

MD[®]
MUSTANG
D Y N A M O M E T E R

LM-1 Digital Air/Fuel Ratio (Lambda) Meter Manual

9/03/03



Warning!



The Oxygen Sensor used in this device gets very hot in operation. Do not touch the 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 or fires.

When installed in the exhaust, the oxygen sensor **MUST** be connected and operating with the LM-1 whenever the car is running. An un-powered oxygen sensor will be quickly damaged when exposed to hot exhaust gases.

Table of Contents

| | |
|---|----|
| Table of Contents | 2 |
| 1. Overview | 3 |
| 2. The LM-1 Instrument | 3 |
| 2.1. The LM-1 Instrument (included)..... | 3 |
| 3. First Time Use | 5 |
| 4. Installation..... | 6 |
| 4.1 Mounting the sensor | 6 |
| 5. Operation | 7 |
| 6. Calibration..... | 7 |
| 7. Recording other vehicle data with the LM-1 | 8 |
| 7.1 Overview | 8 |
| 7.2 Recording..... | 8 |
| 8. Remote display of Lambda and/or AFR | 8 |
| 8.1 Analog Lambda/AFR instrument..... | 8 |
| 8.2 Special considerations when installing LM-1 permanently in the vehicle..... | 9 |
| 9. Programming the LM-1..... | 10 |
| 9.1 Installing the LM-1 Manager Software | 10 |
| 9.2 Hooking up the LM-1 device to the computer..... | 10 |
| 9.3 Resetting the calibration data | 11 |
| 9.4 Updating the software | 11 |
| 9.5 Changing the sensor type..... | 12 |
| 9.6 Programming the analog outputs..... | 13 |
| 9.7 Downloading recorded data..... | 14 |
| 10. Tips, Tricks and Troubleshooting | 18 |
| 10.1 General measurement requirements..... | 18 |
| 10.2 Vehicles with 'smog-pumps' | 18 |
| 10.3 Measuring at the tail-pipe | 18 |
| 10.4 Single Cylinder Engines..... | 18 |
| 10.5 Diesel Engines | 18 |
| 10.5 Reference cell or Pump cell circuit open or shorted errors | 18 |
| 10.6 Sensor Timing Errors..... | 19 |
| 11 Advanced Topics | 20 |
| 11.1 Connecting the LM-1 to simulate a narrow band oxygen sensor..... | 20 |
| 11.2 Using a Serial Remote LCD Display..... | 21 |
| Appendix A: LM-1 Accessories | 22 |
| Appendix B: LM-1 Cable Pinouts | 25 |
| Appendix C: LM-1 error codes | 28 |
| Appendix D: Limited Warranty..... | 29 |
| Revision History..... | 30 |

1. Overview

The LM-1 is a hand-held instrument used to measure the Air/Fuel Ratio (AFR) or Lambda for an engine. For gasoline-driven engines, the theoretically optimal air fuel ratio 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.

The measurement Lambda is the actual air fuel ratio over the stoichiometric ratio. When Lambda is less than 1 the engine runs rich. If lambda is greater than 1 the engine runs lean. 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.

2. The LM-1 Instrument

The LM-1 set contains the following parts:

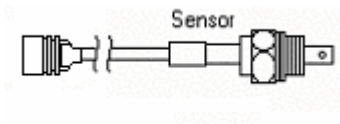
2.1. The LM-1 Instrument (included)

Size: 7" x 4" x 1.5"

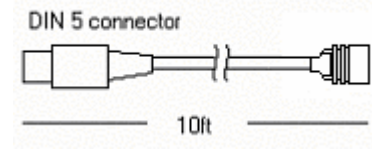


2.2 Included cables and devices

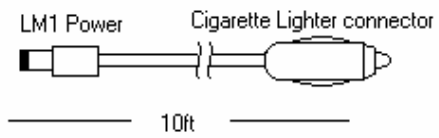
Oxygen Sensor



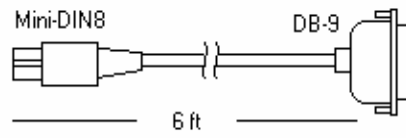
Sensor Cable



Power cable



Serial Cable



Also included:

9V Battery
Bung/Plug set

3. First Time Use

1. Install the included 9V battery in the battery compartment on the bottom of the instrument.
2. Connect the power cable to the 12V Power connector and plug the other end in your cigarette lighter socket in your car. Note that the 9V battery is for powering the LM-1 electronics and display, but it cannot power the oxygen sensor. You must have a 12V power supply available to power the oxygen sensor.
3. **Do not connect the sensor yet.**
4. Switch the meter on.

The display shows either:

**Error 02
Heater open**

when connected to 12V Power, or

**No Sensor Power
Connect 12V PWR**

In the second case, switch the ignition of your car on.

5. Switch the meter off after 10 seconds.
6. Connect the sensor to the sensor interface connector. The sensor must be exposed to air for the first time calibration.
7. Switch the meter on. The display should show now:

**Warming up
57.6% Bat 13.1V**

Indicating that the sensor is warming up to its optimum operating temperature. The display shows what percentage of the temperature is reached and what the battery voltage is that the meter sees on the power connector. The warm-up period will last for about 30 seconds for a cold sensor, depending on the sensor type used.

After the sensor is warmed up the meter automatically calibrates the sensor heater controller to the particular sensor. During this 20-second period the LM-1 collects and calculates sensor specific data required to quickly reach operating temperature in the future. After the first time use the meter will use these values to regulate the sensor's temperature. During the heater calibration the display will show:

Calib Htr 9

Counting to 0. After that the display will show:

Calibr. needed

Note: When using the Bosch Sensors the LM-1 may perform multiple calibration passes. This is normal and need not cause concern. When it completes, continue to step 8.

8. Press the Calibration button.

The meter will now calibrate itself by using air as a reference gas with a known oxygen content. After the calibration period is over (2-3 seconds), the instrument is ready to operate.

4. Installation

4.1 Mounting the sensor

On non-catalytic converter vehicle:

After the instrument is calibrated, and the vehicle's engine is warmed up, readings can be taken from the engine's exhaust. A probe clamp is required if the vehicle will be in motion (not just on the dyno), and is recommended even when the vehicle is stationary. The oxygen sensor needs to have the back part of the sensor (where the wires enter the sensor) exposed to outside air to yield the most accurate results.

On catalytic converter equipped vehicles:

For those vehicles it is typically necessary to have a qualified muffler shop install a second oxygen sensor bung upstream from the catalytic converter (included). The wide-band oxygen sensor will be installed there. Plug the sensor bung when not in use (plug included). The sensor must be installed in the exhaust pipe at the side or in the top.



Do NOT install it below the 3 o'clock or 9 o'clock position. Condensation can form in the exhaust pipe and permanently damage the sensor.

On turbo charged vehicles:

Install the sensor downstream from the turbo 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.



Wide band oxygen sensors – like the one shipped with the LM-1 -- cannot tolerate leaded gasoline and will be permanently damaged after a short period of use. Do NOT use the LM-1 with engines that burn leaded gasoline.

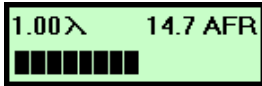


WHEN INSTALLED IN THE EXHAUST, THE OXYGEN SENSOR MUST BE CONNECTED AND OPERATING WITH THE LM-1 WHENEVER THE CAR IS RUNNING. UN-POWERED OXYGEN SENSOR WILL BE QUICKLY DAMAGED WHEN EXPOSED TO HOT EXHAUST GASES.

5. Operation

Once the LM-1 has been installed and is in place (see Chapter 4: Installation), lambda measurements can be taken.

In operation the meter's display shows:



Showing the current lambda value and air-fuel-ratio. The numeric lambda and air-fuel-ratio values are averaged over about 0.2-0.3 seconds so that the numbers are more consistent and easy to read.

If lambda is bigger than 6 (example free air), the display shows the oxygen content of the measured gas instead of AFR.

The bar-graph at the bottom shows the actual instant lambda value in 16 steps. The more of the bar showing, the richer the mixture. The bar at mid-level means a lambda value of 1.0 (AFR of 14.7 for gasoline). If the whole bar shows, the actual lambda value is 0.68 or richer (AFR of 10 or less for gasoline). If none of the bar shows the lambda value is 1.32 or leaner (AFR 19.4 or more for gasoline).

6. Calibration

To achieve maximum precision the LM-1 and its sensor needs to be recalibrated frequently. When the measured lambda is bigger than 6, the display will show the oxygen content of the measured gas in %. For free air it should show 20.9%. If the display value is different by more than 0.6%, recalibrate. You can test the oxygen sensor by breathing on it. The oxygen content of your breath will show.

The sensor **MUST** be operated in free air for calibration.

If the wide-band sensor is installed in a vehicle, wait 6-8 hours after running the engine so that all exhaust gas is dissipated from the exhaust tract of the vehicle. Otherwise, disengage the oxygen sensor and expose the sensor to air (away from the exhaust) for calibration purposes

1. Connect the meter to 12V from the vehicle and switch it on.
2. When the sensor is warmed up, quickly press and release the '**Calibrate**' button.
3. After the calibration is complete, switch the LM-1 off and wait for 30 seconds before you start the car.

The display will show "Free Air Calibr." while it calibrates itself. When the calibration procedure is finished (2-3 seconds) the display returns to normal showing lambda and oxygen content. If the oxygen content now differs from 20.9% by more than 0.6%, repeat the calibration.

When the sensor is changed – either with a replacement sensor or a new type of sensor –, the heater circuit of the LM-1 needs to be recalibrated as well. Follow the steps in chapter 3 'First Time use'. The heater calibration data in the LM-1 will be reset when the meter is operated from 12V without a sensor connected for at least 2 seconds.

7. Recording other vehicle data with the LM-1

7.1 Overview

The LM-1 has the capability to record other vehicle data from other vehicle sensors while driving so as to compile a complete log of engine data. The AUX input connector of the LM-1 allows connecting up to 5 other sensors to the LM-1 whose data values will be recorded. The optional AUX sensor cable for the LM-1 plugs into the side of the LM-1 instrument and has 5 clips to hook up to the other sensors.



Never connect the Aux inputs to 12 volt or battery power. Connecting the inputs to sources that generate greater than 5 volts will result in damage to the LM-1.

The LM-1 simply records the voltage on each input connection with a resolution of 10 bits (a precision of 0.00488 Volt). LM-1 will record up to 44 minutes of data from all sensors including lambda. A new value for each sensor is recorded every 0.08125 seconds (roughly 12 times/second). The recorded data can be later downloaded into a Microsoft Excel spreadsheet or graphed and analyzed by the included software. To download the recorded data into an Excel spreadsheet see chapter 9.7, 'Downloading recorded data'. Software to view and analyze recorded data log files can be downloaded at www.mustangdyne.com

7.2 Recording

To record data in the LM-1, press the **'Record'** button. The LM-1 will show on its display a blinking 'R' between the lambda and AFR/O2 display while recording. To stop recording, press the **'Record'** button again. Each time you start recording a new record 'Session' is created. A total of 44 minutes of data can be recorded in the LM-1. If the internal memory of the LM-1 is full, the blinking 'R' will not show when starting a recording session. Instead it will show an 'F' for 'Full' for a few seconds. To erase all recorded data, press and hold the **'Record'** until 'FR' (for flash reset) shows between lambda and AFR/O2 display. To download the recorded data into an Excel spreadsheet see chapter 9.7, 'Downloading recorded data'. Software to view and analyze recorded data log files can be downloaded at www.mustangdyne.com

8. Remote display of Lambda and/or AFR

In some applications it may be desirable to mount the LM-1 in the engine compartment or under the dash permanently and monitor the air-fuel data remotely using a dash-mounted instrument. The LM-1 provides two options for that application.

8.1 Analog Lambda/AFR instrument.

There are many analog lambda/AFR displays on the market. They are essentially voltmeters for a voltage between 0 and 1 V and measure the analog voltage of a narrow band oxygen sensor. Some are true analog instruments while others provide a LED bar. Because of the very limited sensing range of a narrow band sensor they are essentially useless as true AFR meters. LM-1

allows these instruments to be used as true remote AFR or lambda meters. Connecting these meters to the second analog output of the LM-1 allows to use them as true remote AFR meters, provided the LM-1 analog output is programmed to the characteristics of the used meter. The LM-1's second analog output is factory programmed to provide a linear output between 1V and 2V for an AFR of 10 to 20, allowing using a digital voltmeter as AFR display. Any other linear output range between 0 and 5V can be programmed. See chapter 9.6, 'Programming analog outputs' for details.

8.2 Special considerations when installing LM-1 permanently in the vehicle

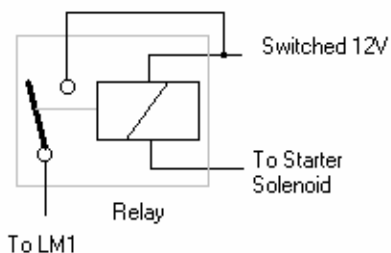


Do NOT install the 9V battery in the LM-1 when installing it permanently in the vehicle.

In a typical permanent installation the LM-1 will be powered by switched 12V from the vehicle (12V switched on when the ignition key is turned on) while its power switch is permanently on. Because LM-1 automatically switches to internal battery power when it does not detect 12V, the internal battery would drain quickly while the vehicle is parked. To avoid this, do not install the 9V battery. The LM-1 will function correctly without it and will be able to record as usual. To download recorded data, follow the alternate steps described in chapter 9.

It is NOT a good idea to connect the LM-1 permanently to 12V and switch it on before the vehicle is started. The sensor would heat up to its operating temperature. Depending on the climate and the sensor position in the exhaust, condensation water can form in the exhaust pipes. This condensation water 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.

To further protect the LM-1 when installed permanently it is a good idea to power it up only after the car is started. The starter motor in some vehicles can create voltage spikes of over 100V that have the potential to do damage. Although rare, this is a real possibility and the LM-1 contains protection circuitry to guard against it. A relay connected as shown below insures that the LM-1 is disconnected while cranking. This reduces further drain on the car battery by the sensor heater and protects the LM-1 against abnormally large voltage spikes.



Connect one terminal of the relay switch and relay coil to switched 12V (number 15 on European cars). Connect the other switch terminal to the 12V input of the LM-1. Connect the other end of the relay coil to the starter solenoid wire (number 50 on European cars). When the starter solenoid is operated, the relay will switch off. In running condition the relay coil current will flow from 12V through the starter solenoid to ground. The relay coil current is normally far too small to operate the starter solenoid.

9. Programming the LM-1

The LM-1 is programmable with the following functionality:

1. Change the relationship between Lambda and AFR.
2. Upgrade and change the software.
3. Switch between sensor types.
4. Change the output characteristics of the Analog outputs.
5. Download recorded data into a spreadsheet.
6. Graph and analyze the recorded data.

9.1 Installing the LM-1 Manager Software

Put the included CD in your CD-drive on your computer and follow the instructions on screen. The LM-1 Software will be installed including pre-set directories for log-data and download software.

The LM-1 Installer also puts entries for the LM-1 Software in the Start-Menu of your computer under the heading 'Innovate!'.

Two version of the Software will be installed:

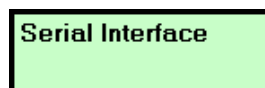
1. LM1 Manager Demo
2. LM1 Manager

The difference between the versions is that the Demo Version does not require the LM-1 to be hooked up to the computer via a serial port. It simulates a connected LM-1 instrument.

9.2 Hooking up the LM-1 device to the computer

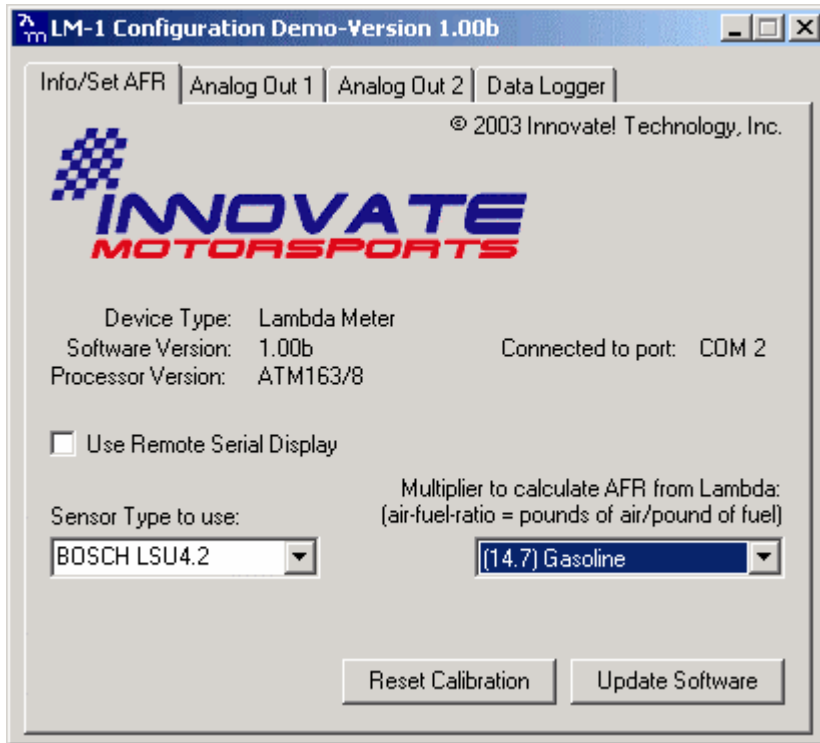
- Connect the included serial download cable to a free serial port on your computer.
- Connect the round Mini-DIN8 connector to the serial port of the LM-1.
- Start the LM-1 Manager
- Switch on the LM-1 Instrument.

The LM-1 display shows:



The LM-1 will stay in serial mode until it is switched off, either by its power switch or by disconnecting 12V if no internal battery is installed.

Your screen should look like this:



On this page you can see the software version of the LM-1, which sensor your LM-1 uses and you can change the multiplier to calculate AFR from Lambda. A number of different multipliers are already pre-selectable but you can change it to a custom one for the particular fuel you are using.

9.3 Resetting the calibration data

Press the Reset Calibration button if you want to reset all calibration data in the LM-1. This will clear all calibration data of the LM-1.

9.4 Updating the software

Click the 'Update Software' in the main page. Update software for the LM-1 has the extension dld. You can download the latest LM-1 software from the Mustang Dynamometer web-site at

www.mustangdyne.com

If your computer crashes during a download, the LM-1 has a recovery mechanism where it will be able to retry the download again and not be disabled by half loaded software. Switch the LM-1 off and on again and then try to restart the LM1 Manager software. The recovery mechanism is designed to be able to recover 99.9% of the time. While we don't anticipate this occurring, it is possible that the LM-1 will not recover correctly and may need to be serviced at our factory. If you suspect this is the case, contact Mustang support.

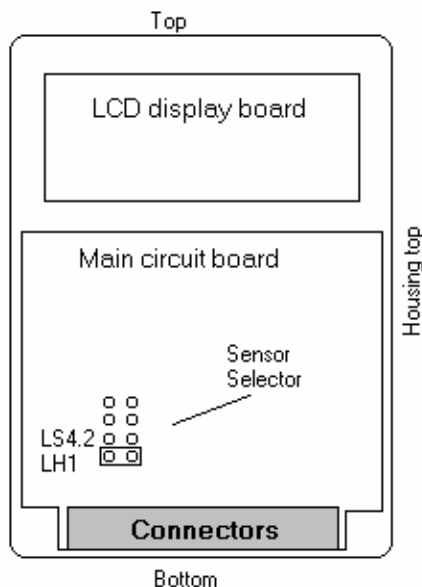
9.5 Changing the sensor type

The LM-1 device is compatible with the following sensors:

| Device Name | OEM Part Number |
|---------------|-------------------|
| Bosch LSU 4.2 | 0 258 007 057/058 |
| Bosch LSU 4 | 0 258 006 066 |
| NTK L1H1 | L1H1 |

To switch a LM-1 to a different sensor type, follow these steps:

1. Select the sensor type to use in the Info/Set AFR Tab of the LM1 Manager and let the LM1 Manager download the appropriate software into the LM-1
2. Disconnect all cables from the LM-1 and remove the 9V battery.
3. Open the LM-1 housing by removing the 4 screws holding the housing bottom to the housing top.
4. Carefully separate the two housing parts. Be careful not to stretch and break the battery cable.
5. On the main circuit board in the top housing part, locate the 8 pin sensor selection header.
6. Move the jumper to the appropriate position for your new sensor. See picture below.

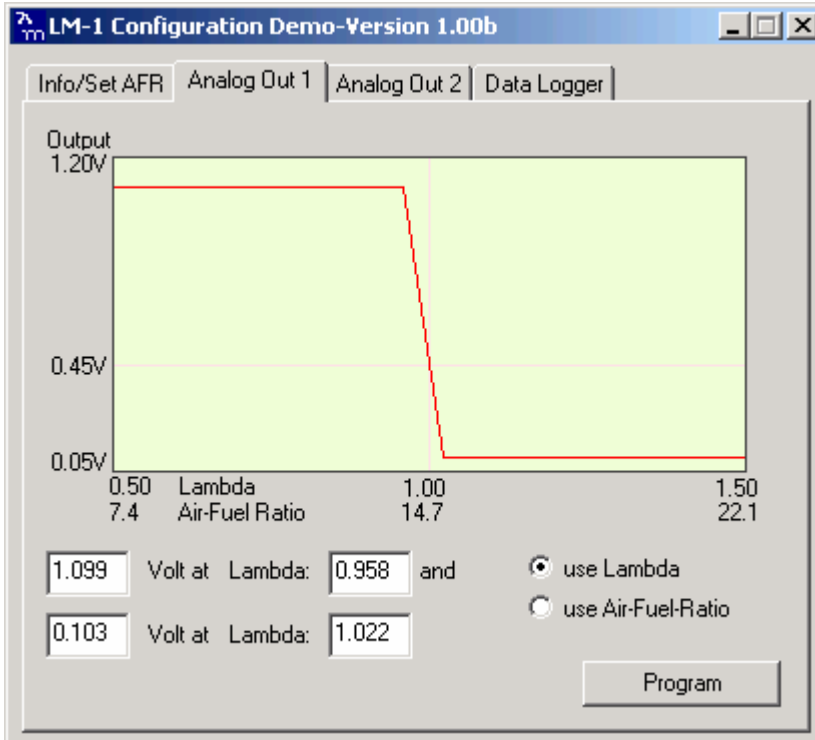


The jumper in this picture is shown installed for the NTK L1H1 sensor.
 The second position from the bottom is for the BOSCH LSU4.2 and LSU 4 sensor.
 The remaining two positions are reserved for future sensors.

7. Reassemble the LM-1, reinstall all cables and the 9V battery if desired.
8. Follow the steps in Chapter 3: First Time Use .

9.6 Programming the analog outputs

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.

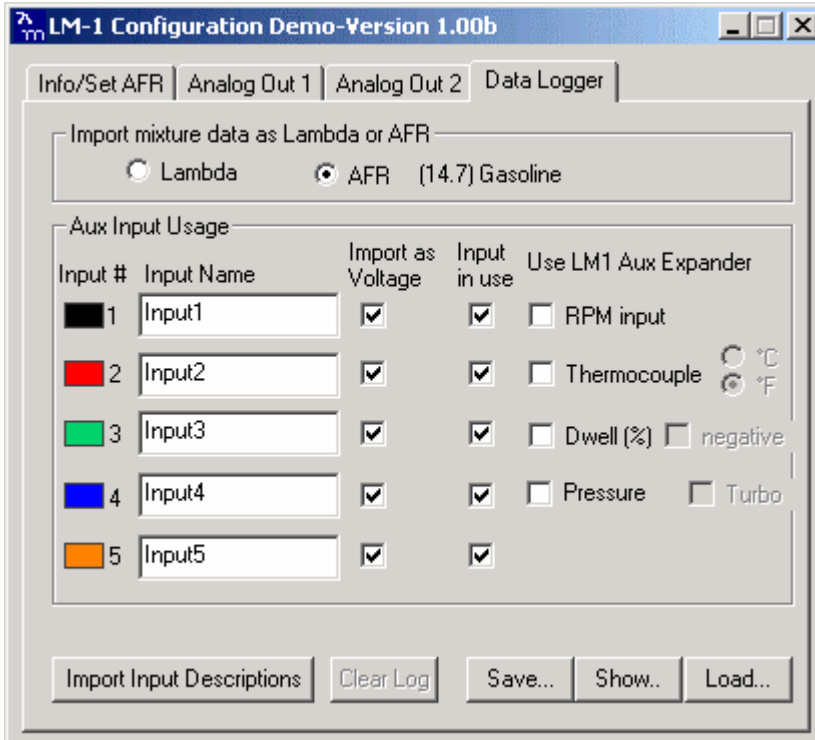
By selecting the 'use Air-Fuel-Ratio' button you can program the curve by AFR instead of Lambda.

Click the Program button to download the new data into the LM-1.

As factory programmed the first output simulates a typical narrow band oxygen sensor. The second output is programmed to output between 1.0 V for an AFR of 10 (gasoline) and 2.0V for an AFR of 20. This allows to connect it to a digital voltmeter or panel meter (0..2V input) to show directly AFR. Other curves of course are easily programmable

9.7 Downloading recorded data

Select the 'Data Logger' tab.
The download page appears:



This display is organized in 6 columns.
The two rightmost columns are used only if you hooked up the optional LM-1 Aux expander module. See details how to use them in the LM-1 Aux expander manual.

The column from left to right:

1. Input trace color.

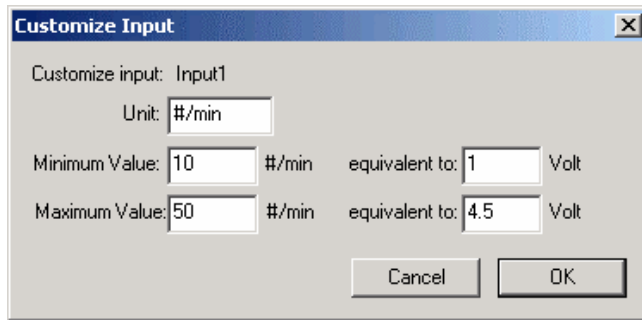
The Inputs are color coded on the AUX input cable. The same color is also used in the traces for the data graph described below.

2. Input Name

Each Input can be renamed into a meaningful name (like TPS, MAP, MAF, CT, IAT) and so on.

3. Import Unit

When checked, the input data is imported as voltage (0-5V) or as sample data (0..1023). Right click on the check mark to customize the interpretation of the input data. The customization dialog box allows you to set the unit value to use (for example pound/min for a MAF sensor), the minimum value the sensor puts out at what voltage and the Maximum value the sensor puts out. See below:



The scale will be automatically expanded to a 0-5V scale. Clicking the check mark in this column switches the input back to either voltage or sample data mode.

4. Input in Use

Check the button if this input is actually hooked up. The LM-1 will record from each input regardless if the input is actually connected to something or not. If it is not used, this check mark allows you to prevent it to be included in the graph, printout or in the saved data file.

9.7.1 Loading and Saving Log Data

Click the 'Load' button to either download LM-1 Log data or re-load a previously recorded log file. The log file data format is compatible with the DIF file format that most spreadsheet programs are compatible with. Each log data file starts with a header that describes the usage of the inputs. To save log data from the LM-1, press the 'Save' button.

9.7.2 Importing Input Descriptions.

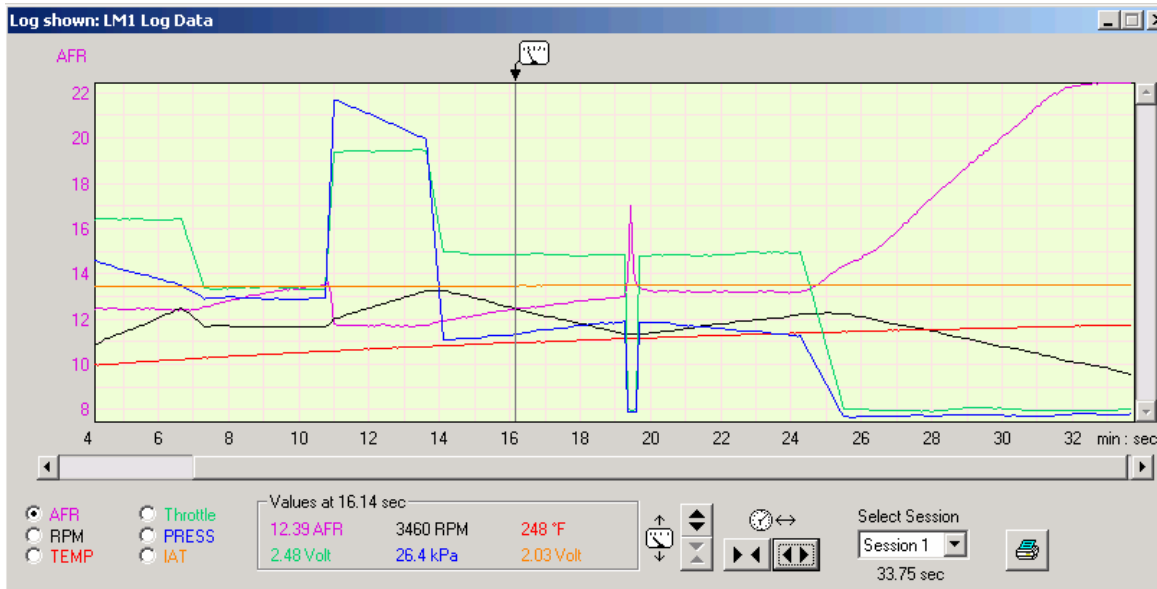
As a convenience the input settings from a previously saved log file can be quickly re-loaded using the 'Import Input Descriptions' button. This saves you from re-entering all the input settings.

9.7.4 Resetting the log in the LM-1.


This button is grayed out if no log data is present in the LM-1. Pressing it clears the log data in the LM-1 unit.



9.7.5 Graphing the log data.

Click the 'Show' button. The log data will be shown as graph as in the following display:



Select the vertical scale for the input of interest by clicking on the appropriate input selection button in the lower left hand corner of the graph window. You can hide or show a trace by right-clicking on the appropriate input selection button.

Change the time scale by pressing the  buttons.

Change the vertical scale of the vertical scaling of the selected input by pressing the  or  buttons.

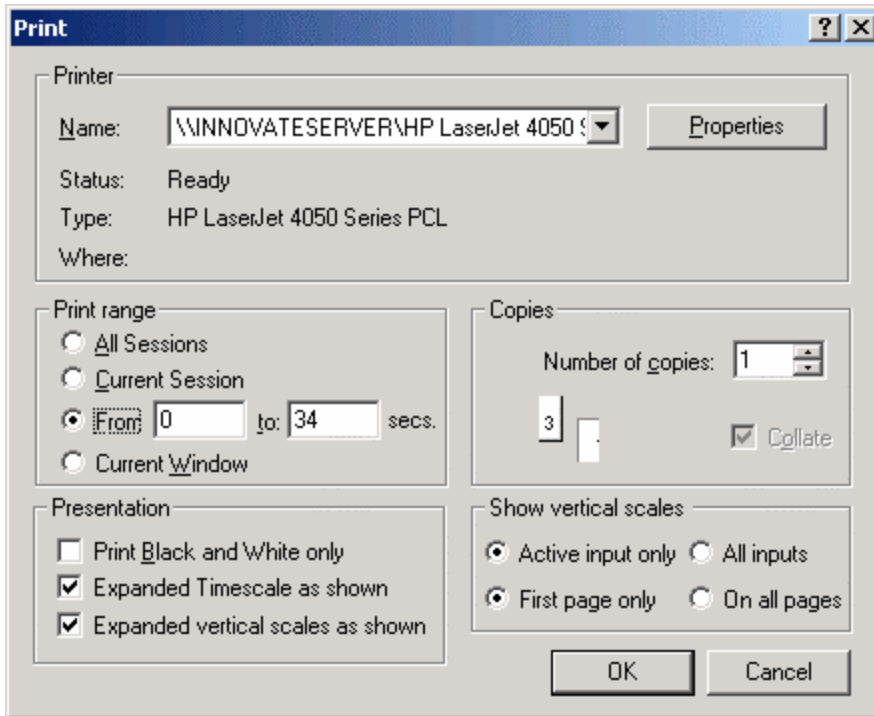
If there is more data that can be shown on the screen you can scroll it into view using the scrollbars or by dragging the graph. If a portion of the trace is either above or below the window you can quickly scroll it into view by right-clicking at the appropriate time in the graph in which you are interested.

Right click on the vertical scale to quickly switch between inputs of interest.

The measurement icon above the graph can be moved anywhere within the graph window to exactly measure the different inputs at the selected point in time.

9.7.6 Printing the log data graph.

To print a graph press the  button. The printer dialog appears:



This dialog is divided into four sections:

In the 'Printer' section select the printer to use. Usually you do not need to touch this section.

The 'Print range' section allows you to select the time range you want to print.

The 'Presentation' section allows you to select if you want to show the time-scale or vertical scales for each input expanded as in the window or at their normal scale.

Check the 'Print Black and White only' button if you do not print on a color printer.

The 'Show vertical scales' section allows you to select if you want to show the vertical scale on the left of the graph on every page or only on the first one, or if you want to show the scales for all traces or only for the input-of-interest trace. The input-of-interest trace (the one currently selected in the graph display) will always be shown next to the graph and the grid-lines represent divisions of that trace.

10. Tips, Tricks and Troubleshooting

10.1 General measurement requirements

The LM-1 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. 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.

Missing ignitions where the air-fuel mixture does not light up also pump unburned oxygen into the exhaust and cause the LM-1 to measure lean.

The only circumstance where the LM-1 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.

10.2 Vehicles with 'smog-pumps'

Older fuel injected vehicles with a 'smog-pump' actually inject air in 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. To accurately measure, install the LM-1 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.

10.3 Measuring at the tail-pipe

On non-catalytic converter equipped vehicles it is possible to measure the air-fuel-ratio at the tail-pipe. It is highly recommended to use the optional LM-1 Exhaust Clamp. Without it too much outside air may enter the exhaust, especially at idle, to prevent correct measurements and leading to a lean measurement. Sticking the sensor itself into the exhaust pipe can yield inconsistent results because the sensor will not have outside air available as a reference gas and its reaction time becomes so slow that the LM-1 will report a sensor timing error. The oxygen sensor needs to have the back part of the sensor (where the wires enter the sensor) exposed to outside air.

10.4 Single Cylinder Engines

These kinds of engines are difficult to measure at the tail-pipe. 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 just wrap a piece of heat resistant cloth around the exhaust clamp to prevent outside air from entering the exhaust.

10.5 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 LM-1 can still be used, but measurements at idle will read as lean.

10.5 Reference cell or Pump cell circuit open or shorted errors

Under some rare circumstances it is possible that the heater calibration data in the LM-1 is partially destroyed. This can manifest in the above-mentioned errors. Follow the steps in chapter 3 'First time use' to reset the heater calibration data.

10.6 Sensor Timing Errors

These errors are typically encountered when the sensor does not have outside air available as reference gas. If you encounter this error, restart the LM-1 and operate the sensor in free air. If you still encounter this error, the sensor may be bad and needs to be replaced.

Replacement sensors are available from your nearest VW dealer under the VW part-number 021-906-262-B

11 Advanced Topics

11.1 Connecting the LM-1 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. EFI equipped cars typically incorporate a narrow band oxygen sensor. These sensors are typically 1, 2, 3 or 4 wire sensors.

The analog output connector of the LM-1 can simulate the operation of a narrow band sensor while the wide-band oxygen sensor is installed in place of the OEM narrow-band sensor. Factory equipped Analog output 1 of the LM-1 is programmed to simulate a narrow band sensor. 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. They **cannot** be simulated.

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 LM-1 to the EFI-computer, first determine what kind of narrow band sensor is used, then follow the instructions below (requires 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 or see above.

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.

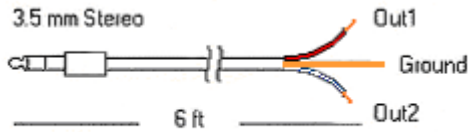
11.2 Using a Serial Remote LCD Display

The optional serial remote LCD display (LMD) connects to the serial port of the LM-1. It has the identical display functions as the built-in LCD display and also provides a 'Record' button. To use the LMD click on the serial display button on the main screen of the LM-1 Manager. The software in the LM-1 will be changed to use the serial display. The built-in LCD display of the LM-1 will no longer be used. LMD is powered by the serial interface from the LM-1 and does not require any other power connections.

The serial cable has a length of 10 feet.

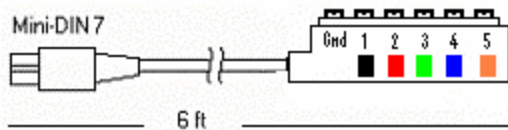
Appendix A: LM-1 Accessories

A.1 Analog output cable



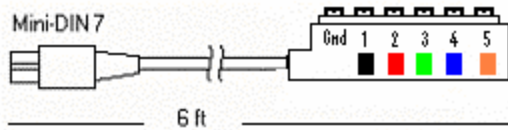
This cable comes with stripped ends to allow you to connect it up easily. Output 1 is the red wire, Output 2 is the white wire, Ground is the bare copper shield.

A.2 Auxiliary Input Cable



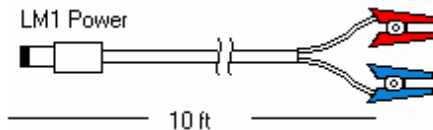
This cable has 6 screw connectors at one end and a Mini-DIN 7 plug at the other end. The 6 screw connectors are for the five auxiliary inputs and the sixth one is ground.

A.3 Auxiliary Input Cable (with RPM converter)

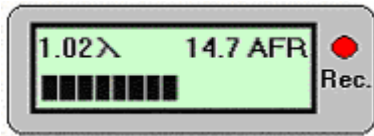


This cable is identical to the standard auxiliary input cable, except that it includes a circuit for capturing RPM with inductive pickup from Cyl. 1 spark plug wire (0-10,230 RPM).

A.4 Power Cable with battery clips

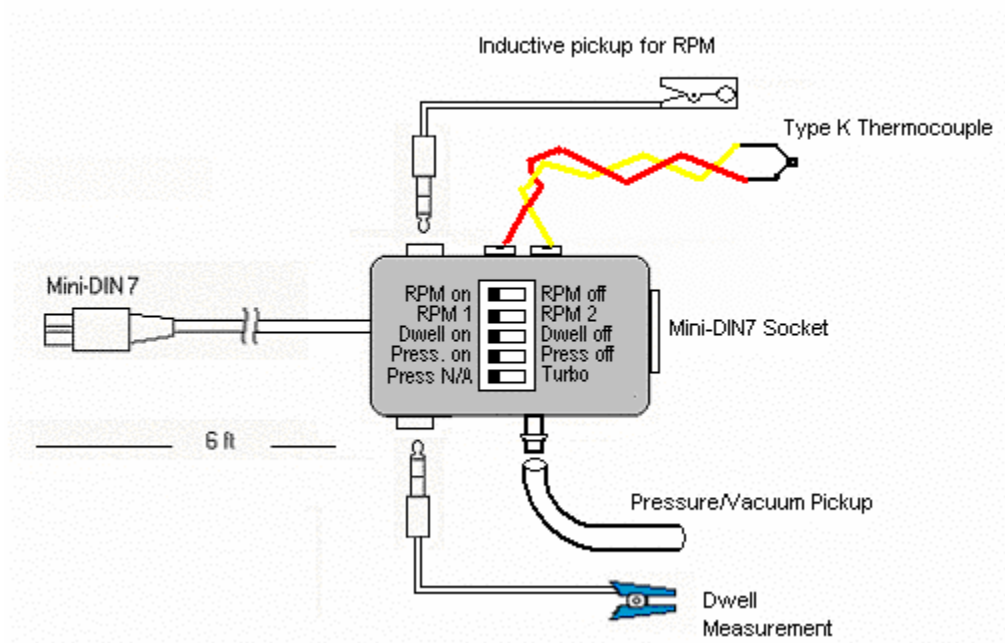


A.5 Remote serial display LMD



This unit is intended to be dash-mounted so that the LM-1 instrument can be mounted out of sight. Its power is supplied by the LM-1 and it connects to the LM-1 serial port.

A.6 LM1 Aux Expander, ("AuxBox")

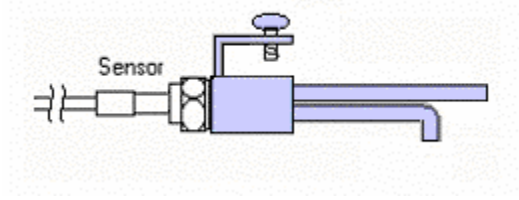


The LM1 Aux Expander contains four sensors and converters:

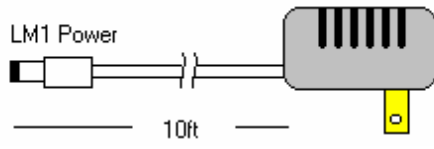
1. RPM with inductive pickup from Cyl. 1 spark plug wire (0-10,230 RPM)
2. Thermocouple input for Type K thermocouple wire
3. Dwell Meter (0..100%) for Ignition dwell or Injector Timing
4. Absolute Pressure Transducer with variable range (0..14.5 PSI or 0..29.5 PSI).

In addition it has a Mini-DIN7 socket for the Aux Expander cable for those inputs not used or switched of in the Aux Expander.

A.7 LM-1 Exhaust Clamp



A.8. LM1-Wall Transformer (Wall-Wart)



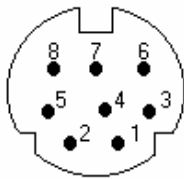
Note: see Quick start guide or website for current accessory pricing and availability

Appendix B: LM-1 Cable Pinouts

B1. Serial Interface (Mini-DIN8 female connector)

Serial Interface:

19.2 kBaud
8 Data bits
1 Stop bit
no parity
no hardware handshaking



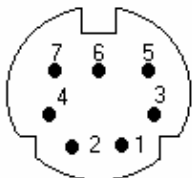
Pin Assignments

Lambda Meter

| Mini-DIN8 | Signal | Computer DB-9 | Computer DB-25 | |
|-----------|--------|---------------|----------------|------------------|
| 1 | n/c | n/c | n/c | |
| 2 | CTS | 8 | 5 | Connected to +5V |
| 3 | RxD | 2 | 3 | |
| 4 | GND | 5 | 7 | |
| 5 | TxD | 3 | 2 | |
| 6 | GND | 5 | 7 | |
| 7 | n/c | n/c | n/c | |
| 8 | n/c | n/c | n/c | |

B2. Aux Input Connector (Mini-DIN7 female connector)

**Note: Connect to signal of maximum 5V only.
Serious damage to meter and/or sensor may result if connected to signals of more than 5V amplitude.**



Pin Assignments

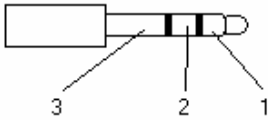
Lambda Meter

Mini-DIN7

Signal

| | |
|---|----------------|
| 1 | Ground |
| 2 | Sensor 5 Input |
| 3 | Sensor 1 Input |
| 4 | Sensor 4 Input |
| 5 | Sensor 2 Input |
| 6 | Sensor 3 Input |
| 7 | +5V from Meter |

B3. Analog Outputs (3.5mm Stereo connector)



Stereo plug shown

Pin Assignments

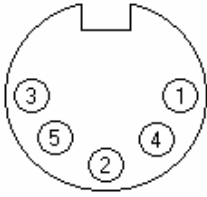
Lambda Meter

Stereo

Signal

| | |
|---|-----------------|
| 1 | Analog output 1 |
| 2 | Analog output 2 |
| 3 | Ground |

B4. Sensor Interface Connector (Standard DIN-5 female)

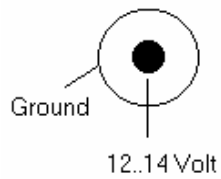


Pin Assignments

Lambda Meter Signal

| | |
|---|-------------|
| 1 | Pump+ |
| 2 | Sens+ |
| 3 | Heater - |
| 4 | Pump-/Sens- |
| 5 | Heater + |

B5. Power Connector (3.5mm power connector female)



Appendix C: LM-1 error codes

| | |
|---------|--|
| Error 1 | Heater circuit shorted |
| Error 2 | Heater circuit open |
| Error 3 | Pump cell circuit shorted |
| Error 4 | Pump cell circuit open |
| Error 5 | Reference cell circuit shorted |
| Error 6 | Reference cell circuit open |
| Error 7 | General System error (typically a software error). |
| Error 8 | Sensor Timing error (typically a damaged sensor). |
| Error 9 | Supply Voltage too low |

Appendix D: Limited Warranty

LIMITED WARRANTY

Mustang stands behind the quality of its products. Mustang makes the following warranty to purchasers of its products: All new Mustang products carry a six-month 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 Mustang shall have no obligation pursuant to it if (i) your Mustang product has been modified or repaired in a manner not previously authorized by Mustang in writing, (ii) the identification markings on your Mustang product have been removed, defaced, or altered; (iii) your Mustang product was subjected to accident, abuse, shipping damage, or improper use; (iv) your Mustang product was not used or configured as specified in the product manual; or (v) your Mustang 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 Mustang hardware product should prove defective during the warranty period, contact Mustang Customer Support for a return material authorization (RMA) at 888-468-7826. 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 Mustang repair location as instructed by Customer Service. Mustang 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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Revision History

1.0 – 5/12/03

Initial release

1.1- 5/14/03

Corrected misc. errata.

2.0 – 6/15/03

Complete revision and update, incl. sections 6, 9, 10, 11

2.1 – 6/20/03

Corrected misc. errata.

2.2 – 6/21/03

Reformatting of TOC.

2.3 – 6/25/03

Corrected/updated Appendix B

2.4 – 6/26/03

Added Appendix D

2.5 – 7/2/03

Corrected/updated programming section (Section 9).

2.6 - 7/9/03

Updated photos

2.7 - 7/23/03

Update included devices list (Section 2.1).

Added Warning at first page and Installation section (Section 4.1).

Update Analog out programming text and screenshot (Section 9.6).

Update LMD display (Section A.5).

Update Serial Display Section (Section 11.2).

2.8 - 9/03/03

Update copy after the screenshot of the Data Logger Configuration (Section 9.7)

Update photos and copy for Analog Output Cable (Appendix A1)

Update copy for Analog Outputs (Appendix B3)

Filename: LM-1_Manual_2.8.doc
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Template: C:\Documents and Settings\Administrator.INNOVATE.000\Application Data\Microsoft\Templates\Normal.dot
Title: Mustang Dynamometer
Subject:
Author: Temp1
Keywords:
Comments:
Creation Date: 9/3/2003 2:22 PM
Change Number: 4
Last Saved On: 9/3/2003 2:25 PM
Last Saved By: Administrator
Total Editing Time: 1 Minute
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As of Last Complete Printing
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Number of Words: 6,594 (approx.)
Number of Characters: 37,592 (approx.)