



# LC-2 Digital Air/Fuel Ratio (Lambda) Sensor Controller Manual



**Warning!**

The Oxygen Sensor used in this device gets very hot in operation.

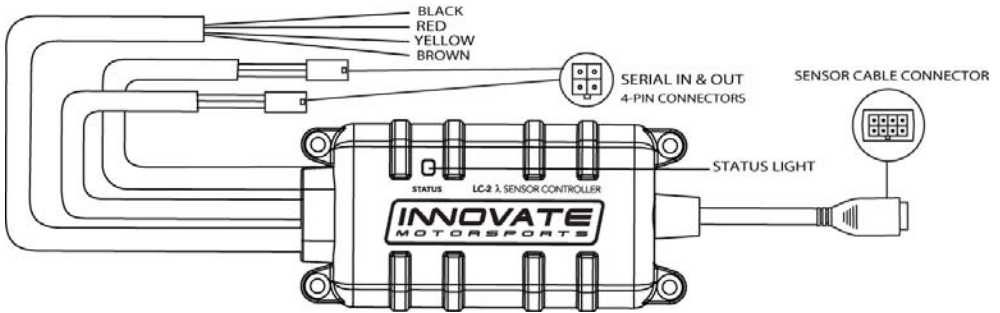
Do not touch the hot sensor. Do not let a hot sensor touch a combustible surface. Do not use the sensor with or near flammable liquids or gases. Failure to heed these warnings may result in severe burns, explosions or fires.

When installed in the exhaust, the oxygen sensor **MUST** be connected and operating with the LC-2 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 LC-2

The LC-2 is a controller that controls a wideband O2 lambda sensor to measure O2 content in exhaust gasses. In this section we will spend a moment getting familiar with the LC-2 lambda controller.



1. **Status Light** – The LC-2 status light indicates the controller's operational status. When the controller is powered, the status light will light up green for 2 seconds indicating controller initialization.

After the initialization, the status light will light will blink or light up constant up to indicate one of the following operational status conditions:

Light Status	Definition
No Light	No power to the LC-2
GREEN, flashing twice a second	Sensor Warm-up
GREEN, series of quick flashes	Sensor Calibration
GREEN, solid	LC-2 operational, taking readings.
RED, series of flashes followed by a pause	The number of flashes indicates an error condition. See Appendix for error code details.

2. **Sensor Cable Connector** – Mates the sensor cable to the O2 sensor.
3. **Wiring** – The LC-2's wiring is very straight forward. All that is needed for basic installation is power (red) and ground (black). The two configurable analog output wires (one yellow and one brown) can be used to feed external Standalone ECUs, 3<sup>rd</sup> party data loggers, and AFR display gauges.
4. **Serial IN & OUT Connectors** – The LC-2's serial connectors are utilized when needed to program analog output settings, data log via the Logworks software with a Windows PC, or to daisy chain with other Innovate Motorsports' devices.

## 2 Mounting and Wiring the LC-2

### 2.1 Mounting

The LC-2 controller body should be mounted inside the cabin or in another dry, protected location away from the elements. Physically mount the unit away from all ignition or stereo components and other potentially RF or EMI emitting sources.

Route the sensor cable in a manner that avoids contact with the exhaust piping and other extreme heat 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).

### 2.2 Wiring

The LC-2 has 4 stripped wires.

1. Connect the **RED** wire to an isolated switched 12V source in your vehicle. A switched 12V source goes ON as soon as “key on” power is active. The circuit to which you will pull power from should be able to support a 3 amp draw. Make sure this connection is protected with a 5A fuse.



Circuits that share power with the vehicle's stereo, ignition system, ECU, lighting, or fuel pump should not be used. When in doubt, create an additional circuit using an automotive relay available at any automotive parts supplier. See the next section for a relay installation diagram.

2. The **BLACK** wire should be grounded to a solid ground source. The best possible ground source would be the battery ground (-) post.



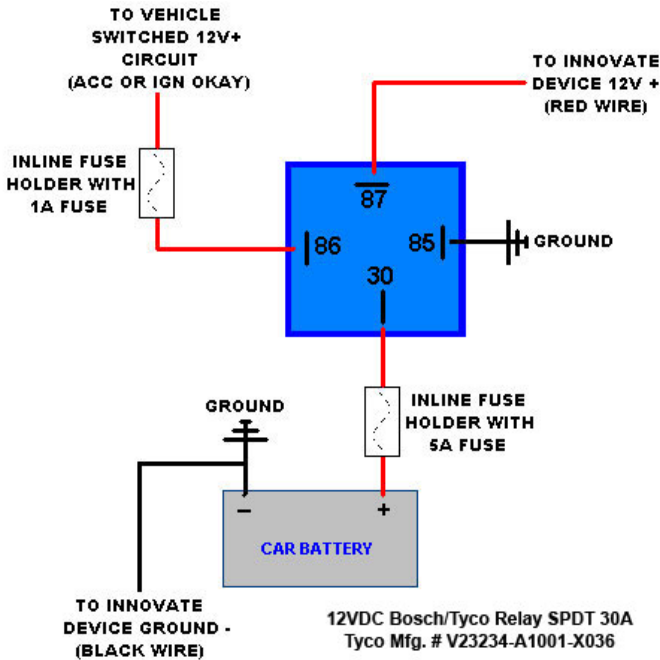
If other Innovate Motorsports devices are going to be daisy-chained along with the LC-2, it is recommended that all devices be connected to a single ground point, ideally the battery ground (-) post.

3. 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, aftermarket programmable ECUs, or AFR display gauges. If either one or both of these wires are not being used, isolate and tape the wire(s) in an out of the way location. Each of the two analog output wires can connect to one device that can accept this 0-5v potential output.

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. Note: The LC-2's ground should share the same

grounding source as the device to which you are feeding the analog outputs, the easiest way to accomplish this is to run an aux ground wire from the ground point of the LC-2 to the ground or signal ground of the device you are interfacing with.

### 2.2.1 Single Innovate Device Relay Wiring Instructions



## 3 Sensor Placement

Optimum bung placement will vary from application to application, but using the guideline below will ensure the longest sensor life with the most accurate readings. Using a bung is the preferred method for mounting the oxygen sensor in all applications.

- Weld the bung at least **24 inches downstream** of the exhaust port outlet (after the collector), or 24 inches after the turbocharger if so equipped. The bung should be welded before the X or H pipe if so equipped.
- Using a clock as reference, mount the bung between the **9:00 o'clock and 3:00 o'clock position**. Welding the bung in the lower section of the exhaust pipe can result in sensor damage caused by condensation making contact with the sensor's internal heating element.

- A **1” bung** (provided in the kit) will best protect the sensor. When fully threaded, the sensor’s tip will sit flush with the exhaust pipe, this does **not** adversely effect the readings.
- The bung should always be welded before the Catalytic Converter. Welding the bung after the catalytic converter will skew the readings toward lean. The skew in readings will vary with engine load and the efficiency of the catalytic converter.
- Leaded fuel and two stroke applications will reduce the sensor’s life. There are many other factors that dictate the sensor’s lifespan so it is impossible to predict it’s total longevity.
- Exhaust leaks, camshaft overlap, and open (shorty) exhausts will cause false lean readings at light engine loads. Typically, once the engine is under load and the exhaust gas volume increases, you will see accurate readings.
- When installed in the exhaust, the oxygen sensor must be connected to a powered, functional LC-2 (no error codes) whenever the engine is running. An un-powered sensor will be damaged in a short period of time when exposed to exhaust gas.
- Do not pre-warm the sensor before starting the engine, simply start the engine as normal. Allowing the sensor to pre-warm before starting the engine will increase the possibility of damaging the sensor from shock-cooling.
- The maximum temperature of the sensor at the bung (the sensor mounting location) should not exceed 500 °C or 900 °F. If these temperatures are exceeded in your application you should install the Innovate Motorsports HBX-1 heat sink bung extender. (p/n 3729.)



**As the O2 sensor measures the oxygen content of the exhaust gas to provide an accurate O2 reading, even a small pin-hole leak in a poorly welded sensor bung will effect the accuracy and performance of your O2 sensor. Remember, any deviation from the instructions provided for proper sensor installation will lead to inaccurate O2 readings.**

## 4 Sensor Calibration

Once the LC-2 has been wired and a suitable location has been found for both the controller and the sensor, it is time to perform the sensor calibration. Innovate Motorsports’ ‘Direct Digital’ wideband measurement technology allows you to calibrate the sensor to compensate for sensor wear and

atmospheric pressure variances. This procedure takes just a few moments and it will ensure 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**, this means removed from the exhaust system completely.

1. With the sensor disconnected, apply power to the LC-2. When power is applied, the status light will light up green for 2 seconds while the controller initializes. The status light will then turn red and flash a two blink sequence indicating an Error 2 condition. This error state indicates that no sensor is detected. Leave unit powered on for a minimum of 30 seconds while it is flashing the Error 2.
2. Power down the LC-2 and attach the oxygen sensor to the sensor cable and the sensor cable to the LC-2. When making these connections, make sure they are fully seated and locked. Again, make sure that the sensor is in free air (not in the exhaust).
3. Power up the LC-2. The status light will light up green for 2 seconds while the system initializes. The status light will then start flashing green twice a second indicating that the sensor is heating up to it's operating temperature. After 30-60 seconds, the status light will flash green for a series of very quick flashes indicating the sensor calibration is being performed. Lastly, the light will light up solid green indicating that the unit is operational and ready to take read O2 content in the exhaust gas.



You may disconnect the sensor from the sensor cable in order to thread the sensor into the exhaust. To do this without losing your calibration, make sure the unit remains powered off while the sensor is disconnected. If you power up the LC-2 without a sensor connected, your calibration will be lost and require the calibration to be repeated. (see step #1 above).

#### **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 car, daily driver (richer mixture):*

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

## **5 Software (LogWorks 3 and LM Programmer)**

### **5.1 Download the Logworks 3 software package**

1. Open your web browser and go to:  
<http://www.innovatemotorsports.com/support.php>
2. The LogWorks 3 software download will be the very first thing on the page, click the link to download the software.

### **5.2 Installing software**

1. Double click on the Logworks 3 installer previously downloaded.
2. The installer will start, follow the prompts to install the software.
3. Once the software has been installed the LogWorks software, LM Programmer and LC-2 manual can then be located by navigating through Start->Programs->LogWorks3.

### **5.3 Connecting to LM Programmer**

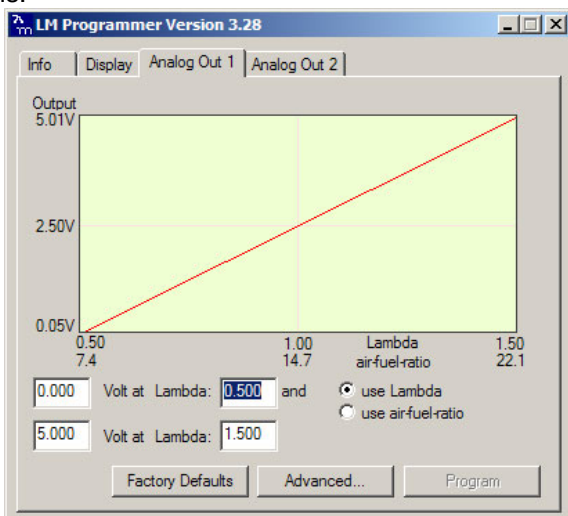
LM Programmer is used to update firmware, change fuel types, change sensor type, and program the two analog outputs.

1. Connect the OUT port of the LC-2 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 LC-2
2. Power up the LC-2.
3. Launch LM Programmer. The LM Programmer application can be launched from *Start->Programs->LogWorks3->LM Programmer* from the Windows task bar.

#### **5.3.1 Analog Outputs**

1. Connect the LC-2 to the computer and launch LM Programmer.

2. Select one of the Analog output tabs. The Analog output tab 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 or A/F ratio value and the associated voltages.

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 unit of measure displayed.

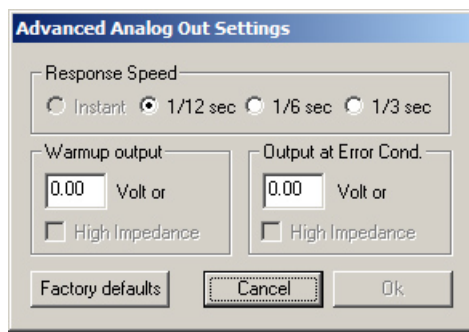
Click the 'Program' button to upload the new programming data into the LC-2. Once the unit is programmed the 'Program' button will grey out.

### 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 is 1.1 V for an AFR of 14 and .1 V for an AFR of 15. Other settings, of course, are easily programmable between the minimum and maximum range specified earlier.



**Avoid connecting or disconnecting any of the serial ports labeled IN or OUT while the unit is powered ON.**



### 5.3.2 Advanced output programming

The 'Advanced' button allows the user 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 update 1/12 of a second. The default voltage output is set at 0 volts for both the Warm-up and Error Condition.

When setting the LC-2 to the slower response speed, the measured mixture data will be averaged over the response time setting before being sent via the analog output.

### 5.3.3 Updating the Firmware



**Do not update the firmware if the versions are the same or older than already loaded. A firmware update should only be necessary if there has been a new release that specifically fixes a problem that you are experiencing with the controller.**

1. Connect the LC-2 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 LC-2. **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. If there have been revisions to the firmware, you will find them 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 LC-2.
6. Click OK, DO NOT power off or disconnect the LC-2 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.

### 5.3.4 Changing Sensor Type

*Note: The LC-2 must be running firmware version 1.01 or later with LM Programmer 4.0 or later to access the sensor type menu.*



The LC-2 is multi sensor compatible with the Bosch LSU 4.2 and 4.9 sensors. In order to go from one sensor type to another the LC-2 must be connected to the LM Programmer software and the appropriate sensor type must be selected. The “Sensor Type to use” setting can be found in the ‘Info’ tab when LM Programmer connects to the LC-2. Once the sensor type is changed a sensor calibration must be performed with the sensor outside of the exhaust (see Sensor Calibration chapter.)

Sensor Cable P/N	3ft	8ft	18ft
LSU 4.2	3843	3810	3828
LSU 4.9	3890	3887	3889

Sensor P/N	
LSU 4.2	3737
LSU 4.9	3888

Note: All sensor cables for the LSU 4.9 are easily identified by a '4.9' marking molded on the sensor connector side.




**Use the appropriate sensor cable for the sensor type as each sensor has a different style connector. Spliced cable can not only affect the wideband's performance but in worst cases it can damage the sensor and/or controller.**



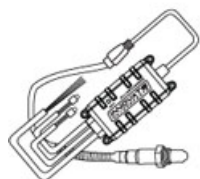
**Selecting the wrong sensor type to the sensor being used will not only give you erroneous readings and/or errors. It can also permanently damage the sensor.**

#### 5.4 Logging data from your LC-2 with LogWorks

1. Connect the OUT port of the LC-2 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 LC-2. Power up the LC-2
2. Launch LogWorks. The LogWorks 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 the serial COM port. Select the COM port the device is connected to and then click Connect.
4. To start recording go to *File->New Realtime Log* or, in the Toolbar, click on the  Tool.

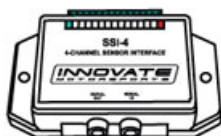
##### 5.4.1 Adding and Logging MTS channels

The Innovate Motorsports' MTS (Modular Tuning System) allows you to daisy chain multiple devices together via the serial IN and OUT connectors to form one single synchronous log. MTS log chains can consist of a single unit connected directly to a laptop (connect your LC-2 directly to a computer,) two units, or multiple devices connected together, up to 32 channels. Below are some MTS logging examples using a PL-1 to record the information on a SD memory log:



**LC-2**

Air/Fuel Ratio



**SSI-4** (p/n 3783)

RPM, TPS, Drive Shaft  
RPM & MAP

(example only, see our website  
for additional channel input configurations)



**PL-1** (p/n 3875)

Recorded to  
SD Card in  
Pocket Logger



**LC-2 x4**

4-channels  
Air/Fuel Ratio



**LMA-3** (p/n 3742)

RPM, MAP, TPS,  
Injector Duty Cycle  
& EGT



**PL-1** (p/n 3875)

Recorded to  
SD Card in  
Pocket Logger

Innovate Motorsports' MTS devices have two types of serial interface connectors, the legacy 2.5mm stereo and the 4 pin Molex. The following patch cables are available to interface your devices together:

4 Pin Molex to 4 Pin Molex - 4ft	p/n 3846
2.5mm to 2.5mm Stereo - 4ft	p/n 3760
2.5mm to 2.5mm Stereo - 6in	p/n 3789
4 Pin Molex to 2.5mm Stereo - 4ft	p/n 3812

## Appendix A: 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](http://www.innovatemotorsports.com) for a return material authorization (RMA). 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 B: LC-2 Error Codes and Troubleshooting Tips

<b>Error Code</b>	<b>Error Message</b>	<b>Likely Root Cause</b>	<b>Fix</b>
<b>Error 1</b>	Heater circuit shorted	Short in sensor	Replace sensor.
<b>Error 2</b>	Heater circuit open	1. Damaged sensor cable or sensor. 2. Sensor connector not fully seated and locked into position.	1. Verify that all sensor connectors are fully seated and locked into position. 2. Replace sensor 3. Replace sensor cable.
<b>Error 3</b>	Pump cell circuit shorted	1. Short in sensor cable 2. Short in sensor 3. Sensor calibration incorrect	1. Replace sensor cable. 2. Replace sensor. 3. Perform sensor recalibration.
<b>Error 4</b>	Pump cell circuit open	1. Damaged sensor cable or sensor. 2. Connectors not fully seated 3. Sensor calibration incorrect	1. Verify that all sensor connectors are fully seated and locked into position. 2. Perform sensor calibration 3. Replace sensor cable. 4. Replace sensor.
<b>Error 5</b>	Reference cell circuit shorted	1. Short in sensor cable 2. Short in sensor	1. Replace sensor cable. 2. Replace sensor.
<b>Error 6</b>	Reference cell circuit open	1. Damaged sensor cable or sensor.  2. Connectors not fully seated	1. Verify that all sensor connectors are fully seated and locked into position. 2. Replace sensor. 3. Replace sensor cable.
<b>Error 7</b>	System error	System error	Reboot LC-2 by cycling power.
<b>Error 8</b>	Sensor Timing error (typically a damaged sensor).	1. Sensor over-heating or over-cooling (error condition only occurs at wide open throttle )  2. Sensor is damaged	1. Perform sensor calibration. 2. Move sensor bung as far downstream as possible. 3. Add an HBX-1 (p/n 3729) to isolate the sensor from the pipe. 4. Replace sensor.
<b>Error 9</b>	Supply Voltage too low	Supply voltage too low for sensor regulation	1. Verify you have 12V at your power source and the circuit can support a 3 amp draw.

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