

Again, the display should 'sweep', but instead of an error, the display will display "Htr". This indicates that the sensor is being heated up to operating temperature. After 30-60 seconds, the display will switch from "Htr" to "CAL", indicating that the sensor is being calibrated. A few seconds later, your MTX-L will begin displaying AFR. Since the sensor is in free air, the gauge will default to the upper limit of 22.4.

The calibration procedure has completed and the system is now ready for use.

Important: You can disconnect and reconnect the sensor and sensor cable for installation without losing your calibration. However, if you power up the MTX-L without a sensor connected, **your calibration will be reset** (see step #1 above).

2.4.1 Calibration Schedule

Normally aspirated (daily driver)
- Calibrate before installation of new sensor
- Calibrate new sensor again after 3 month of use
- Thereafter calibrate once a year or every 20,000 miles, whichever comes first

Turbo Application, daily driver (tuned rich)
- Calibrate before installation of new sensor
- Calibrate new sensor again after 3 month of use
- Thereafter calibrate twice a year or every 10,000 miles, whichever comes first

Race Application
- Calibrate before first installation of new sensor
- Calibrate once per race weekend

Dyno use
- Calibrate a new sensor
- Calibrate every 2-3 days, depending on usage

2.5 *Changing the MTX-L's gauge face and/or bezel*

1. Lay the MTX-L face down and remove the three #2 phillips screws from the outside rim of the back plate.
2. Carefully lift out the bezel from the gauge cup.
3. Configure the gauge as desired by changing the gauge face and or bezel.

*Be sure to remove protective film from the gauge face. This can be done easily with a piece of scotch tape.

4. Make sure every piece is positioned correctly using the locating tab and reassemble the gauge.
5. Reinstall the 3 #2 phillips screws.

3 Software (LogWorks 3 and LM Programmer)

3.1 *Installing software*

1. Install the CD that came with your MTX-L on your Windows based personal computer.
2. The installer will automatically start, follow the prompts to install the software.
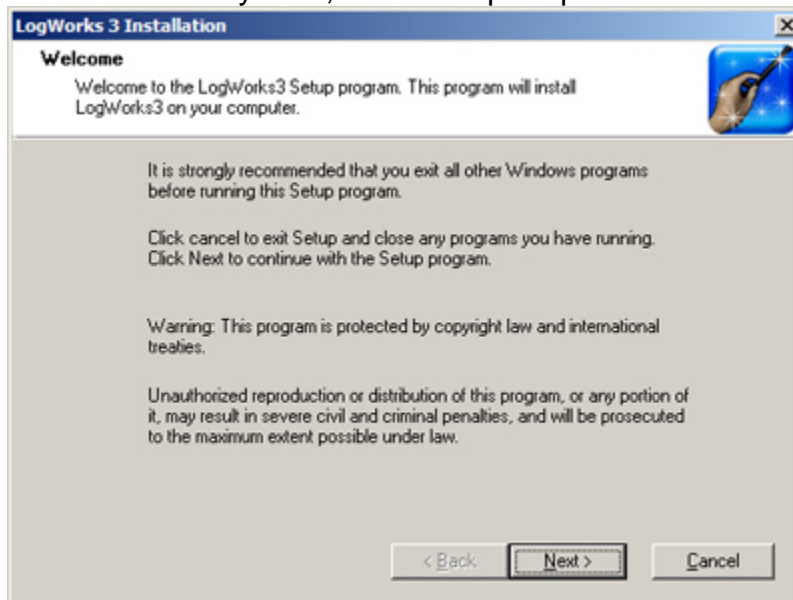
3. Once the software has been installed the LogWorks software, LM Programmer and MTX-L manual can then be located by navigating through Start->Programs->LogWorks3.

3.2 *Connecting to LM Programmer*

LM Programmer is used to update firmware, change fuel types, set display ranges, and program the two analog outputs.

1. Connect the OUT port of the MTX-L to the provided serial programming cable. Connect the other end of the serial programming cable to your computer. If your computer does not have a serial port, you can purchase a USB to Serial adapter

from Innovate Motorsports (P/N 3733) or use any USB to serial adaptor that includes drivers. Make sure that nothing is connected to the IN port of the MTX-L.

2. Power up the MTX-L.
3. Launch LM Programmer. The LM Programmer application can be launched from *Start->Programs->LogWorks3->LM Programmer* from the Windows task bar.

3.2.1 Analog Outputs

1. Connect the MTX-L to the computer and launch LM Programmer.
2. Select one of the Analog output tabs. The Analog output page looks like this:
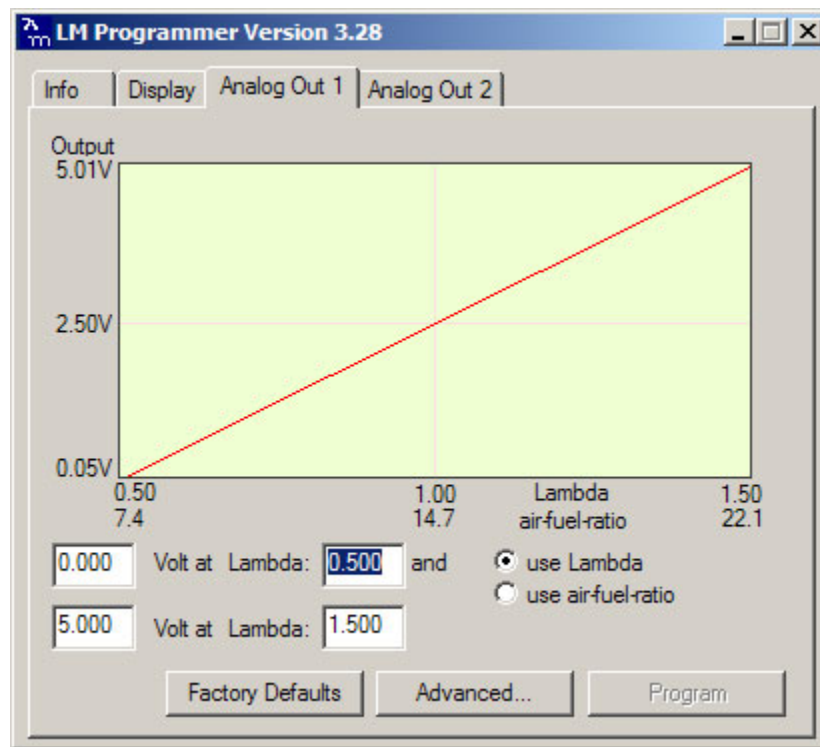
This shows the analog output voltages versus Lambda for one of the two analog outputs. The graph display is automatically scaled to the selected voltages. For each output you can specify a minimum and maximum lambda value and the associated voltages. Below the minimum and above the maximum lambda values the output voltages stay constant at the associated programmed voltage.

By selecting the 'use Air-Fuel-Ratio' button you can program the curve by AFR instead of Lambda. This does not change the programming, only the representation of the data. When programming by AFR the LM Programmer converts the number to Lambda

before programming the MTX-L. So there might be some small 'rounding errors' when you open LM Programmer and review your settings in the future.

Click the 'Program' button to download the new data into the MTX-L. Once the unit is programmed the 'Program' button will grey out.

The analog output can be programmed from 0 to 5 volts and from 1.5 to 8.191 lambda. **Factory Programmed Defaults:**

Analog Output 1 is programmed to output between 0 V for an AFR of 7.35 (gasoline) and 5.0V for an AFR of 22.39. Analog Output 2 simulates a typical narrow band oxygen sensor. The configuration is 1.1 V for an AFR of 14 and .1 V for an AFR of 15.

Other curves, of course, are easily programmable.

3.2.2 Advanced output programming

The 'Advanced' button allows programming to set the analog out update speed and the voltage output during sensor Warm-up and Error Condition. The factory defaults of the analog outputs is to update the outputs 1/12 of a second. The factory default voltage output is set for 0 volts for both the Warm-up and Error Condition.
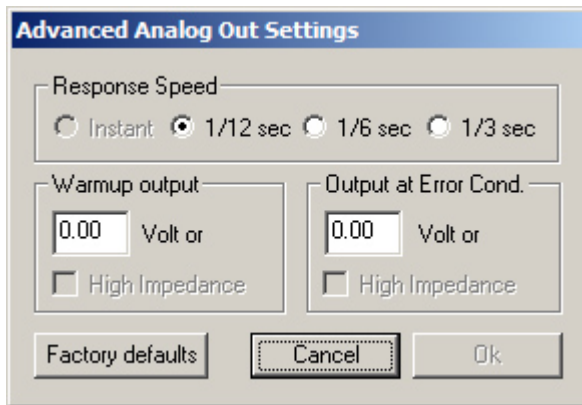

When setting the MTX-L to the slower response speed settings the measured mixture data will be averaged over the response time setting before being output.

3.2.3 Customizing your fuel type

The MTX-L gauge comes pre-programmed to display AFR in the gasoline scale. By connecting the gauge to LM Programmer, fuel type settings for different fuels can be setup. This setting can be found on the lower right hand corner of the Info tab in LM Programmer.

3.2.4 Customizing your display range
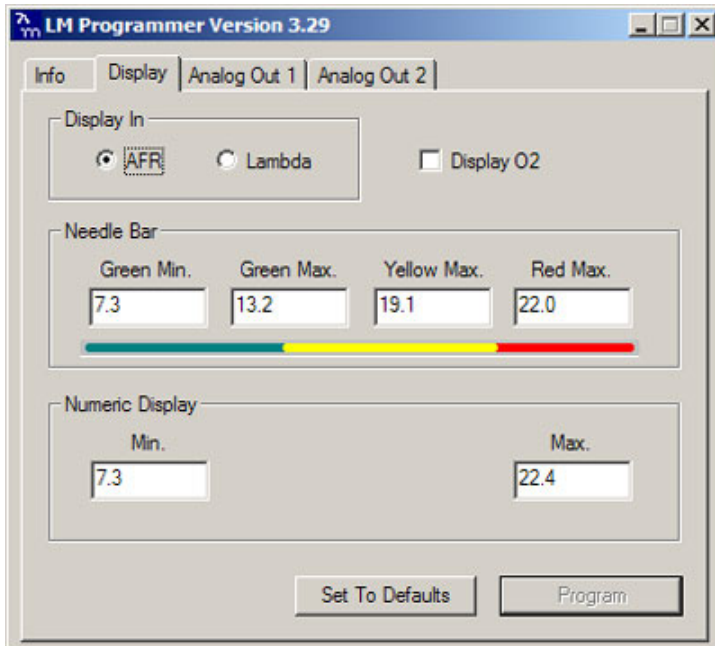
The MTX-L gauge can be setup to display different ranges from both the Needle Bar and the Numeric Display. There is also an option to display lambda or AFR. Lastly, the gauge can be setup to display percentage of Oxygen once the readings go beyond 7 lambda.

3.2.5 Updating the firmware

1. Connect the MTX-L to the computer and launch LM Programmer.
2. Once connected, LM Programmer will display the current version of the firmware that is installed in the MTX-L. Do not update the firmware if the versions are the same. A firmware update should only be necessary if there has been a new release.
3. On the very first tab of LM Programmer you will see a button labeled "Update Firmware," click this button.
4. Select the firmware file with the dld extension. The latest firmware file will be available for download from the Support section of the Innovate Motorsports web site.
5. The software will now prompt you to confirm that you wish to overwrite the firmware currently on your MTX-L.
6. Click OK, DO NOT power off or disconnect the MTX-L from the computer until the firmware progress screen completely disappears. Once finished you may disconnect the unit from the computer and exit out of the software.

3.3 *Logging data from your MTX-L with LogWorks*

1. Connect the OUT port of the MTX-L to the provided serial programming cable. Connect the other end of the serial programming cable to your computer. If your computer does not have a serial port, you can purchase a USB to Serial adapter from Innovate Motorsports (P/N 3733) or use any USB to serial adaptor that includes drivers. Make sure that nothing is connected to the IN port of the MTX-L. Power up the MTX-L
2. Launch LM Programmer. The LM Programmer application can be launched from *Start->Programs->LogWorks3->Logworks3* from the Windows task bar.
3. Once LogWorks launches go to *File->Connect.* You will be prompted to connect to serial COM port. Click Connect.
4. *To start recording go to File->New Realtime Log* or, in the Toolbar, click on the 🔴Tool.

4 Wiring Analog Outputs

The analog outputs on the MTX-L are 'single ended'. That is, each output uses just one wire. It is assumed that the MTX-L and the device it is being connected to are already sharing the same 'ground'. In a vehicle, this is generally true, but there can be small offsets in voltage when devices are grounded to, say, the chassis at different points. You can minimize these offsets by sharing a good, common ground point, or you can adjust for them by configuring the analog output voltages on the MTX-L.

5 Tips, Tricks, & Troubleshooting

5.1 *Air/Fuel and Lambda*

The Stoichiometric AFR value is the AFR multiplier. So for (standard, unblended) gasoline its 14.7. If you set it to 14.7 the MTX-L display will show 14.7 AFR for Lambda 1.0. If you set it to 6.4 (methanol) the MTX-L will show 6.4 AFR for Lambda 1.0.
You can look at Lambda as the percent of richness. If running Lambda 0.85 (12.5 AFR for gasoline) you are running 15% rich. For methanol 15% rich means 5.44 AFR. That's where the value of Lambda comes in. If you run blended fuels where you don't know the stoich value, you look at Lambda and adjust to 10-20% rich, depending where your max power is. The % value of richness required by an engine (for max power) does change relatively little (fairly independent of fuel). But if for example you adjust an engine running methanol to 12.5 AFR, you would be running so lean that it would probably not even run.
The MTX-L can be used to read Air/Fuel Ratio (AFR) or Lambda for an engine. For *gasoline*-driven engines, the theoretically optimal air fuel ratio for efficiency is 14.7 pounds of air for every pound of fuel. At this ratio, theoretically, all available oxygen in the air combines with all available fuel. This ratio is called the stoichiometric ratio. Stoichiometric for different fuels are as follows:

Gasoline   14.7
LPG (Propane)   15.5
Methanol   6.4
Ethanol   9.0
CNG   17.2
Diesel   14.6

The measurement Lambda is the actual air fuel ratio over the stoichiometric ratio. A Lambda measurement of "1" equates to the air fuel ratio of 14.7 (for gasoline engines). When Lambda is less than 1 the engine runs "rich", i.e., unburned fuel exists in the exhaust stream. If lambda is greater than 1 the engine runs lean, i.e., free oxygen (0^2) is present in the exhaust. Depending on the engine, maximum power is typically delivered when the engine runs slightly rich (for example at lambda values of 0.8 to 0.9 for most engines). This instrument provides a means to measure the actual air fuel ratio or lambda in the engine in operation directly from the exhaust. For this a special wide-band oxygen sensor is used to measure the lambda value derived from the oxygen content (or lack thereof) of the exhaust gases.

5.2 *General measurement requirements*

The MTX-L measures the air-fuel-ratio by measuring the amount of oxygen in the exhaust (for lean conditions) or the amount of unburned or partially burned fuel (for rich conditions). You should correct for the following in order to get optimum results from the MTX-L:

1) An exhaust leak will allow oxygen to enter the exhaust stream and therefore will measure leaner than the engine is actually running. For correct measurement, air-leaks in the exhaust MUST be prevented under all circumstances.
2) Missing ignitions (where the air-fuel mixture does not ignite) also pump unburned oxygen into the exhaust and cause the MTX-L to measure lean.
3) The only circumstance where the MTX-L will measure richer than the engine is running is if the pressure in the exhaust tract is excessive (and the engine is running on the rich side to begin with).

5.3 *Vehicles with 'smog-pumps'*

Older fuel injected vehicles with a 'smog-pump' actually inject air into the exhaust stream to aid their catalytic converter in the burn-up of unburned or partially burned fuels. This additional air will make the exhaust look leaner than the engine is running. For an accurate measure, install the MTX-L sensor up-stream of the outputs of the smog-pump. If this is not possible, temporarily disable the smog-pump by removing its drive belt.

5.4 *Single Cylinder Engines*

These kinds of engines are difficult to measure at the tail-pipe using an Exhaust Clamp. The oscillations of the exhaust gas are so large that a lot of outside air enters the exhaust and prevents correct measurement. Sometimes it helps to temporarily wrap a piece of heat resistant cloth around the exhaust clamp to prevent outside air from entering the exhaust.

5.5 *Diesel Engines*

Diesel Engines and gas turbines run at wide open throttle at all times. They do not have a throttle but regulate power by the amount of injected fuel. The MTX-L can still be used, but measurements at idle will read as lean.

5.6 *Connecting the MTX-L to simulate a narrow band oxygen sensor*

It is possible to install the wide-band sensor in place of the OEM oxygen sensor. In this case the meter's analog output signal will replace the OEM oxygen sensor's signal to the fuel injection computer. *Note: Please review your analog output settings; the configuration for a narrowband is 1.1 V for an AFR of 14 and .1 V for an AFR of 15.*

EFI equipped cars typically incorporate a narrow band oxygen sensor. These sensors are typically 1, 2, 3 or 4 wire sensors. Some vehicles are equipped with oxygen sensors that do not produce an output voltage but change their resistance depending on exhaust gas content. These sensors cannot be simulated. They are used in less than 1% of all vehicles. Refer to your vehicles specifications if you think that your vehicle may be in this category. The same is true for vehicles already factory equipped with a wide-band oxygen sensor. These cannot be simulated either.

Some EFI-computers will create a fault when the heater power wires of the oxygen sensor are disconnected. In this case mount the old oxygen sensor in a safe place (but not necessarily in the exhaust) and connect the heater wires to it to keep the EFI-computer happy.

⚠ Be careful where you mount the stock sensor, as heated sensors will get hot.

To connect the MTX-L to the EFI-computer, first determine what kind of narrow band sensor is used, then follow the instructions below (you will need a digital multimeter to determine correct OEM sensor wires):

a. Vehicle has a 1-wire sensor:
Wire analog output 1 directly to the wire.

b. Vehicle has a 2-wire sensor:
While the engine is off determine which of the 2 wires has a low resistance between the wire and the sensor body. This is the heater power for the sensor. Wire analog output 1 directly to the other wire. Leave the heater power wire unconnected but make sure it cannot ground itself.

c. Vehicle has a 3-wire sensor:
Typically the 3 wires are: heater power, Ground, and sensor element connection. Generally they have 1 black wire and 2 white wires. Connect the black wire from the EFI computer to analog output 1 of the meter. Leave the other wires unconnected but make sure they cannot contact any metal parts or see above. If the wiring colors are different, then heater power can simply be determined by measuring the voltage on the wires when the engine is running. The wire showing 12V or more is the heater power. The sensor element connection voltage fluctuates around 0.45V when the car is warmed up.

Wire analog output 1 directly to this wire. The Ground connection has low resistance to chassis ground (less than 1 Ohm). Measure while the engine is off.

d. Vehicle has a 4-wire sensor
Typically the 4 wires are: heater power, heater ground, sensor ground, and sensor element connection. Proceed as for the 3-wire sensor.

Appendix A: Specifications

Power
Power requirements   8-18 Volt / 2 A (max, 1 A nominal)
Serial Communication
Serial Port Speed   19.2 kbit/sec
Packet/Logging Speed   81.92 msec/sample packet
Sample Resolution   10 bits (0..5V at 0.1% resolution)

Mechanical
Hole Size   2 1/16" (52mm)

Software
Supported OSs   Windows 98, ME, 2000, XP, and Vista

Temperature
Max Operating   -20 to +85 deg Celsius
Temperature

Appendix B: Limited Warranty

LIMITED WARRANTY
Innovate stands behind the quality of its products. Innovate makes the following warranty to purchasers of its products: All new Innovate products carry a one year warranty from the date of purchase. If proof of purchase cannot be provided, warranty will be determined by date of manufacture.

When Warranty Void
This warranty shall terminate and Innovate shall have no obligation pursuant to it if (i) your Innovate product has been modified or repaired in a manner not previously authorized by Innovate in writing, (ii) the identification markings on your Innovate product have been removed, defaced, or altered; (iii) your Innovate product was subjected to accident, abuse, shipping damage, or improper use; (iv) your Innovate product was not used or configured as specified in the product manual; or (v) your Innovate product was subjected to operating conditions more severe than those specified in the product manual.

Exclusions From This Warranty
Oxygen Sensors are excluded from this warranty.

Repairs Under This Warranty
In the unlikely event that your Innovate hardware product should prove defective during the warranty period, contact Innovate Customer Support at www.innovatemotorsports.com for a return material authorization (RMA) or at (800) 348-3037. Products returned for service must be securely packed to prevent damage and shipped charges pre paid, along with proof of purchase and the return material authorization number, to the Innovate repair location as instructed by Customer Service. Innovate within a reasonable amount of time from its receipt of your product so shipped, will ship to you, at its option, the repaired product or a new or reconditioned product of comparable or greater specified functionality. All repaired or replacement products shall be warranted for the remainder of the original product warranty.

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Appendix C: Connectors

1. Sensor

Pin	Use
1	IPUMP+
2	SENSE/PUMP-
3	SHTR
4	VBAT
5	SENSE+
6	SHIELD GND
7	SHTR
8	VBAT

2. Power and Analog Cable

3. Serial Out

Pin	Use
1	RX
2	TX
3	GND
4	GND

4. Serial In

Pin	Use
1	TX
2	RX
3	GND
4	*MTS Sense

Appendix E: Error Codes and Troubleshooting Tips

Error Code	Error Message	Likely Root Cause	Fix
Error 1	Heater circuit shorted	1. Short in cable 2. Short in sensor	1. Repair/replace cable. 2. Replace sensor.
Error 2*	Heater circuit open	1. Damaged sensor cable. 2. Cable connector not fully seated 3. Sensor Damaged	1. Inspect sensor cable for rips or tears. 2. Verify Sensor is fully seated into connector, make sure it 'clicks.' 3. Replace Sensor
Error 3	Pump cell circuit shorted	1. Short in sensor cable 2. Short in sensor 3. Sensor overheating 4. EGT >1700º F	1. Repair sensor cable. 2. Replace sensor. 3. Move your sensor bung as far downstream as possible OR add a heatsink to isolate the sensor from the pipe.
Error 4	Pump cell circuit open	1. Damaged sensor cable. 2. Cable connector not fully seated 3. Sensor Damaged	1. Inspect Sensor cable for rips or tears. 2. Verify Sensor is fully seated into connector, make sure it 'clicks.' 3. Replace Sensor
Error 5	Reference cell circuit shorted	1. Short in sensor cable 2. Short in sensor	1. Inspect sensor cable for rips or tears. 2. Replace sensor.
Error 6	Reference cell circuit open	1. Cable connector not fully seated 2. Damaged sensor cable 3. Damaged Sensor	1. Verify Sensor is fully seated into connector, make sure it 'clicks.' 2. Inspect sensor cable for rips or tears. 3. Replace sensor
Error 7	General System error (typically a software error).	Software error	Reboot MTX-L by cycling power. Reload firmware if necessary.
Error 8	Sensor Timing error (typically a damaged sensor).	1. Sensor overheating. (The Bosch LSU4.2 is rated to operate at a sensor housing temperature of < 900 degrees (measured at the bung) for maximum accuracy and control. When this operating temperature range is exceeded, the sensor can no longer be accurately controlled.) 2. Sensor is damaged 3. Overly Rich condition	1. a. Perform sensor heater recalibration; b. Move your sensor bung as far downstream as possible. Right before the cat, or 2-3 feet from the end of the tailpipe are good locations; c. Add a heatsink to isolate the sensor from the pipe. The HBX-1 is an available accessory. 2. Replace sensor. 3. Correct Tune and recalibrate the sensor.
Error 9	Supply Voltage too low	Supply voltage too low for sensor regulation	Check your 12V connection for corrosion.

* Whenever Error 2 is displayed, existing sensor calibration data is discarded.

Revision History

1.0 11/18/10
Initial Release

1.1 12/17/10
Added analog output configuration, Bezel/gauge face installation, and new screenshot for customizing the range display.