



## **LC-1 Digital Air/Fuel Ratio (Lambda) Sensor Controller Manual**



**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 LC-1 whenever the car is running. An un-powered oxygen sensor will be quickly damaged when exposed to hot exhaust gases.**

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# 1 Overview

The LC-1 is a stand-alone Wideband Controller 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. 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 ( $O^2$ ) 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.

## 2 Mounting and Wiring the LC-1

1. Find a suitable location under your vehicle where the LC-1 body can be mounted. Using zip ties or other suitable method, fasten the body of the LC-1 device securely to the frame-rails or other mounting points as far away from the heat of the exhaust system as the sensor cable allows. DO NOT zip-tie the LC-1 by the cables.

2. Route the cables from the LC-1 (except sensor cable) into the car interior under the dash.

3. LC-1 Cable connections:

A. Interface and power cables with 6 stripped ends\*:

a. <b>Red</b>	12V supply
b. <b>Blue</b>	Heater Ground
c. <b>Metallic</b>	System Ground
d. <b>Yellow</b>	Analog out 1
e. <b>Brown</b>	Analog out 2
f. <b>Black</b>	Calibration wire

B. Serial In connection, 2.5mm stereo (female) marked as IN

C. Serial Out connection, 2.5 mm stereo (female) marked as OUT.

\* 3.1 If you have an LC-1 with only 7 stripped ends the wiring is as follows:

a. <b>Red</b>	12V supply
b. <b>Blue</b>	Heater Ground
c. <b>White</b>	System Ground
d. <b>Yellow</b>	Analog out 1
e. <b>Brown</b>	Analog out 2
f. <b>Green</b>	Analog Ground
g. <b>Black</b>	Calibration wire

4. Connect the **RED** wire to a switched 12V source in your car. 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 5A.

5. The **BLUE** and **WHITE** wires should all be grounded to the same ground source and although these grounds are of the same source, the **BLUE** wire should be wired separate from the **WHITE** wire to avoid analog ground noise. Optimally, these (and any other MTS device ground) will be soldered to the same lug, and connected to a single point. When this isn't possible, connect each one to a separate lug, and attach in close proximity. Multiple lugs on the same bolt is not optimal, and can result in unwanted signal "noise." When possible, soldering is always better than crimping.

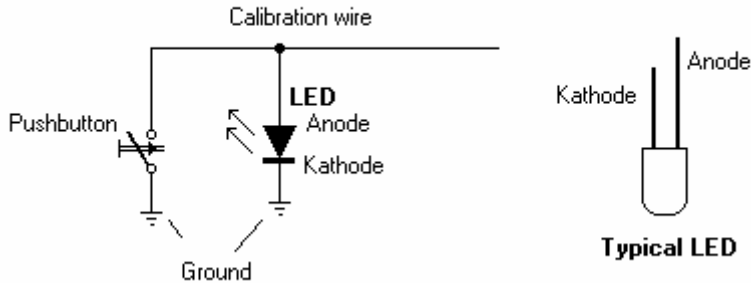
6. *Optionally*, the **YELLOW** (Analog out 1) and/or **BROWN** (Analog out 2) can be connected to the analog inputs of other devices such as data loggers and ECUs. If either one or both of these wires are not being used isolate and tape the wire(s) out of the way. The default analog outputs are as follows: Analog output one is 1.1V = 14 AFR and .1V = 15 AFR. This is a simulated narrowband signal. Analog output two is setup as 0V = 7.35 AFR and 5V = 22.39 AFR. **Note: The LC-1's heater ground and system ground wires should be grounded at the analog input's ground.** Refer to chapter 2.2 for recommended wiring schematics.

7. *Optionally* connect a momentary push-button switch between ground and the **BLACK** calibration wire. Please refer to section 2.1.

*Note:* The use of the calibration wire is not necessary if the LC-1 is connected to Innovate Motorsports' XD-1 digital gauge. If the wire is not are not being used, isolate and tape the wire out of the way.

8. *Optionally* connect a indication LED (1.2-2.2V, 1-30mA is recommended) between the calibration wire and ground. Please refer to section 2.1

### **2.1 Indicator LED and Calibration button hookup:**



The LED will communicate the LC-1's status. To monitor LC-1 status, connect the red wire (Anode) of the included LED to the calibration wire (black) of the LC-1 and connect the black wire (Cathode) of the LED to the ground wire of the momentary switch. The grounds to both the cathode side of the LED and the Push button should be connected with the Heater ground.

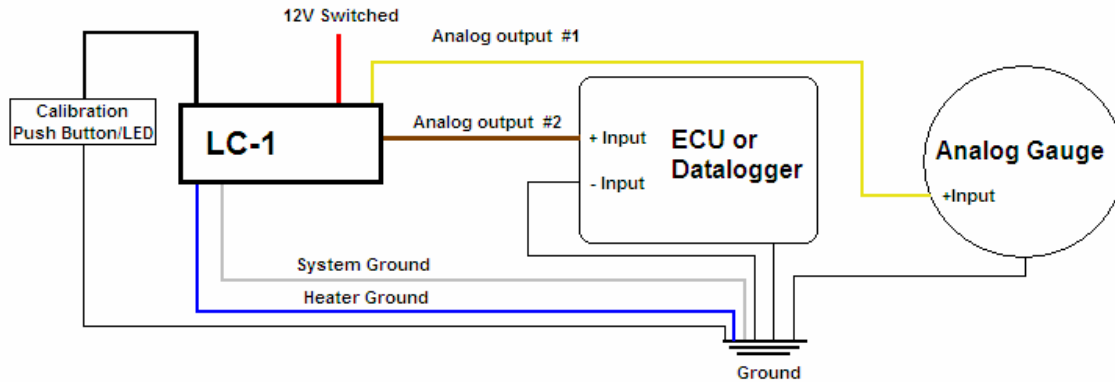
- a. Note: The included LED will fit the following hole size and panel thickness: a 5/32" (0.155" - 0.158") hole size and a panel thickness of 28-16gauge (0.031" - 0.062").
- b. Optionally, any 1.2V - 2.2V (1mA- 30mA) LED may be used. A typical LED has 2 wires called Anode and Cathode. The Cathode side is typically the shorter of the 2 wires or the black wire.

Pressing the push-button or connecting it quickly to ground starts a free air calibration process in the LC-1. **MAKE SURE THE SENSOR IS IN FREE AIR FOR THAT.** See chapter 4 for details.

See Appendix B for LED status codes.

## 2.2 Connecting the LC-1 to an ECU or data logger

All Innovate MTS devices like the LC-1 with dual serial ports should have their system grounds connected together to a common ground point. If an external data logger or ECU is to be fed by an MTS device, the MTS ground should be located at or near the ECU or data logger's input signal ground. Some ECU's or data loggers have differential inputs. A differential input has a separate ground INPUT for each sensor input. This ground input MUST be connected also to ground as shown in these diagrams. If one analog output of the LC-1 is used to drive an AFR display and the other output is used to connect to an ECU, the AFR display ground should be connected to the ECU ground. **The schematics below can also adapted for 7-wire LC-1s. Simply wire the Green analog ground wire with the System ground.**



## 2.3 Electrical Grounding Concerns

The electrical environment inside a car provides unique challenges, combining high voltages and currents, low-voltage signals, convoluted signal paths, and variable conditions (i.e., fans turning on and off, or starter cranking).

When using precision electronics, it is important for ALL electronics to share a common ground. Remember that "Ground" is more than just the return path for any circuit- it is also the reference against which any voltage is measured.

Since it is not always practical to ground every device to the exact same location, here are some tips on grounding:

1. The BEST grounding scheme is all grounds (i.e., ECU, Gauges, LC1 heater, LC1 system, etc.) **SOLDERED** into a single lug and bolted to the engine block.
2. The next best is all grounds attached to the same source, as close as possible, but on separate lugs. This is because even the corrosion between lugs can create ground offset and noise. Incidentally, this is why many ECUs have separate ground wires for injectors vs. ECU system ground- separating high voltages and low voltages reduces noise.
3. Grounding to the engine block is usually better than grounding to the frame.
4. Grounding a gauge to the radio is usually bad- ground offset can vary with volume.
5. Grounding to an ECU housing is generally not optimal- housings are strapped to the frame for shielding, but not necessarily grounded.
6. One of the **WORST** things to do is to ground most of your electronics to one place (i.e. the engine block), but ground one device somewhere else (i.e., the frame). Not only can this result in ground offsets, it can also create a "path of least resistance" for high currents **THROUGH** a low-current device. This can result in melted wires and vaporized diodes, when, for example, starter currents flow through gauges.

## 2.4 Mounting the sensor using a Bung.

**Using a bung is the preferred method for mounting the O<sup>2</sup> 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 and plug is included in the LC-1 kit). 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. (Insert the plug into the bung when not in use). **The bung must be installed in the exhaust pipe at the side or on top, NOT on the bottom of the exhaust pipe.** Best 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 a Bung as described above. Use of a bung is the preferred method for mounting the O<sup>2</sup> sensor for both catalytic and non-catalytic cars.

**On TURBO CHARGED vehicles:**

Install the bung 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.



**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.**



**Wide band oxygen sensors – like the one shipped optionally with the LC-1 – are designed to work with unleaded gasoline. Using them with leaded gasoline will significantly reduce the lifespan of the sensor. The reduction is directly proportional to the metal content of the fuel. In most cases, a wide band sensor will provide accurate measurements somewhere between 50 hours and 500 hours with leaded fuel.**



**WHEN INSTALLED IN THE EXHAUST, THE OXYGEN SENSOR MUST BE CONNECTED AND OPERATING WITH THE LC-1 WHENEVER THE CAR IS RUNNING. AN UN-POWERED OXYGEN SENSOR WILL BE DAMAGED WHEN EXPOSED TO EXHAUST GAS.**



The maximum temperature of the sensor at the bung (the sensor hexagon) should not exceed 500 °C or 900 °F. If these temperatures are exceeded in your application you should either install a copper heat sink (instructions below) or the Innovate Motorsports Heat-Sink Bung extender (HBX-1).

The bung extender is recommended for situations where airflow is restricted or the encountered heat is higher than a heat sink can handle.

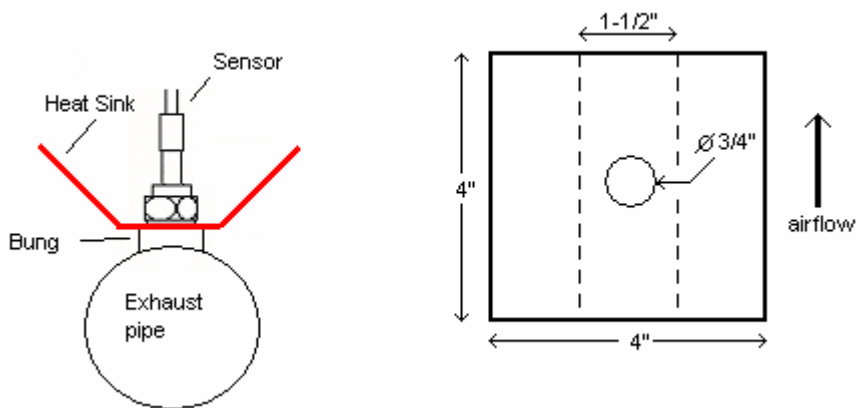


It is NOT a good idea to connect the LC-1 permanently to 12V and switch it on with a separate switch before the vehicle is started. Depending on the climate and the sensor position in the exhaust, condensation water can form in the exhaust pipes. This condensation water could then be blown by the exhaust stream against the hot sensor when the car is started. The resulting heat shock can permanently damage the sensor.

### 2.5 How to fabricate a copper heat sink

Use a 4" x 4" (10cm x 10 cm) sheet of copper sheet metal 14ga (1.5mm) thick. Drill a hole in the center with the same diameter of the oxygen sensor threads ~3/4" (19mm).

Fold the sides up 45 deg and mount it between the sensor and the bung like you would a big washer. Orient it such that the sides are exposed to good airflow.



## 3 First Time Use

1. Do not connect the sensor yet.
2. Switch 12V supply to the LC-1 on and wait for 10 seconds.
3. Switch the 12V supply off after 10 seconds.
4. Connect the sensor to the sensor interface connector. **The sensor must be exposed to air for the first time calibration.**



5. Switch the LC-1 on and wait for 2 minutes.

If you connected a LED to the calibration button, you will at first see the LED blink slowly and steadily. If it blinks for a fixed number of pulses, then switches off for 2 seconds and then repeats, you have an error code. See Appendix for details.

Slow and steady blinking indicates that the sensor is warming up to its optimum operating temperature. 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 LC-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 optional LED will blink fast and steady.

After that period the LC-1 will automatically perform a free air calibration. During this 2 second period a connected LED will go off. The LC-1 will now calibrate itself by using air as a reference gas with known oxygen content.

After the free air calibration is finished the LED should light up steady and continuously, indicating correct operation of the LC-1.

## 4 Calibration

There are two types of calibration for the LC-1: free air calibration and sensor heater calibration. Sensor heater calibration and first free air calibration is automatically performed the first time a new sensor is used, while free air calibration should be executed frequently.

### ***4.1 Free air calibration***

To achieve maximum precision, the LC-1 and its sensor needs to be recalibrated frequently.

**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. Better yet, disengage the oxygen sensor and expose the sensor to air (away from the exhaust) for calibration purposes:

1. Connect the LC-1 to 12V from the vehicle and switch it on.
2. After the sensor has warmed up, either press the pushbutton or connect the calibration wire to ground for a brief period.
3. After the calibration is complete, switch the LC-1 off and wait for 30 seconds before you start the car.

If a LED indicator is connected to the calibration wire, it will be off during free air calibration.

### ***4.2 Sensor heater calibration***

If you change the sensor – either with a replacement sensor or a new type of sensor –, the heater circuit of the LC-1 needs to be recalibrated as well. (See steps in chapter 4 'First Time

Use'). The heater calibration data in the LC-1 will be reset when the device is operated from 12V without a sensor connected for at least 5 seconds. You can force a reset by doing this, and then recalibrate by turning the unit off, reconnecting the sensor, and turning the unit on.

After the sensor is warmed up the meter automatically calibrates the sensor heater controller to the particular sensor. During this 20-second period the LC-1 collects and calculates sensor-specific data required to quickly reach operating temperature in the future.

**Note: When using the Bosch Sensors the LC-1 may perform multiple calibration passes. This is normal and need not cause concern. When it completes, the LC-1 also will perform a free air calibration. Make sure the sensor is operating in free air for the heater and free air calibration.**

### ***4.3 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 car, 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 car**

- 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

## **5 Remote display and recording of Lambda and/or AFR**

In many applications it may be desirable to monitor the air-fuel data remotely using a dash-mounted instrument. The LC-1 provides two options for that application.

### ***5.1 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. With the LC-1, connecting these meters to the second analog output of the LC-1 allows them to be used as true remote AFR meters, provided the LC-1 analog output is programmed to the characteristics of the used meter. The LC-1's analog output 2 is factory programmed to provide a linear output between 0V and 5V for an AFR of 7.35 to 22.39. Any other linear output range between 0 and 5V can be programmed. See chapter 6.5: Programming the analog outputs for details.

## **5.2 Digital XD-16 Instrument**

1. Connect the Serial OUT connection to the Serial IN connection of the XD-16 with the included 2.5mm to 2.5mm cable. Make sure the XD-1 is programmed as AFR instrument for the first channel like for an LM-1.
2. Connect the terminator plug (2.5mm male plug with no cable) into the Serial IN connection of the LC-1.
3. If real-time recording with the Innovate LogWorks software, connect the included 2.5mm stereo to DB-9 cable to a serial port on your laptop.

## **5.3 Laptop recording of AFR or Lambda**

1. If real-time recording with the Innovate LogWorks software, connect the Serial OUT connection (unmarked) with the included 2.5mm stereo to DB-9 cable to a serial port on your laptop.
2. Connect the terminator plug (2.5mm male plug with no cable) into the Serial IN connection of the LC-1.

## **5.4 Multi channel AFR recording with multiple LC-1's and/or LM-1**

If multiple LC-1's are used, connect the Serial OUT of the first LC-1 to the Serial IN of the next one. Connect the serial out of that one again to the Serial IN of the next one and so on. Connect the laptop computer to the Serial OUT of the last LC-1 in the chain.



**The first LC-1 in the chain MUST have its Serial IN plugged with the terminator plug.**

If an LM-1 is used as well, it MUST be the first device in the chain. The Mini-DIN8 to serial cable (P/N: 3759, not included) allows you to connect the Serial Port of the LM-1 to the Serial IN of the first LC-1.

## 6 Programming the LC-1

The LC-1 is programmable with the following functionality:

1. Change the relationship between Lambda and AFR.
2. Upgrade and change the software.
3. Change the output characteristics of the Analog outputs.

### 6.1 Installing the LM Programmer Software

Put the included CD in your CD-drive on your computer and follow the instructions on screen. The Software will be installed including pre-set directories for log-data and downloaded software. The LM Installer also puts entries for the LM Software in the Start-Menu of your computer under the heading 'LogWorks2'.

### 6.2 Hooking up the LC-1 device to the computer

1. Connect the Serial OUT connection with the included 2.5mm stereo to DB-9 cable to a serial port on your laptop.
2. Connect the terminator plug (2.5mm male plug with no cable) into the Serial IN connection of the LC-1.

Start the LM-Programmer software. The screen should look like this:



On this page you can see the software version of the LC-1 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.

If you plan to use multiple LC-1's, change the device name to something identifying which LC-1 is connected where. For example LC1-Cyl1 for a LC1 connected to Cylinder 1. The device name can be up to 8 characters long.

### **6.3 Resetting the calibration data**

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

### **6.4 Updating the Firmware**

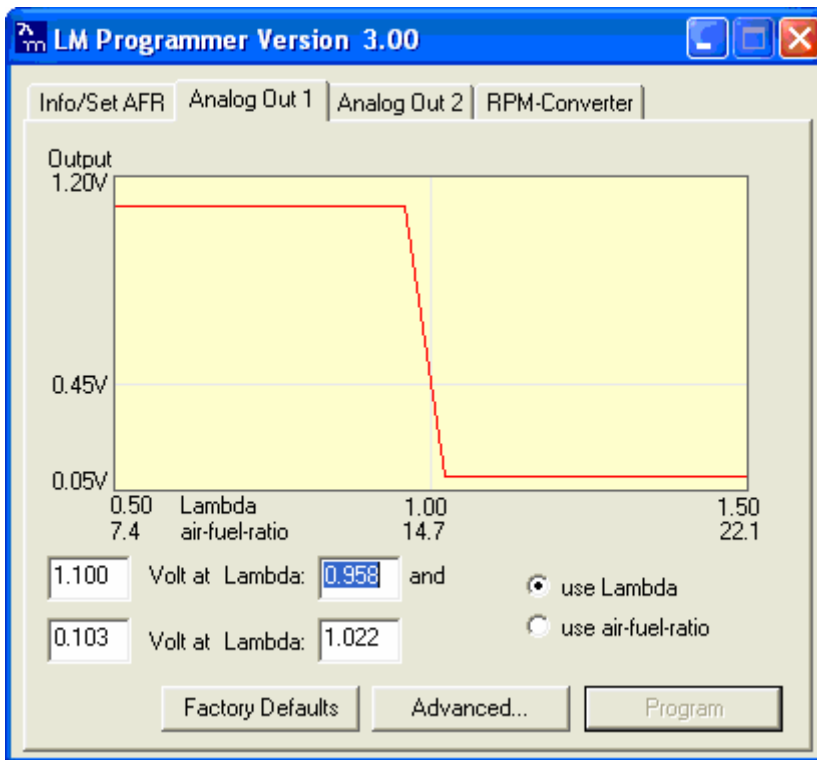
Click the 'Update Firmware' in the main page to upgrade to the latest *firmware* for the LC-1. Firmware for the LC-1 has the extension dld. You can also download the latest firmware and software (LM Programmer and Demo) from the Innovate! Motorsports web-site at

<http://www.tuneyouengine.com>

If your computer crashes during a firmware upgrade, the LC-1 has a recovery mechanism where it will be able to retry the download again and not be disabled by half loaded firmware. Switch the LC-1 off and on again and then try to restart the LC1 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 LC-1 will not recover correctly and may need to be serviced at our factory. If you suspect this is the case, contact Innovate support.

### **6.5 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. 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 LC-1.**

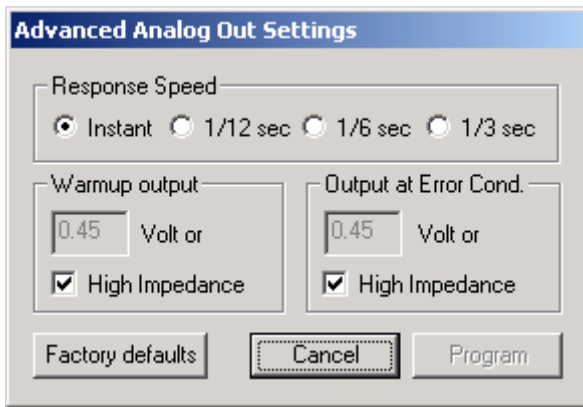
Click the Program button to download the new data into the LC-1.

As factory programmed the first output simulates a typical narrow band oxygen sensor. The second output is programmed to output between 0 V for an AFR of 7.35 (gasoline) and 5.0V for an AFR of 22.39. Other curves of course are easily programmable

### ***6.5.1 Advanced output programming***

The normal state of the analog outputs is to update the outputs every time the LC-1 takes a new measurement. The LC-1 is fast enough to distinguish individual pockets of exhaust gas. For many applications this will be too fast. The advanced programming allows to set the analog out update speed.

Press the "Advanced button" to set the advanced analog out settings. The following dialog box will appear:



When setting the LC-1 to the slower response speed settings the measured mixture data will be averaged over the response time setting before being output.

You can also specify what output voltage is visible on the analog outputs during warm-up of the sensor and during error conditions.

The 'High Impedance' setting allows to specify that the analog outputs do not drive the output during warm-up or error condition. They will be free floating. This is important for more closely simulating a narrow band sensor. Many EFI systems monitor the impedance of a narrow band sensor during engine warm-up to determine sensor readiness. A narrow band sensor that's too cold will have a high impedance.

## **7 Tips, Tricks and Troubleshooting**

### ***7.1 General measurement requirements***

The LC-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). You should correct for the following in order to get optimum results from the LC-1

- 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 LC-1 to measure lean.
- 3) The only circumstance where the LC-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 to begin with).

### ***7.2 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 LC-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.

### ***7.3 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 LC-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.

### ***7.4 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.

### ***7.5 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 LC-1 can still be used, but measurements at idle will read as lean.

### ***7.6 Reference cell or Pump cell circuit open or shorted errors***



Under some rare circumstances it is possible that the heater calibration data in the LC-1 can become partially destroyed. This can manifest in the above-mentioned errors. Follow the steps in chapter 4 'First time use' to reset the heater calibration data.

## **7.7 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 LC-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 or direct from Innovate Motorsports.

Sensor timing errors are also common when the sensor overheats. Relocate the sensor further downstream in the exhaust, install a heat sink or Heat-Sink Bung extender (HBX-1).

Sometimes it's possible to encounter Error 08 when the exhaust gas suddenly gets too rich. Normally the LC-1 will display a 'too rich' indication if the exhaust gas is too rich. If the mixture gets rich very suddenly, the LC-1 cannot distinguish between a too rich condition and a sensor timing error.

## **7.8 Analog Output tricks/hints**

Sometimes there is a ground offset between the device that receives the analog output voltage and the LC-1. This can be especially true if the System ground is not connected to the same ground as the measurement device using the analog out. Both devices reference different grounds and therefore see different voltages. So to compensate for the ground offsets the analog output voltage points have to be shifted by the ground offsets. To measure what the real ground offset is, you can program the analog outputs temporarily to output a flat line voltage by entering the same voltage in both fields for the two analog out programming points. This way the analog output voltage will be fixed, independent of current AFR and can therefore be measured and compensated for easily.

To log analog outputs from the LC-1 into an LM-1, simply connect analog output #2 (brown wire) to an available input on the LMA-2 (RPM converter Aux. In Cable) or LMA-3 (5-sensor "AuxBox"). Set LogWorks inputs match the LC-1 outputs. As discussed in section 7.6 above, factory settings for the second output is programmed where 0V=.5λ (AFR of 7.35 for gasoline) and 5.0V=1.523λ (AFR of 22.39 for gasoline).



**Note:**

***The analog outputs are NOT designed to power other devices or sensors. So using the flat-line setting at 5V and expecting to power a sensor from it will not work and can damage the LC-1.***

# **8 Advanced Topics**

## **8.1 Connecting the LC-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 LC-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 LC-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. 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 LC-1 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 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.

## Appendix A: LC-1 Cable Pinouts

### A1. Sensor Interface Connector (Standard DIN-5 female)

Lambda Meter	Signal	Wire Colors Bosch LSU4.2	Wire Colors NTK L1H1
1	Pump+	red	white
2	Sens+	black	red
3	Heater -	white	yellow
4	Pump-/Sens-	yellow	black
5	Heater +	gray	orange

## Appendix B: LED blinking codes

- |   |   |
|---|---|
| 1. Blinking steady about 2 times/second:    | <b>Warming up</b>                       |
| 2. Blinking steady at about 4 times/second: | <b>Heater calibration</b>               |
| 3. LED off                                  | <b>No Power or free air calibration</b> |
| 4. Blink sequence with 2 second pause       | <b>Error indication</b>                 |

### **Error indication details:**

Count the number of fast flashes between 2 second pauses. The number of flashes indicates the error code as in

- |           |         |
|-----------|---------|
| 1 Flash   | Error 1 |
| 2 Flashes | Error 2 |

And so on. See Appendix C for error code details.

## Appendix C: LC-1 Error Codes and Troubleshooting Tips

Error Code	Error Message	Likely Root Cause	Fix
<b>Error 1</b>	Heater circuit shorted	<ol style="list-style-type: none"> <li>Short in cable</li> <li>Short in sensor</li> </ol>	<ol style="list-style-type: none"> <li>Repair/replace cable.</li> <li>Replace sensor.</li> </ol>
<b>Error 2</b>	Heater circuit open	<ol style="list-style-type: none"> <li>Damaged sensor cable or Cable connector not fully seated</li> </ol>	<ol style="list-style-type: none"> <li>Verify Sensor connector is fully seated into unit. Repair/replace Sensor or cable.</li> </ol>
<b>Error 3</b>	Pump cell circuit shorted	<ol style="list-style-type: none"> <li>Short in sensor cable</li> <li>Short in sensor</li> <li>Sensor heater calibration incorrect</li> <li>Sensor overheating</li> <li>EGT &gt;1700° F</li> </ol>	<ol style="list-style-type: none"> <li>Repair sensor cable.</li> <li>Replace sensor.</li> <li>Perform sensor heater recalibration.</li> <li>Move your sensor bung as far downstream as possible OR add a heatsink to isolate the sensor from the pipe.</li> </ol>
<b>Error 4</b>	Pump cell circuit open	<ol style="list-style-type: none"> <li>Damaged sensor cable or sensor connector not fully seated</li> <li>Sensor heater calibration incorrect</li> </ol>	<ol style="list-style-type: none"> <li>Verify sensor connector is fully seated into unit. Repair/replace cable.</li> <li>Perform complete heater calibration (not just free air calibration). See section 4</li> </ol>
<b>Error 5</b>	Reference cell circuit shorted	<ol style="list-style-type: none"> <li>Short in sensor cable</li> <li>Short in sensor</li> </ol>	<ol style="list-style-type: none"> <li>Repair sensor cable.</li> <li>Replace sensor.</li> </ol>
<b>Error 6</b>	Reference cell circuit open	<ol style="list-style-type: none"> <li>Damaged sensor cable or sensor connector not fully seated</li> <li>Damaged Sensor</li> </ol>	<ol style="list-style-type: none"> <li>Verify sensor connector is fully seated into unit.</li> <li>Replace sensor</li> </ol>
<b>Error 7</b>	General System error (typically a software error).	Typically a software error	Reboot LC-1 by cycling power. Re-flash unit if necessary.
<b>Error 8</b>	Sensor Timing error (typically a damaged sensor).	<ol style="list-style-type: none"> <li>Sensor overheating. (The Bosch LSU4.2 is rated to operate at a sensor housing temperature of &lt; 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. )</li> <li>Sensor is damaged</li> </ol>	<ol style="list-style-type: none"> <li> <ol style="list-style-type: none"> <li>Perform sensor heater recalibration;</li> <li>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;</li> <li>Add a heatsink to isolate the sensor from the pipe. The HBX-1 is an available accessory.</li> </ol> </li> <li>Replace sensor.</li> </ol>
<b>Error 9</b>	Supply Voltage too low	Supply voltage too low for sensor regulation	Check your 12V connection for corrosion.

## **Appendix C: 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 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 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 for a return material authorization (RMA) at 949-502-8400. 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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# Revision History

## **1.0 – 1/23/05**

Initial release.

## **1.1 – 5/16/05**

Corrected error in section 6.4

## **1.2 – 5/26/05**

Updates to section 3

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Update Chapter 2

## **1.4 – 03/01/06**

Update Chapter 2

## **1.5 – 03/16/06**

Added Push Button/ LED, Calibration Schedule, and updated wiring schematic

## **1.6 – 06/08/06**

Updated Tips and Tricks.

## **1.7 – 02/14/07**

Update 6 Wire LC-1 and new schematic