



LM-2

Digital Air/Fuel Ratio Meter

User Manual

Note: This manual assumes that firmware version 1.10 is installed on your LM-2



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-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 LM-2

The LM-2 is a single or dual channel wideband controller with a built-in OBD II scan tool, RPM input, four analog inputs, MTS serial I/O, SD memory card recording and two analog outputs per wideband channel. The following screens will help you get familiar with the unit.

Front

Mode Button

Press once to cycle through channel display screens. Press and hold to enter menu.

Cancel Button

Press to cancel out of menu or to stop recording.

Record

Press once to record or press again to stop recording. Press and hold to force a new log.



LCD Display

Up Arrow

Scroll through available channels. Move through menu

Enter

Accept an entry in the menu screen.

Down Arrow

Scroll through available channels. Move through menu

Left



Inductive Clamp

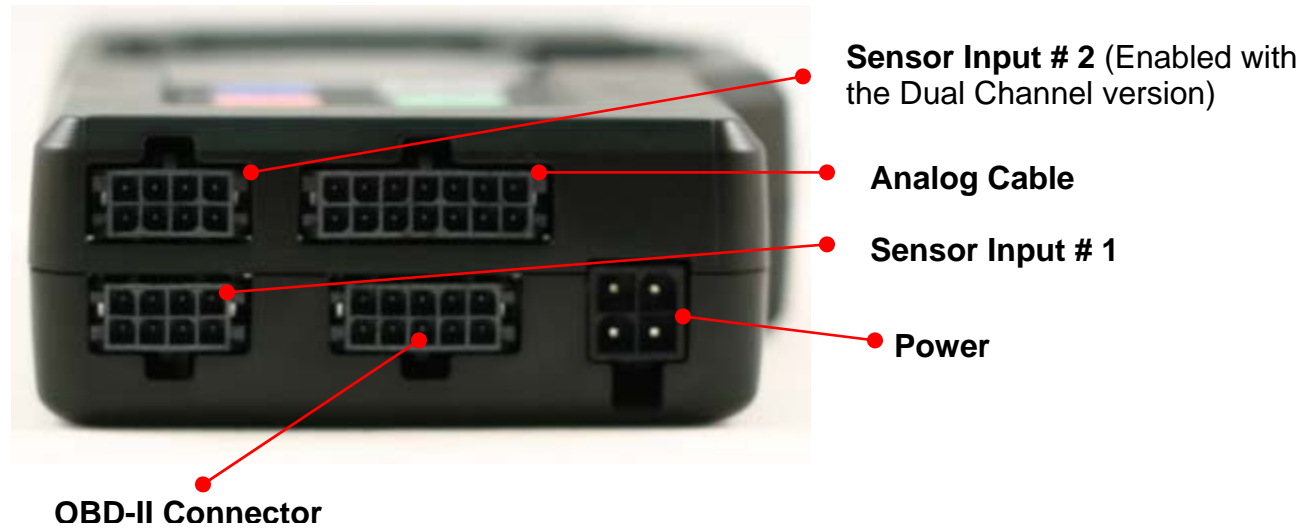
MTS Serial IN

MTS Serial OUT

Top





Bottom



1.1 Main Screen

There are 5 different screen view options. These can be cycled by pressing the Mode button.

<p><i>One Channel</i> O2 Sensor 2</p> <p>0.98</p> <p>Lambda</p> <p>18:45:56 E2 0MH</p>	<p><i>Two Channels</i> O2 Sensor 2 OBD RPM</p> <p>0.99 2470</p> <p>Lambda RPM</p> <p>18:46:08 E2 MH</p>
<p><i>Four Channels</i> OBD SPARKADY OBD IAT</p> <p>-64.0 -40</p> <p>0 -100.00</p> <p>OBD LOAD_PCT OBD SHRTFT4</p> <p>06:31:16 E2 E2 H</p>	<p><i>One Channel Line Graph</i> OBD RPM</p> <p>2730</p>  <p>07:59:12 E2 MH</p>
<p><i>One Channel Fill Graph</i> OBD RPM</p> <p>2550</p>  <p>08:01:56 E2 0 H</p>	

1.2 Status Bar

The bottom edge of the screen is the status bar and will look something like this:

21:35:17 E9 E9 r A.0MH

The left most portion is the current time (which can be set via menu and is set automatically by LM Programmer).

18:46:08 E2 MH

During Recording, an upper case 'R' and a counter will display on the lower left:

A black LCD display with red and white text. The text reads "R 000:40 E2 E2 MH". The 'R' is red, the counter "000:40" is white, and the error codes "E2 E2" and "MH" are white.

Counting minutes and seconds of recording.

Similarly, during playback a upper case 'P' and a counter will display:

A black LCD display with red and white text. The text reads "P 000:40 E2 E2 MH". The 'P' is red, the counter "000:40" is white, and the error codes "E2 E2" and "MH" are white.

Counting elapsed time during playback.

Note: If Recording does not start (see later section), also look here, the word "Card?" will appear if no SD card is detected when Record is selected. The word "Full!" will appear if you have either filled the SD card, or exhausted the available log names (see section on recording).

Moving to the right, the next two indications are O2 sensor status, which can be one of the following:

A black LCD display with red and white text. The text reads "21:35:11 E9 E9 r A MH". The time "21:35:11" is white, the error codes "E9 E9" are red, and the indicators "r A" and "MH" are white.

HW - Heater Warm-up

Cal - Calibrating

O2 - Reading O2 context (lambda over 8.something)

L - Reading Lambda (or AFR)

Ex - Error, Check Appendix E for error code meanings and trouble shooting tips

Note: If the LM-2 is a single channel model, the second indication will be blank, not an error code.

The next indicator, "R", will appear when a) RPM is selected for logging/use (see menus) and b) an RPM signal is detected. Note, when RPM is enabled, but no RPM signal is detected, this symbol will appear in lower case ("r").

A black LCD display with red and white text. The text reads "21:35:17 E9 E9 r A O MH". The time "21:35:17" is white, the error codes "E9 E9" are red, and the indicators "r A O" and "MH" are white.

The "A" indicator means that the 4 Analog Inputs are selected for logging/Use (see menus). It is all or nothing. The display will be blank if disabled.

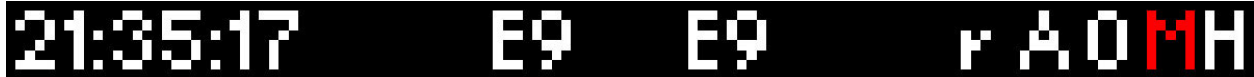
A black LCD display with red and white text. The text reads "21:35:17 E9 E9 r A O MH". The time "21:35:17" is white, the error codes "E9 E9" are red, and the indicators "r A O" and "MH" are white.

The "O" indicates that an OBD-II connection is active. This indicator will blink at the relative 'sample rate', which will vary on the number of channels selected and the vehicle's protocol. The display will be blank if the unit is not connected to an OBD-II port.

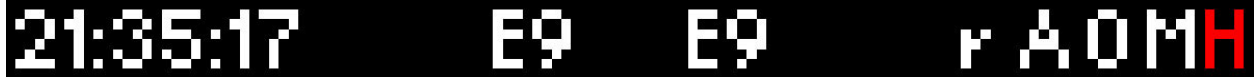
A black LCD display with red and white text. The text reads "21:35:17 E9 E9 r A O MH". The time "21:35:17" is white, the error codes "E9 E9" are red, and the indicators "r A O" and "MH" are white.

The blinking "M" indicates that MTS serial data is being generated. This will blink at the relative MTS packet rate (for comparison with the O indicator). If the unit is not the "head" unit, then this will only blink when packets are being received via the Serial In

connector.

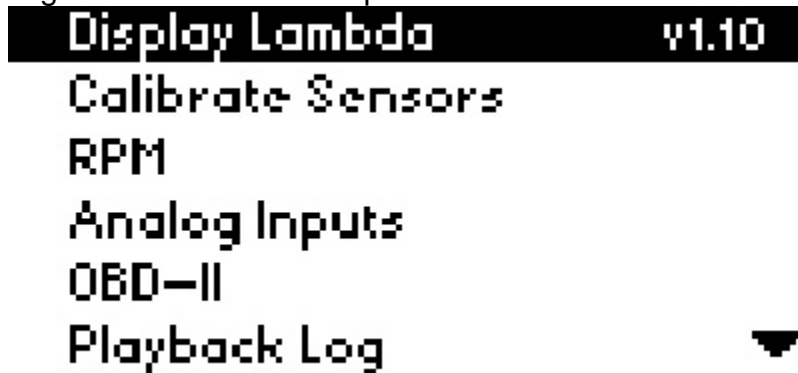
A digital display with a black background and white/red text. The text is arranged in a single line: '21:35:17' on the left, followed by two 'E9' characters in the middle, and 'r AOMH' on the right. The 'H' in 'AOMH' is red.

Last, "H" indicates that the unit is the MTS head unit. If the unit is not head this indicator will appear as a "-"

A digital display with a black background and white/red text. The text is arranged in a single line: '21:35:17' on the left, followed by two 'E9' characters in the middle, and 'r AOMH' on the right. The 'H' in 'AOMH' is red.

1.3 Configuration Menu Screen

To enter the Configuration Menu Screen press and hold the **Mode** button.

A digital display showing a menu. The text is white on a black background. The menu items are: 'Display Lambda v1.10' (with 'v1.10' on the right), 'Calibrate Sensors', 'RPM', 'Analog Inputs', 'OBD-II', and 'Playback Log'. A small white downward-pointing arrow is located to the right of 'Playback Log'.

Navigating the Menu:

- “Enter” Accepts
- “Cancel” Returns one menu level
- “Mode” Returns to Main Screen
- Arrows** adjust selection or value
- “Record” has no effect

When “Mode” is first pressed, the following choices appear:

- **Display AFR or Lambda.** *The factory default setting is AFR.*
- **Calibrate Sensors** - Free Air Calibrate ALL O2 sensors connected will be calibrated
- **RPM** – Enable/Disable RPM and Configure RPM.
- **Analog Inputs**- Enable/Disable Analog Inputs and Configure Inputs.
- **OBD-II** - Configure Number of Channels (0-16), Channel Use, Get/Clear DTC codes Display in Metric/Imperial Units, and Start Trace File.
- **Playback Log**
- **Reverse/Normal Display**
- **Set Date/Time** - Set the current date/time

Important Note: Entering the Configuration Menus will stop recording and suspend MTS packet output

1.4 Recording

To start a record session press the **Record** button. The LM-2's display will then inverse and the status bar will display an upper case 'R' and a counter on the lower left hand corner of the screen. To stop the record session press the **Record** button a second time.

Note: Loss of power while the LM-2 is recording will lose all data from the current session being recorded.

When recording is first activated, a file is created. The naming convention is:

mmddyXX.d32

These are the month, day, and year that the file is created. The XX is to accommodate multiple files on the same day (counting begins at "00").

Once a file exists, sessions are appended to it for each additional recording. The exceptions to this are:

1. The MTS channel count/type has changed
2. The user requests a new log file by pressing and holding "Record" (or holding the record button on an external XD-16.)

The first instance will occur if devices are added or removed the MTS serial chain , or if channels are enabled/disabled on the LM-2.

When a new file is created, it will be given the day's date and a unique counter:

07010800.d32

07010801.d32

Etc

Note: When the LM-2 is recording the display will inverse. In the status bar, an upper case 'R' and a counter will display on the lower left

1.5 Playback

1. Press and hold the **Mode** button to go into the Configuration Menu Screen.
2. Select *Playback log* and press the **Enter** button.
3. A list of available logs present on the memory card will be displayed. Make your selection and press the **Enter** button.

Note: Depending on the size of the log the next screen some time to appear.

4. A list of available sessions will be displayed. Make your selection and press the **Enter** button.
5. The selected session will now start playing. The status bar will display an upper case 'P' and a counter on the lower left hand corner of the screen.

*Note: While the session is being played back you can press the **Menu** button to cycle through the different display screens and you may also press the **Arrow** buttons to change the displayed channels.*

- To stop the playback you may press the **Cancel** button at any time or allow the playback to run its course.

2 Air/Fuel Ratio Setup

Innovate Motorsports' 'Direct Digital' wideband measurement principle allows you to calibrate the sensor to compensate for sensor wear. This procedure takes no more than a couple seconds and it will insure the most accurate readings throughout the oxygen sensor's life.

2.1 Sensor Calibration

The calibration procedure requires that the oxygen sensor be in free air, not in the exhaust.

- Connect the oxygen sensor to the provided sensor cable and then to the appropriate port on the LM-2. **Note:** The dual channel LM-2 model allows you to connect both oxygen sensors to the unit at the same time to do the calibration simultaneously.

- Connect the LM-2 to the cigarette power plug with the provided cigarette power adapter.

- The sensor(s) will start warming up. The LM-2 will display WXX, where XX is the percentage of temperature reached. Notice the status bar displaying a 'W'.

```

02 Sensor 1
W43
AFR
09:47:50 W MH

```

- Next is the calibration procedure. Press and hold the **Mode** button until the Configuration Menu appears. Select 'Calibrate Sensors' and press the **Enter** button.

```

Display AFR v0.9
Calibrate Sensors
Enable RPM
Enable Analog Inputs
OBD-II
Set Time/Date

```

- The display will momentarily display 'Cal' and then it will switch to reading a percentage of oxygen. If the oxygen content now differs from 20.9% by more than 0.6%, repeat the calibration.

```

02 Sensor 1          02 Sensor 1
Cal                 20.9

```

6. The LM-2 is calibrated and ready for use.



The LM-2 must be powered by the cigarette adapter (12 volts) in order to properly heat the Oxygen sensor and measure Air/Fuel. If the unit is only to be used connected to the OBDII port it will properly function as a scan tool.

2.2 Sensor Placement

Using a bung is the preferred method for mounting the O² 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 LM-2 kit). The bung must be installed in the exhaust pipe at the side or on top, NOT on the bottom of the exhaust pipe. Any decent muffler or exhaust shop can do this for you. The wide-band oxygen sensor is then installed into the bung to take a reading. (Insert the plug into the bung when not in use). The ideal position is between 10:00 and 2:00 position.

On NON-CATALYTIC converter vehicles:

You have the option with non-catalytic cars to also use an exhaust clamp as described below. Use of a bung is the preferred method for mounting the O² sensor for both catalytic and non-catalytic cars.

On TURBO CHARGED vehicles:

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

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





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



Wide band oxygen sensors, like the one shipped with the LM-2, are designed to work with unleaded gasoline. Use with leaded gasoline will significantly reduce the lifespan of the sensor. The reduction is directly proportional to the metal content of the fuel and the tune of the engine. 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 LM-2 WHENEVER THE CAR IS RUNNING. AN UN-POWERED OXYGEN SENSOR WILL BE DAMAGED WHEN EXPOSED TO EXHAUST GAS IF NOT PROPERLY POWERED.



The maximum temperature of the sensor at the bung (the sensor hexagon) should not exceed 500 °C or 900 °F. If these temperatures are exceeded in your application you should either install a double length bung (one inch) or the Innovate Motorsports Heat-Sink Bung extender (HBX-1).
The double length bung is also recommended for situations where airflow is restricted.



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

2.3 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 Application, daily driver (tuned rich)

- Calibrate before installation of new sensor
- Calibrate new sensor again after 3 month of use
- Thereafter calibrate twice a year or every 10,000 miles, whichever comes first

Race Application

- Calibrate before first installation of new sensor
- Calibrate once per race weekend
- For added sensor life we also recommend our optional double length bung (part number 3764

Dyno use:

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

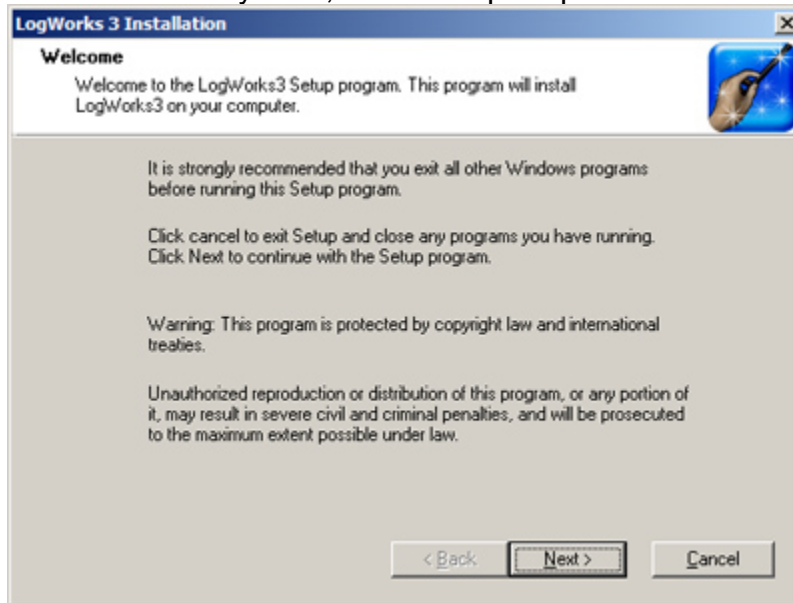
3 Software (LogWorks 3 and LM Programmer)



It is important to install the provided software to the computer prior to connecting the LM-2. Failure to do so may lead to connection complications.

3.1 Installing software and Connecting the LM-2 to computer

1. Install the CD that came with your LM-2 in your personal computer.
2. The installer will automatically start, follow the prompts to install the software.



3. Connect one end of the USB cable to the LM-2 and the other end to your computer.
4. Power up the LM-2. *Note: The unit is not powered up by the USB connector.*
5. Windows will now recognize the device and prompt the “New Hardware Wizard.” Click Next.



6. Select “Install the Device Automatically” and click Next.
7. A progress screen will appear. During this installation process the screen below will pop up. Click “Continue Anyway.”



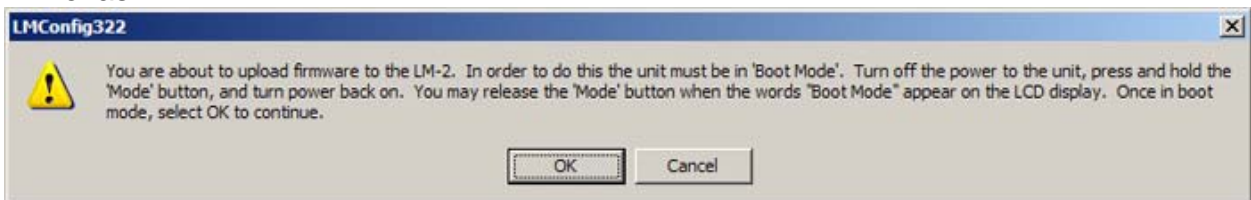
8. The last screen will inform you that the unit has been successfully installed. Click “Finish.” The unit is installed and ready to use.

3.2 Updating Firmware

1. Connect the LM-2 to your computer with the provided USB cable.
2. Power up the LM-2. *Note: The unit is not powered up with the USB connector.*
3. Launch LM Programmer. The LM Programmer application can be launched from *Start->Programs->LogWorks3->LM Programmer* from the Windows task bar.
4. Once connected the LM Programmer will display the current version of the firmware that is installed in the LM-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.
5. On the very first tab of LM Programmer you will see a button labeled “Update Firmware,” click this button.



6. Select the firmware file with the dld extension.
7. The software will now prompt you to put the LM-2 in “Boot Mode.” In order to accomplish this you must power the unit off. Next, while pressing the **Mode** button on the LM-2, power the unit back ON. The LM-2’s display will show that it is now in “Boot Mode.” Press the OK button on the software to start the firmware reflash.



8. You may disconnect and exit out of the software once the firmware update is finished.

3.3 Downloading Logs from Memory Card

Note: An SD memory card reader is necessary to retrieve logs from the memory card. The logs can not be downloaded through the LM-2..

1. Remove the memory card from the LM-2 and insert it in your SD memory card reader.
2. Launch LogWorks 3. The LogWorks 3 application can be launched from *Start->Programs->LogWorks3->LogWorks3* from the Windows task bar.
3. Click on *File->Import/Download->Import LM-2 Log*.
4. A window will pop up which will allow you to select the desired log from the memory card. Click *Open*.

4 OBD-II

The LM-2 allows you to read up to 16 channels of “OBD-II” (“On Board Diagnostic”) information directly from your vehicle’s engine control unit (ECU). A log file can be recorded on the included SD card, and played back on a personal computer using Innovate’s LogWorks software (included with the LM-2) or other 3rd party MTS-compatible applications.

4.1 Locate the OBD-II Connector in your vehicle

This is typically the most dangerous aspect of LM-2 installation. A safety helmet is wholly optional, but a flashlight can be extremely helpful. The connector is required to be within 3’ of the driver’s seat in the vehicle and accessible without tools. Generally it is somewhere just behind the bottom edge of the dashboard, immediately in front of the driver, but it may be in a relatively obscure place, like hidden behind an ashtray.

If you are unable to locate the connector by inspection your best bet would be to either ask a mechanic familiar with the make and model vehicle or locate an online hobbyist/enthusiast group devoted to your vehicle.



Here is a sample OBD-II connector. Please note that the orientation of the connector varies from vehicle to vehicle.



For example, in this example, the wide part of the connector is ‘down’. In other installations this wide part of the connector will be up. In still other installations the entire connector may be ‘facing’ the floorboard.

On many newer vehicles the connector is concealed behind a small door or removable plastic cover plate.

Also, the connector itself may be covered with a small, removable, rubber cap.



4.2 Selecting Channels on the LM-2

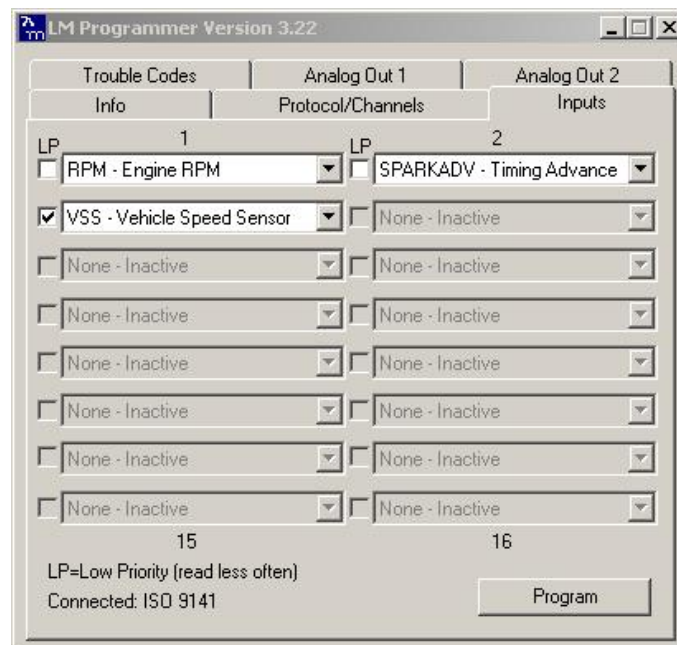
1. Press and hold the **Mode** button to go into the Configuration Menu Screen. Select *OBD-II* and press the **Enter** button.
2. Select *Configure OBD-II*.
3. You will now be given the option to select a particular OBD II protocol or you can leave it on 'Automatic' which will scan all available protocol until it connects. Press **Enter**.A screenshot of a menu titled "OBD-II Protocol:". It shows "0 Automatic" selected. At the bottom, it says "Not Connected".
4. Select the number of OBD II channels to read (A maximum of 16 channels can be selected). It is recommended to start off with 2 to 3 channels to evaluate the speed at which the ECU delivers data. Press **Enter**.
5. You will now be able to scroll through all available channels and make your selection. *Note:* If you are connected the unit will filter and only display the available channels available by the ECU. Press **Enter**.A screenshot of a menu titled "Channel 1 Function:". It shows "1 OBD RPM" selected. At the bottom, it says "Connected: ISO 9141".
6. Chose if the channel is Low or High Priority. Please see section 3.5 of the manual. Press **Enter** to move to the next channel.
7. After all channels have been selected the unit will return to the main screen.



If a PID (channel) is not available for the particular vehicle, the data will read 0)

4.3 Selecting Channels with the LM Programmer software

1. Connect the LM-2 to your computer with the provided USB cable.
2. Power up the LM-2. Note: The unit is not powered up with the USB connector.
3. The LM Programmer application can be launched from *Start->Programs->LogWorks3->LM Programmer* from the Windows task bar. A small dialog box will appear indicating that the program is looking for connected Innovate Devices, then the main dialog should appear.
4. The Inputs tab allows you to set the number of MTS channels to generate.
5. Click the Inputs tab. Only the number of channels selected on the Protocol/Channels page can be edited. The available values for logging on the connected ECU are listed in the drop list for each Input. Some vehicles will support larger lists than others.



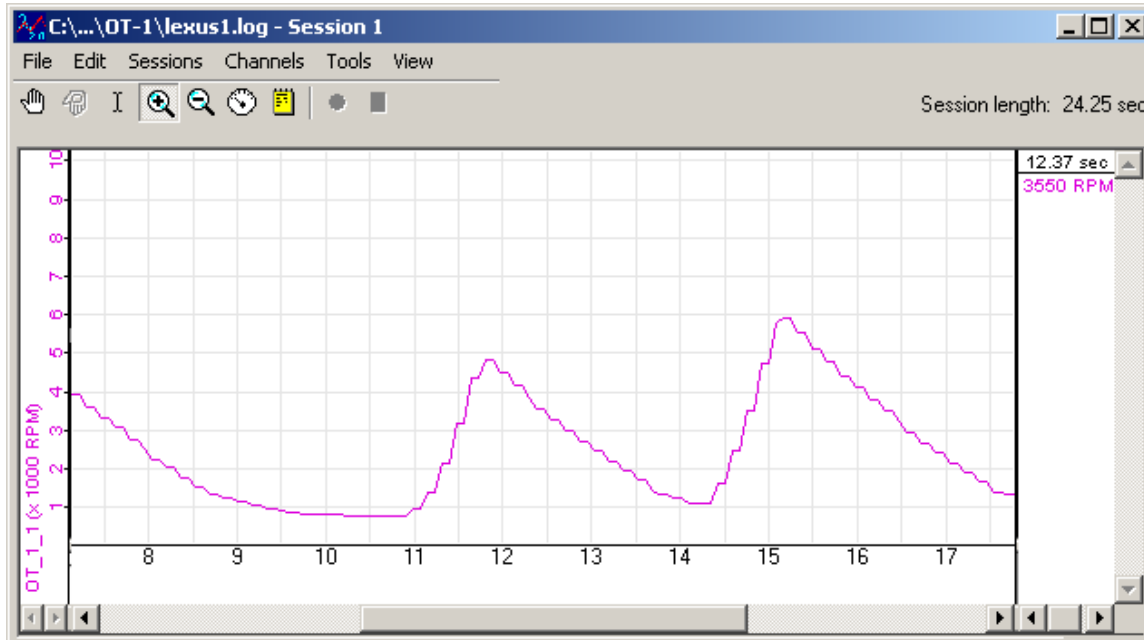
6. Hit the 'Program' button to send the configuration.



Also, it cannot be stressed enough that different ECUs will have dramatically different response speeds. Below are two extreme examples.

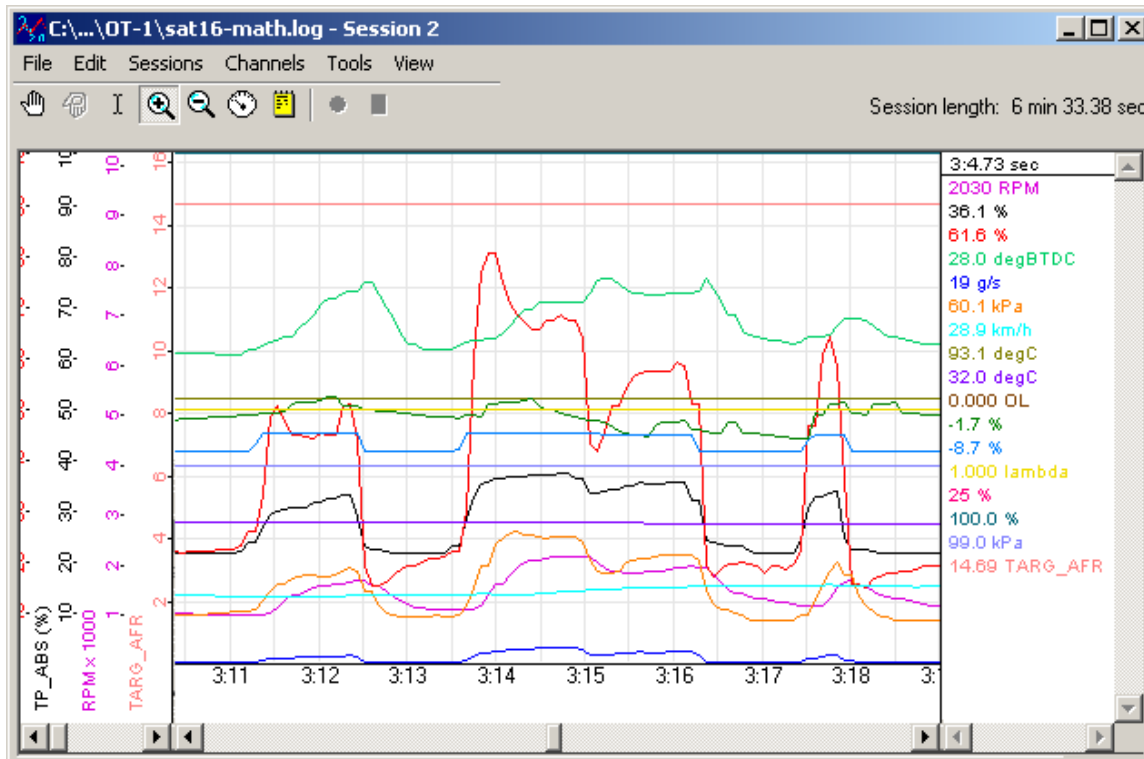
4.4 OBD-II Channel Speed

The first is a log trace of one channel (RPM) from a 2001 Lexus:



Notice that the data appears 'steppy' and, based on the timeline, appears to be updating about 6 times per second.

Next we have a log trace of 16 channels (RPM, MAF, MAP, TP, you name it) from a 2006 Saturn:

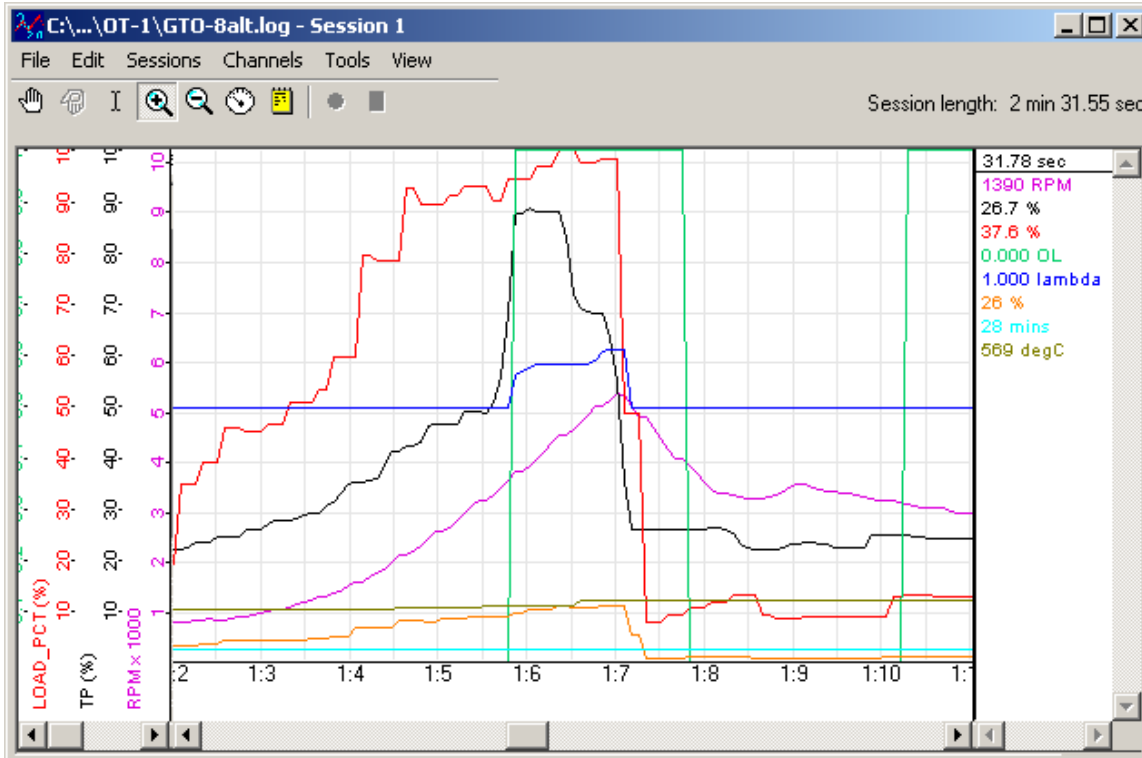


Even if we zoom in to a closer time scale, the data is quite smooth. Performance is controlled by two things:

- The Connection Speed
- ECU Responsiveness

The Lexus in the first example is using ISO 9141 and 10.4K bits per second. The Saturn is using ISO 15765 (CAN) at 500K bits per second. So it is easy to understand the difference in performance.

However, the responsiveness of the ECU also can be a significant factor. Consider this log from a 2006 Pontiac GTO:



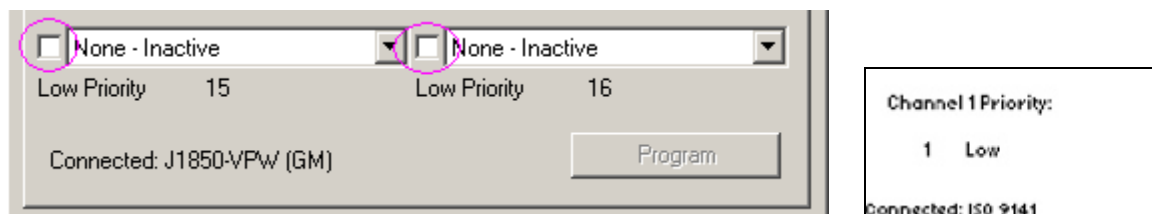
Like the Saturn, it is connected using 500K bit CAN, but we can begin to see some ‘steppiness’ in the RPM channel with only 8 channels being collected. In addition, some values, like the Calculated Load are coarser still. Presumably because the ECU itself is only calculating them a few times per second.

With this in mind, it is probably best to assign channels only a few at a time and then select “Program”. The ECU will disconnect, reconnect with the new choices, and then the overall sample rate of the current settings can be observed using the blinking vehicle light on the LM-2.

It is then up to you, the user, to decide what is an acceptable balance.

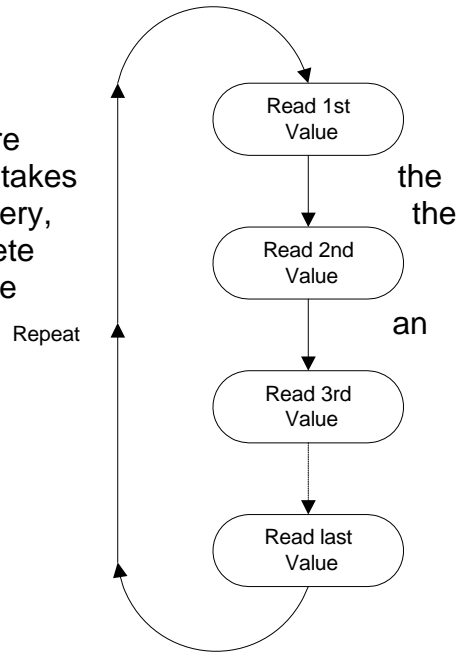
4.5 Set the Priority of OBD-II Inputs (Optional)

Next to each Input Selection on the Inputs page In LM Programmer there is a small checkbox labeled “Low Priority.” This option is also available when selecting channels through the LM-2’s display:

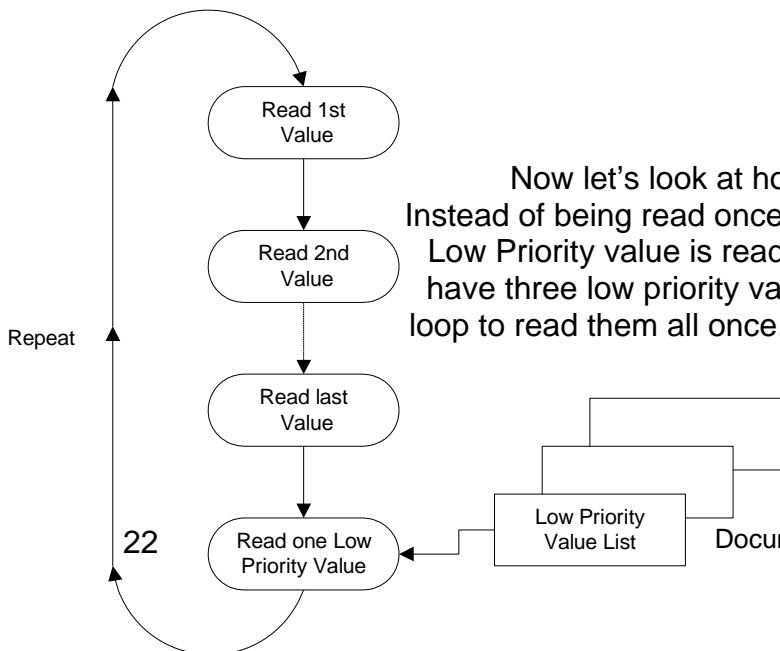


Since it is often a battle getting an ECU to deliver data fast enough, it is reasonable to ask why one would lower the priority of a channel? The simple answer is, some ECU values just do not change very fast. So, reading those values less often means that values that do change quickly can be read more often. To understand how this works let's take a look at how the LM-2 normally reads values:

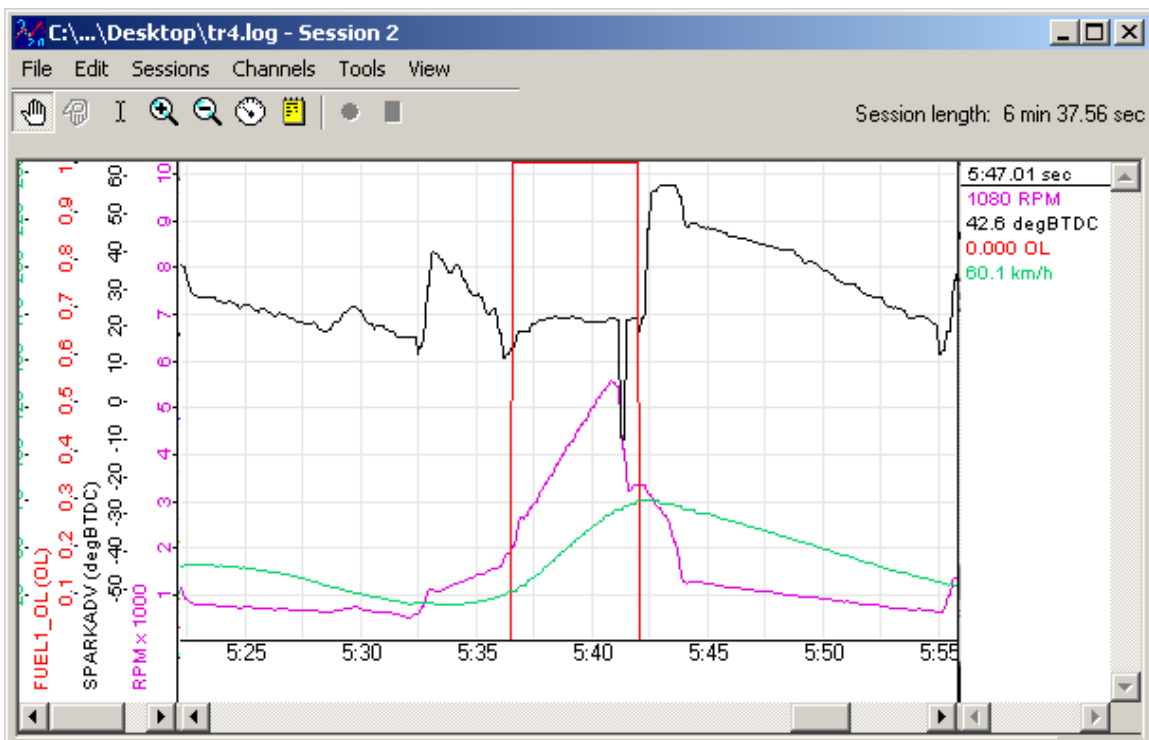
As we can see from the diagram on the right, values are read from the ECU one after another, in a loop. Since the ECU has a certain amount of time to respond to each query, the longer the list of channels, the longer it takes to complete the loop. Obviously, the longer it takes to complete the loop, the larger the time gap between each read of individual value.



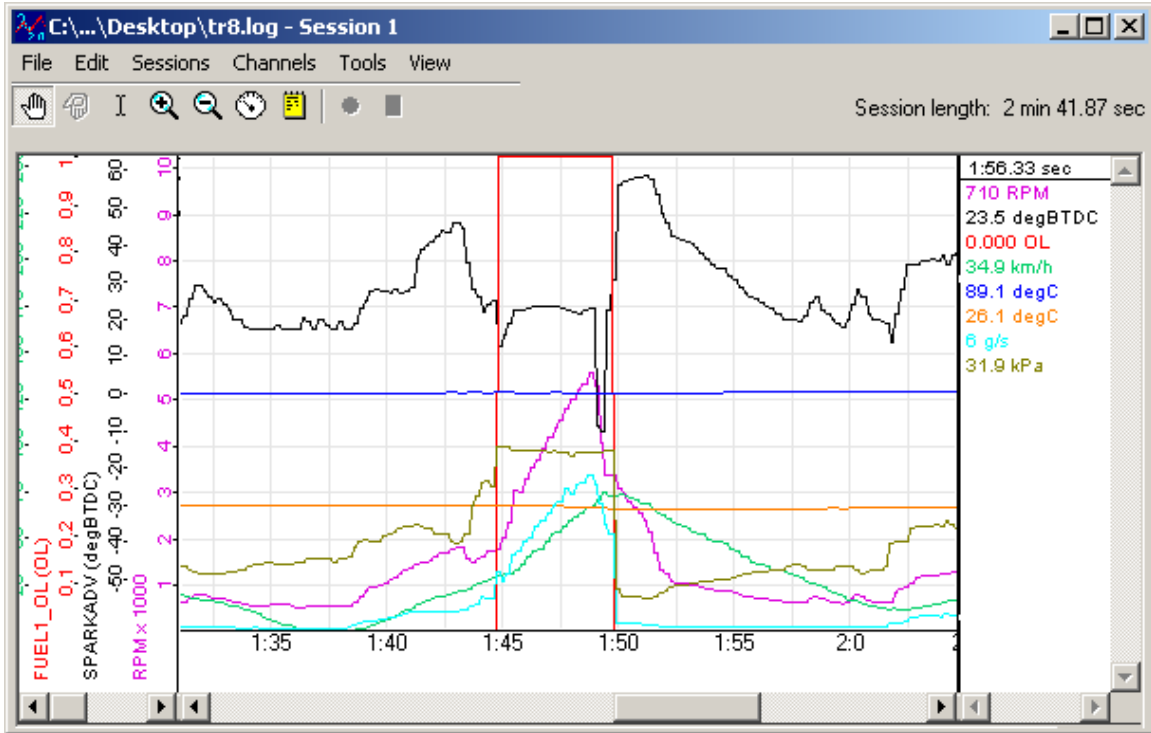
Now let's look at how Low Priority Values fit into this. Instead of being read once each time through the loop, only one Low Priority value is read each time through the loop. So, if you have three low priority values, it will take three passes of the loop to read them all once.



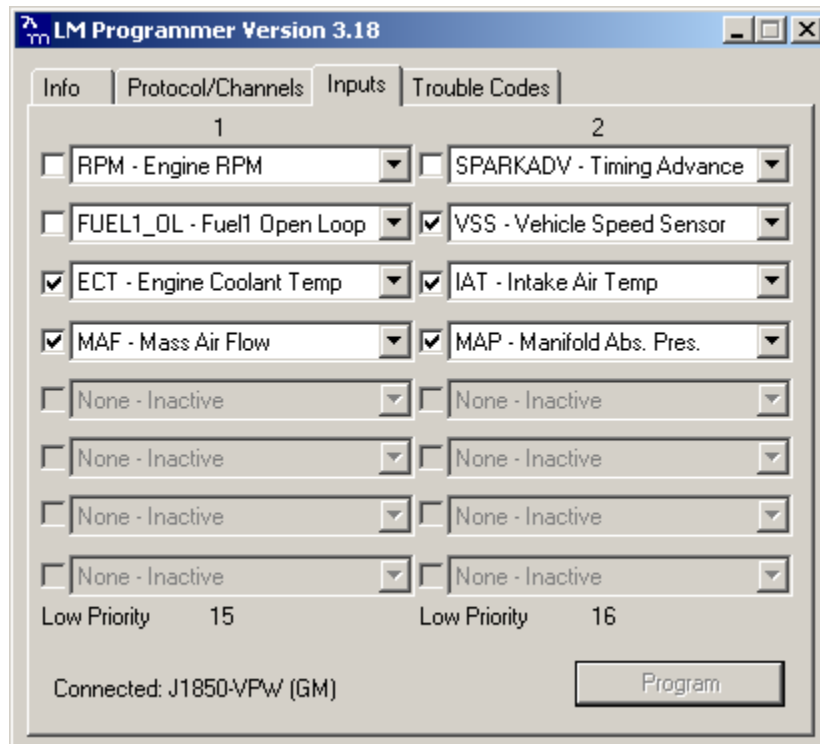
With our racetrack shaped diagram fresh in mind, let's look at Low Priority inputs in practice. In this example the vehicle can provide four LM-2 channels that update at full MTS rates. Even four channels are still very usable. For example, here is RPM, SPARKADV (ignition timing), FUEL1_OL (Open Loop Status) and VSS (Vehicle Speed Sensor):



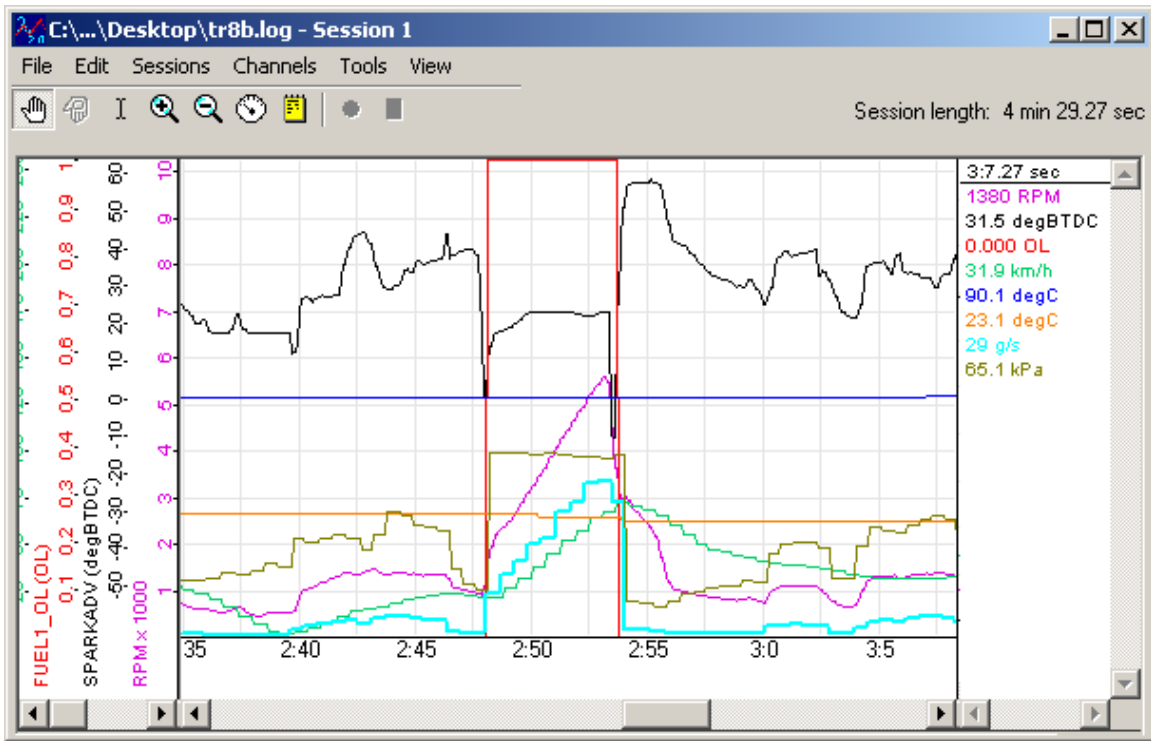
But what would happen if we also added ECT, IAT, MAF, and MAP? If we left all our channels at normal priority, some critical channels may not be fast enough for our purposes:



But not all channels change quickly and we are more concerned with some channels than others. For example, let's say we are primarily concerned with RPM, SPARKADV, and FUEL1_OL. We'd like VSS, IAT, ECT, MAF, and MAP but we do not care if they update slowly. So, we can mark those channels as low priority:



Now, when we log the data, RPM, SPARKADV, and FUEL1_OL, look like our original four channel log:



This extra resolution comes at the expense of our Low Priority inputs. These channels all share the ECU 'bandwidth' once used by VSS alone. But, this lets us have high resolution critical data combined with lower priority, lower resolution data in the same log.

4.6 Check Vehicle Trouble Codes on the LM-2

1. To view your vehicle trouble codes press and hold the **Mode** button to go into the Configuration Menu Screen.
2. Select OBD-II and press the **Enter** button.
3. Select "Get DTC's". A list (if any) of error codes will be displayed on the screen. To see the specific meaning of the error code, select it and click **Enter**. Click **Enter** again to return to the list.
4. Press **Mode** or **Cancel** to exit.

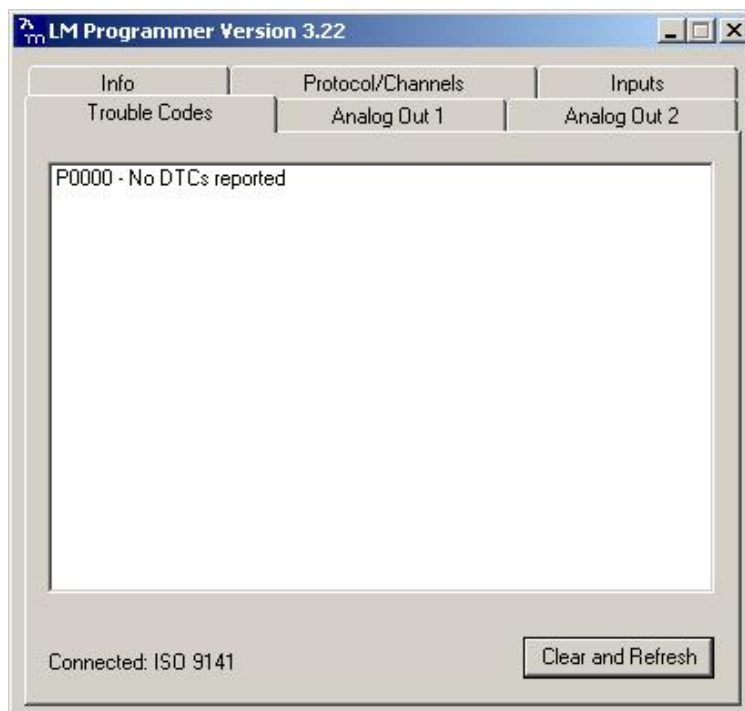
4.7 Clear Vehicle Trouble Codes on the LM-2

1. To clear your vehicle trouble codes press and hold the **Mode** button to go into the Configuration Menu Screen.

2. Select OBD-II and press the **Enter** button.
3. Select Clear DTC Codes and press the **Enter** button.

4.8 Check and Clear Vehicle Trouble Codes with LM Programmer

1. Connect the LM-2 to the vehicle via the OBD II connector.
2. Power up the LM-2. Note: The unit is not powered up with the USB connector.
3. The LM Programmer application can be launched from Start->Programs->LogWorks3->LM Programmer from the Windows task bar. A small dialog box will appear indicating that the program is looking for connected Innovate Devices, then the main dialog should appear.
4. Click the tab labeled "Trouble Codes."



Standard Trouble Codes are listed both with a number and a description. Manufacturer specific codes will generally just appear as a number, though sometimes, the general category can be identified.

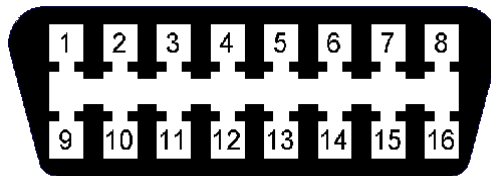
You can request that the ECU clear the pending codes using the Clear and Refresh button at the bottom right corner of the page.

Note: On some vehicles, the ignition must be on, but the vehicle not started, for the Clear DTC request to be accepted.

4.9 OBD II Basics

OBD stands for “On Board Diagnostics”. It represents a collection of industry and legislative standards for getting basic diagnostic information from passenger vehicles sold in the US since Model Year 1996. The “II” means that this is the second attempt at standardizing across all makes and models.

OBD-II standardized what type of information ECU's must provide, but did not set a single standard on how the information should be communicated (typically called a ‘Communication Protocol’ or just ‘Protocol’) or even the electrical characteristics of the communication link itself (usually referred to as the ‘Physical Communication Link’). Instead, the various car manufacturers were each allowed to keep using their own existing protocols and physical links. We can see this compromise on the OBD-II connector itself:



Pin Assignments:

1. -	9. -
2. J1850+	10. J1850-
3. -	11. -
4. Chassis Ground	12. -
5. Signal Ground	13. -
6. CAN (J2284) High	14. CAN (J2284) Low
7. ISO 9141 K line	15. ISO 9141 L line
8. -	16. Battery Power

Note: Pins marked with ‘-’ are sometimes used for make/model specific purposes.

Looking closely we can see that there are really three different electrical ‘pairs’, each representing a different type of physical communication link. J1850 (pins 2&10), CAN (pins 6&14), and ISO (pins 7&15). On top of these three physical communication links are six different communication protocols:

- The J1850 pair uses either J1850pwm (Ford) or J1850vpw (GM)
- The CAN pair uses either ‘standard’ ISO 15765 or ‘extended’ ISO 15765
- The ISO pair use either ISO 9141 or ISO 14230 (sometimes referred to as KWP2000)

So, in order to get OBD-II information from any OBD-II compatible vehicle an interface needs to ‘speak’ six different languages over three different types of electrical links. Starting in MY2008, this will drop to one electrical link (CAN) and two protocol variations

(ISO 15765 standard or extended) but that still leaves about 12 years of 'compromise' vehicles. Fortunately the LM-2 can take care of most of this complexity automatically. So, from a user's point of view OBD-II can primarily be considered on the basis of what is consistent and standard, namely:

- The Connector
- The Information Provided

OBD-II information comes in two basic flavors, "PIDs" and "DTCs". PIDs, or "Parameter IDs", represent real time measurements about the state of the power plant; information such as RPM and ignition timing. The definitive reference on these standard PIDs is the J1979 Standard (last revised 4/2002), published by the SAE International (www.sae.org). Not all ECUs support all PIDs, but the LM-2 understands and converts over 100 of the most common ones (see Appendix B for a complete list).

DTCs, or "Diagnostic Trouble Codes" are, as the name implies, problems reported by the ECU. Codes can be "Standard" or "Manufacturer Controlled". An example of a standard code would be P0051. This code means "HO2S Heater Control Circuit Low, Bank 2, Sensor 1" for all OBD-II vehicles. But P1336 is in the non-standard code range. The exact meaning is up to the vehicle maker. Without information from the car maker all we know from the code itself is that the beginning, P13xx, suggests that it is in the general category of "Ignition System or Misfire."

The definitive listing of standard DTCs is J2012 (last revised 4/2002), also published by SAE International. All these standard DTCs are reported as both a number and in plain English by the LM-2. Manufacturer Controlled DTCs are reported solely by number.

5 Analog Cable

The provided analog cable has 14 stripped ends. The wire assignments are as follows:

Analog Out 1 + (Lime Green) Analog Out 1 – (Yellow)	Analog Out 2 + (Brown/White) Analog Out 2 – (Dark green)
Analog In 1 + (Purple) Analog In 1 – (Black)	Analog In 2 + (Grey) Analog In 2 – (Brown)
Analog In 3 + (White) Analog In 3 – (Red)	Analog In 4 + (Peach) Analog In 4 – (Orange)
RPM + (Black/White) RPM – (Blue)	

5.1 RPM Input

The LM-2 has a direct tach signal input signal. This input can be used to feed a signal from the negative lead of a coil, ECU, negative lead of an injector, or ignition box (i.e. MSD 6AL). This tach signal can be feed to the RPM + (Black/White) wire. The negative wire (Blue) can be connected to ground if a tach signal is not being registered.

5.1.1 Enable/Disable RPM

Enabling the RPM channel will allow you to display the channel on the LM-2 and log it on the SD memory card. Disabling the channel will do the exact opposite.

1. Press and hold the **Mode** button to go into the Configuration Menu Screen.
2. Select *RPM* and press the **Enter** button.
3. You will not have the option to *Enable/Disable RPM*.

5.1.2 Configure RPM

1. Press and hold the Mode button to go into the Configuration Menu Screen
2. Select *RPM* and press the **Enter** button.
3. Select *Configure RPM* and press the **Enter** button.
4. You will now have the option of selecting the Tach input source, use the arrows to change the selection. 0 is the input from the Analog Cable, 1 is the input from the Inductive Clamp. Press **Enter**.
5. You will not have the option to select the 'Polarity.' Rising Edge is the most common way to measure a tach signal. If you find that your readings are very erratic you should change this setting to Falling Edge. Press **Enter**.
6. Select the RPM range. Options are 10230 RPM or 20460 RPM. Press **Enter**..
7. Select Pulses per Rotation. Below are two tables to aid in your selection:

Cylinder number and RPM calibrate number 4 Cyl engine

Number of Cylinders	4-Stroke pulses/Crank-Rotation	Calibrate Number	Comment
1	1/2	1	Use also when using inductive clamp on spark wire or power wire of COP system of 1 cylinder only for all cylinder numbers
2	1	2	Use also when using inductive clamp on spark wire or power wire of Waste spark coil of 1 cylinder only. Waste spark system: 1 coil for every 2 cylinders.
3	1-1/2	3	
4	2	4	
5	2-1/2	5	
6	3	6	
8	4	7	
10	10	8	
12	12	9	

Cylinder number and RPM calibrate number 2 Cycle and Rotary Engine

Number of Cylinders	2-Stroke pulses/Crank-Rotation	Calibrate Number	Comment
1	1	2	Use also when using inductive clamp on spark wire or power wire of COP system of 1 cylinder only for all cylinder numbers Also use for rotary engine.
2	2	4	Use also when using inductive clamp on spark wire or power wire of Waste spark coil of 1 cylinder only. Waste spark system: 1 coil for every 2 cylinders.
3	3	6	
4	4	8	
5	5	8	
6	6	9	

Once the selection is made press **Enter**. You will be brought back to the main screen.

5.2 Analog Inputs

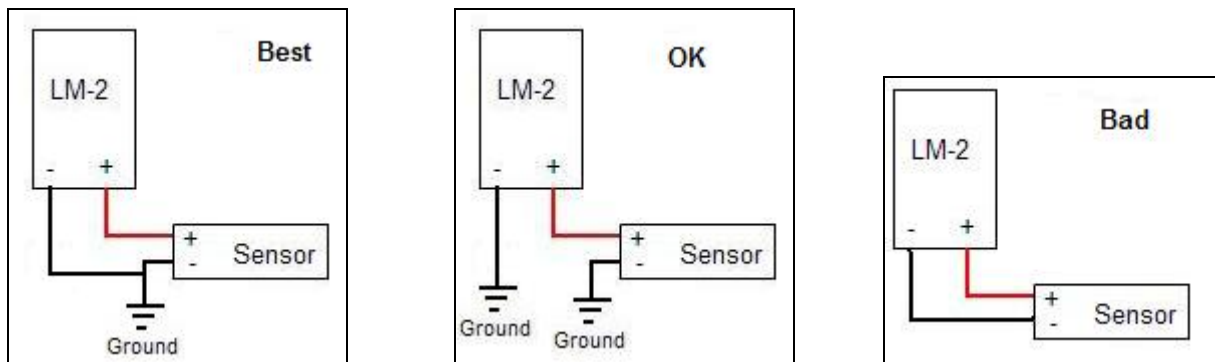
The LM-2 has 4 analog inputs for external 0-5V sensors. Each input has a corresponding positive lead (+) for the signal and a negative lead (-) for the ground signal source. It is important to wire both of these leads to get accurate measurements.

5.2.1 Enable/Disable Analog Inputs

1. Press and hold the **Mode** button to go into the Configuration Menu Screen.
2. Select *Analog Inputs* and press the **Enter** button.
3. You will not have the option to Enable/Disable the Analog Inputs.

5.2.2 Wiring Analog Inputs

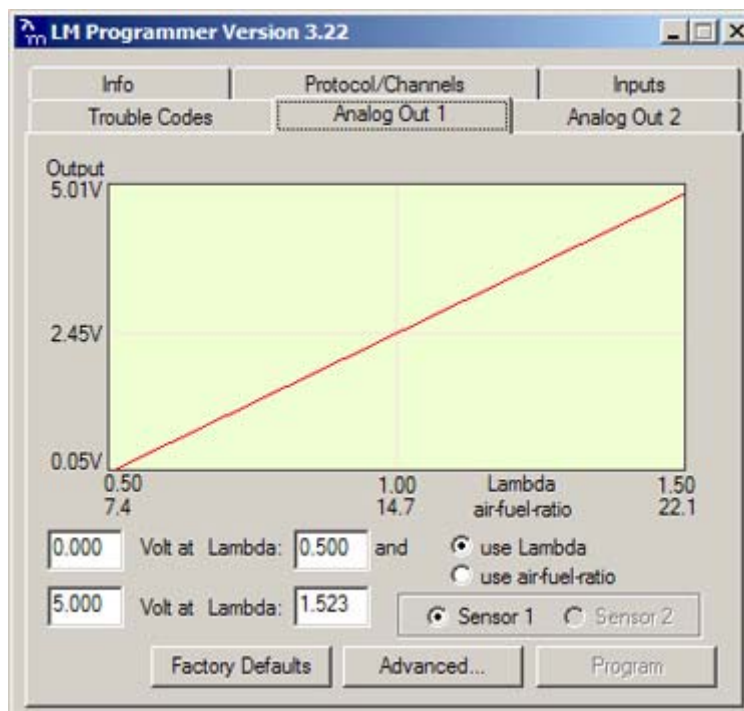
The LM-2's inputs are differential. A differential input does not measure a signal relative to electrical ground. Instead it measures the relative voltage between two signals. That is, it does not measure the '+' signal in relationship to ground, but in relationship to the '-' signal. It measures the 'difference' between them (hence the name differential input!) Below you will find diagrams that should better illustrate the correct way to wire in external sensors. Please note that the + lead is signal positive, NOT power.



5.3 Analog Outputs

5.3.1 Programming the analog outputs

1. Connect the LM-2 to your computer with the provided USB cable.
2. Power up the LM-2. Note: The unit is not powered up with the USB connector.
3. Launch LM Programmer. The LM Programmer application can be launched from *Start->Programs->LogWorks3->LM Programmer* from the Windows task bar.
4. 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 LM-2.

Click the 'Program' button to download the new data into the LM-2. Once the unit is programmed the 'Program' button will grey out.

Note for Dual A/F channel units: You can program each analog output to represent the data from sensor 1 or 2 by selecting the appropriate radio box.

Factory Programmed Defaults:

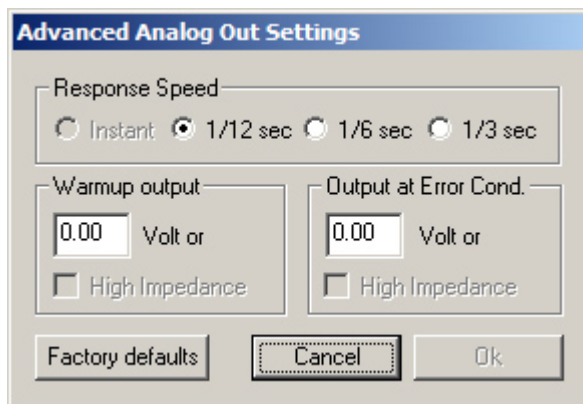
Single Channel A/F units: Analog Output 1 is programmed to output between 0 V for an AFR of 7.35 (gasoline) and 5.0V for an AFR of 22.39. Analog Output 2 simulates a typical narrow band oxygen sensor. The configuration is 1.1 V for an AFR of 14 and .1 V for an AFR of 15.

Dual Channel A/F units: Analog Output 1 and Analog Output 2 are programmed to output between 0 V for an AFR of 7.35 and 5.0V for an AFR of 22.39. They represent sensor 1 and sensor 2, respectively.

Other curves, of course, are easily programmable.

5.3.2 Advanced output programming

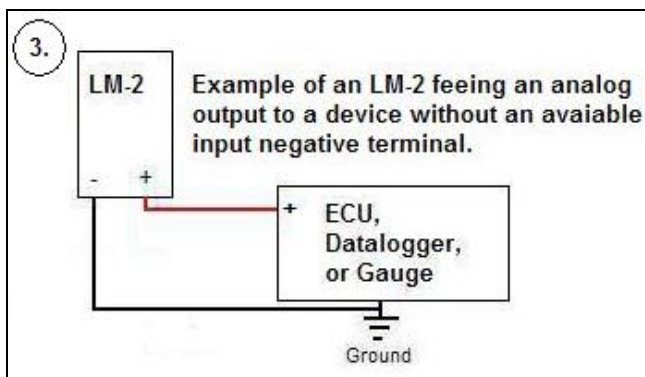
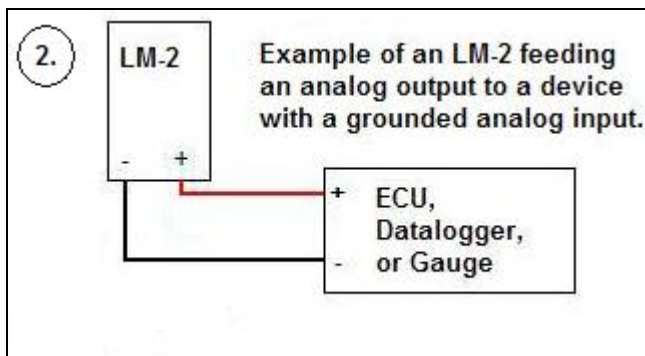
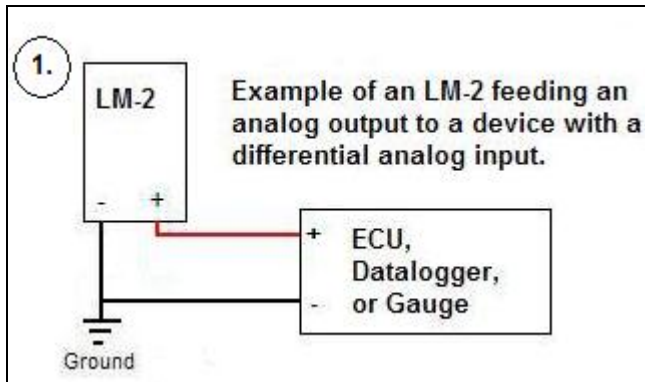
The 'Advanced' button allows programming to set the analog out update speed and the voltage output during sensor Warm-up and Error Condition. The factory defaults of the analog outputs is to update the outputs 1/12 of a second. The factory default voltage output is set for 0 volts for both the Warm-up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



When setting the LM-2 to the slower response speed settings the measured mixture data will be averaged over the response time setting before being output.

5.3.3 Wiring Analog Outputs

The analog outputs on the LM-2 are differential. As with the analog inputs, the negative lead (-) must be connected to ground for the readings to be accurate. Below are the three different ways the analog outputs of the LM-2 can be wired. If you are unsure whether your analog input is differential or not you may wire the analog output as shown in diagram 1.



6 Tips, Tricks, & Troubleshooting

6.1 Air/Fuel and Lambda

The Stoichiometric AFR value is the AFR multiplier. So for (standard, unblended) gasoline its 14.7. If you set it to 14.7 the LM-2 display will show 14.7 AFR for Lambda 1.0. If you set it to 6.4 (methanol) the LM-2 will show 6.4 AFR for Lambda 1.0.

You can look at Lambda as the percent of richness. If running Lambda 0.85 (12.5 AFR for gasoline) you are running 15% rich. For methanol 15% rich means 5.44 AFR. That's where the value of Lambda comes in. If you run blended fuels where you don't know the stoich value, you look at Lambda and adjust to 10-20% rich, depending where your max power is. The % value of richness required by an engine (for max power) does change relatively little (fairly independent of fuel). But if for example you adjust an engine running methanol to 12.5 AFR, you would be running so lean that it would probably not even run.

The LM-2 can be used to read Air/Fuel Ratio (AFR) or Lambda for an engine. For *gasoline*-driven engines, the theoretically optimal air fuel ratio for efficiency is 14.7 pounds of air for every pound of fuel. At this ratio, theoretically, all available oxygen in the air combines with all available fuel. This ratio is called the stoichiometric ratio. Stoichiometric for different fuels are as follows:

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

The measurement Lambda is the actual air fuel ratio over the stoichiometric ratio. A Lambda measurement of "1" equates to the air fuel ratio of 14.7 (for gasoline engines). When Lambda is less than 1 the engine runs "rich", i.e., unburned fuel exists in the exhaust stream. If lambda is greater than 1 the engine runs lean, i.e., free oxygen (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.

6.2 General measurement requirements

The LM-2 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 LM-2

- 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 LM-2 to measure lean.
- 3) The only circumstance where the LM-2 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).

6.3 Vehicles with 'smog-pumps'

Older fuel injected vehicles with a 'smog-pump' actually inject air into the exhaust stream to aid their catalytic converter in the burn-up of unburned or partially burned fuels. This additional air will make the exhaust look leaner than the engine is running. For an accurate measure, install the LM-2 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.

6.4 Single Cylinder Engines

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

6.5 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-2 can still be used, but measurements at idle will read as lean.

6.6 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-2 and operate the sensor in free air (remove from exhaust.) 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 (part number 3737.)

Sensor timing errors are also common when the sensor overheats. Relocate the sensor further downstream in the exhaust and/or install a Heat-Sink Bung extender (HBX-1). This problem is easier to diagnose as you will only see the error code come up at wide open throttle.

Sometimes it's possible to encounter Error 08 when the exhaust gas suddenly gets too rich.

6.7 Connecting the LM-2 to simulate a narrow band oxygen sensor

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

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

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



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

To connect the LM-2 to the EFI-computer, first determine what kind of narrow band sensor is used, then follow the instructions below (you will need a digital multimeter to determine correct OEM sensor wires):

a. Vehicle has a 1-wire sensor:

Wire analog output 1 directly to the wire.

b. Vehicle has a 2-wire sensor:

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

c. Vehicle has a 3-wire sensor:

Typically the 3 wires are: heater power, Ground, and sensor element connection. Generally they have 1 black wire and 2 white wires. Connect the black wire from the EFI computer to analog output 1 of the meter. Leave the other wires unconnected but make sure they cannot contact any metal parts or see above. If the wiring colors are different, then heater power can simply be determined by measuring the voltage on the wires when the engine is running. The wire showing 12V or more is the heater power. The sensor element connection voltage fluctuates around 0.45V when the car is warmed up. Wire analog output 1 directly to this wire. The Ground connection has low resistance to chassis ground (less than 1 Ohm). Measure while the engine is off.

d. Vehicle has a 4-wire sensor

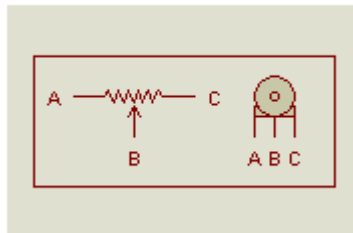
Typically the 4 wires are: heater power, heater ground, sensor ground, and sensor element connection. Proceed as for the 3-wire sensor.

6.8 Attenuating a Tach Signal

The problem of an erratic tach signal happens if there is a lot of ringing at high voltages. To counteract this, it is sometimes necessary to attenuate the tach signal by about 30dB or so. This is accomplished with a 20k or 50k variable potentiometer which can be purchased at Radio Shack or any electronics store.

Wiring

1. Connect the tach signal to terminal A.
2. Connect the terminal B to Ground. (Do not connect this to the Blue tach signal ground on the LM-2's analog cable.)
3. Connect terminal C to the tach signal input of the LM-2's analog cable which is the Black wire with a White stripe.



Tuning RPM

1. Turn the pot all the way to the right (until no RPM is registered).
2. Start turning the pot to the left and stop when you start registering a tach signal and the LM-2 displays an 'R' on the status bar.

6.9 OBD II connection diagnostic trace

In the rare situation where the LM-2 is not able to connect to the vehicle's OBD-II protocol creating a trace file will greatly aid in diagnosing the problem.

1. Press and hold the **Mode** button to go into the Configuration Menu Screen.
2. Select *OBD-II* and press the **Enter** button.
3. Use the **Arrow** buttons to scroll down to *Start Trace File* and press the **Enter** button. A 't' will alternate (or stay steady) in the "O" spot on the status bar.
4. Connect the LM-2 to the vehicle's OBD-II port. Wait one minute.
5. Wait one minute, then either press **Record** to stop, or select "Stop Trace File" from OBD-II menu.
6. A file named OBDIxx.TXT will be saved on the SD card (xx counts up to 99).
7. E-mail this file along with the year, make, and model of the vehicle to the support staff at Innovate Motorsports.

Appendix A: Specifications

Power

Power requirements Single Channel 8-14 Volt / 2 A (max, 1 A nominal)
Dual Channel 8-14 Volt / 4 A (max, 2 A nominal)

Serial Communication

Serial Port Speed 19.2 kbit/sec
Packet/Logging Speed 81.92 msec/sample packet
Sample Resolution 10 bits (0..5V at 0.1% resolution)

Software

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

OBD-II Specifications

Number of Channels 16 (max)
Supported protocols ISO 157650 (CAN), J1850PWM, J1850VPW, ISO 9141,
ISO 14230 (KWP2000)

USB Specifications

Protocol Version 2.0
Supported OSs Windows 98, ME, 2000, XP, and Vista

Temperature

Max Operating -20 to +80 deg Celsius
Temperature

Appendix B: Limited Warranty

LIMITED WARRANTY

Innovate stands behind the quality of its products. Innovate makes the following warranty to purchasers of its products: All new Innovate products carry a 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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Appendix C: Connectors

1. Sensor 1 (2 optional)

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

Tip: Sensor 1 is near the back of the unit and marked with a circled “1”

2. OBD-II

Pin	Use
1	GND
2	VBAT
3	J1850+
4	J1850-
5	ISO K
6	ISO L
7	CAN-H
8	CAN-L
9	Alt-CAN-H
10	Alt-CAN-L

Notes: The “Alt CAN” Buss is for instrument monitoring and is not connected to the J1962 connector in the standard Innovate Cable. Also, the unit can be powered via this connector for basic operation. However, the O2 sensor circuits are not powered when OBD-II is used as the power source. The O2 sensor(s) require the normal power connection.

3. Analog

Looking at the connector with the clip up, pin 1 is the lower left.

PIN	USE	COLOR
1	Analog In 1 -	Black
2	Analog In 2 -	Brown
3	Analog In 3 -	Red
4	Analog In 4 -	Orange
5	Analog Out 1 -	Yellow
6	Analog Out 2 -	Dark Green
7	RPM -	Blue
8	Analog In 1 +	Purple
9	Analog In 2 +	Grey
10	Analog In 3 +	White

11	Analog In 4 +	Peach
12	Analog Out 1 +	Lime Green
13	Analog Out 2 +	Brown/White
14	RPM +	Black/White

Note: All these inputs and outputs are “differential”. That is, the negative inputs must be connected to ground.

4. Serial Out

Pin	Use
1	RX
2	TX
3	GND
4	GND

5. Serial In

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

6. Inductive Clamp

Pin	Use
1	Coil +
2	Coil –

7. USB

Pin	Use
1	NC
2	D-
3	D+
4	NC
5	GND

The unit CANNOT be powered from USB. It must be powered via OBD-II or the main power connector for use.

8. Power

Pin	Use
1,3	GND
2,4	VBAT

Appendix D: Supported PIDs

Name – Description	Units	Min.	Max
"RPM - Engine RPM",	"RPM",	0.0,	10230.0,
"TP - Throttle Position(abs)", "%",	0.0,	100.0,	
"LOAD_PCT - Engine Load(calc)",	"%",	0.0,	100.0,
"SPARKADV - Timing Advance(cyl1)",	"degBTDC",	-64.0,	63.5,
"MAF - Mass Air Flow",	"g/s",	0.0,	655.35,
"MAP - Manifold Abs. Pressure",	"kPa",	0.0,	255.0,
"VSS - Vehicle Speed Sensor",	"km/h",	0.0,	255.0,
"ECT - Engine Coolant Temp",	"degC",	-40.0,	215.0,
"IAT - Intake Air Temp",	"degC",	-40.0,	215.0,
"PTO_STAT - PTO Status",	"PTO",	0.0,	1.0,
"FUEL1_OL - Fuel Sys1 Open Loop",	"OL",	0.0,	1.0,
"FUEL2_OL - Fuel Sys2 Open Loop",	"OL",	0.0,	1.0,
"SHRTFT1 - Short Term Fuel Trim 1",	"%",	-100.0,	99.22,
"LONGFT1 - Long Term Fuel Trim 1",	"%",	-100.0,	99.22,
"SHRTFT2 - Short Term Fuel Trim 2",	"%",	-100.0,	99.22,
"LONGFT2 - Long Term Fuel Trim 2",	"%",	-100.0,	99.22,
"SHRTFT3 - Short Term Fuel Trim 3",	"%",	-100.0,	99.22,
"LONGFT3 - Long Term Fuel Trim 3",	"%",	-100.0,	99.22,
"SHRTFT4 - Short Term Fuel Trim 4",	"%",	-100.0,	99.22,
"LONGFT4 - Long Term Fuel Trim 4",	"%",	-100.0,	99.22,
"FRP - Fuel Rail Pressure",	"kPa",	0.0,	765.0,
"FRP_MED - Fuel Rail Pressure",	"kPa",	0.0,	5177.27,
"FRP_HIGH - Fuel Rail Pressure",	"kPa",	0.0,	655350.0,
"EQ_RAT - Commanded Equiv. Ratio",	"lambda", 0.0,		1.999,
"LOAD_ABS - Absolute Load Value",	"%",	0.0,	802.75,
"EGR_PCT - Commanded EGR",	"%",	0.0,	100.0,
"EGR_ERR - EGR Error",	"%",	-100.0,	99.22,
"TP_R - Throttle Position(rel)", "%",	0.0,	100.0,	
"TP_B - Throttle Position B(abs)",	"%",	0.0,	100.0,
"TP_C - Throttle Position C(abs)",	"%",	0.0,	100.0,
"APP_D - Acc. Pedal Position D",	"%",	0.0,	100.0,
"APP_E - Acc. Pedal Position D",	"%",	0.0,	100.0,
"APP_F - Acc. Pedal Position D",	"%",	0.0,	100.0,
"TAC_PCT - Commanded Throttle",	"%",	0.0,	100.0,
"EVAP_PCT - Commanded Evap. Purge",	"%",	0.0,	100.0,
"EVAP_VP - Evap. Vapor Pressure",	"Pa",	-8192.0,	8191.0,
"AIR_UPS - Secondary Air DNS",	"UPS",	0.0,	1.0,
"AIR_DNS - Secondary Air DNS",	"DNS",	0.0,	1.0,
"AIR_OFF - Secondary Air DNS",	"OFF",	0.0,	1.0,
"FLI - Fuel Level Indicator",	"%",	0.0,	100.0,
"BARO - Barometric Pressure",	"kPa",	0.0,	255.0,
"AAT - Ambient Air Temp",	"degC",	-40.0,	215.0,
"VPWR - Control Module Voltage",	"Volts", 0.0,		65.535,
"MIL - Malfunction Indicator Lamp",	"MIL",	0.0,	1.0,
"DTC_CNT - DTC Count",	"DTCs",	0.0,	1023.0,
"MIL_DIST - Distance MIL active",	"km",	0.0,	65535.0,
"MIL_TIME - Hours MIL active",	"hours", 0.0,		1023.0,
"CLR_DIST - Distance MIL clear",	"km",	0.0,	65535.0,
"WARM_UPS - Warm Ups MIL clear",	"WUs",	0.0,	1023.0,
"RUNTM - Run Time",	"mins",	0.0,	1023.0,
"O2S11 - O2 Sensor(NB) 1-1",	"Volts", 0.0,		1.275,
"SHRTFT11 - O2 Fuel Trim 1-1",	"%",	-100.0,	99.22,
"O2S12 - O2 Sensor(NB) 1-2",	"Volts", 0.0,		1.275,
"SHRTFT12 - O2 Fuel Trim 1-2",	"%",	-100.0,	99.22,
"O2S21 - O2 Sensor(NB) 2-1",	"Volts", 0.0,		1.275,
"SHRTFT21 - O2 Fuel Trim 2-1",	"%",	-100.0,	99.22,
"O2S22 - O2 Sensor(NB) 2-2",	"Volts", 0.0,		1.275,
"SHRTFT22 - O2 Fuel Trim 2-2",	"%",	-100.0,	99.22,
"O2S31 - O2 Sensor(NB) 3-1",	"Volts", 0.0,		1.275,
"SHRTFT31 - O2 Fuel Trim 3-1",	"%",	-100.0,	99.22,
"O2S32 - O2 Sensor(NB) 3-2",	"Volts", 0.0,		1.275,

"SHRTFT32 - O2 Fuel Trim 3-2",	"%",		-100.0,	99.22,
"O2S41 - O2 Sensor(NB) 4-1",	"Volts",	0.0,		1.275,
"SHRTFT41 - O2 Fuel Trim 4-1",	"%",		-100.0,	99.22,
"O2S42 - O2 Sensor(NB) 4-2",	"Volts",	0.0,		1.275,
"SHRTFT42 - O2 Fuel Trim 4-2",	"%",		-100.0,	99.22,
"EQ_RAT11 - WideO2 Equiv-Ratio 1-1",	"lambda",	0.0,		1.999,
"WO2S11 - WideO2 Voltage 1-1",	"Volts",	0.0,		7.999,
"EQ_RAT12 - WideO2 Equiv-Ratio 1-2",	"lambda",	0.0,		1.999,
"WO2S12 - WideO2 Voltage 1-2",	"Volts",	0.0,		7.999,
"EQ_RAT21 - WideO2 Equiv-Ratio 2-1",	"lambda",	0.0,		1.999,
"WO2S21 - WideO2 Voltage 2-1",	"Volts",	0.0,		7.999,
Name – Description	Units		Min.	Max
"EQ_RAT22 - WideO2 Equiv-Ratio 2-2",	"lambda",	0.0,		1.999,
"WO2S22 - WideO2 Voltage 2-2",	"Volts",	0.0,		7.999,
"EQ_RAT31 - WideO2 Equiv-Ratio 3-1",	"lambda",	0.0,		1.999,
"WO2S31 - WideO2 Voltage 3-1",	"Volts",	0.0,		7.999,
"EQ_RAT32 - WideO2 Equiv-Ratio 3-2",	"lambda",	0.0,		1.999,
"WO2S32 - WideO2 Voltage 3-2",	"Volts",	0.0,		7.999,
"EQ_RAT41 - WideO2 Equiv-Ratio 4-1",	"lambda",	0.0,		1.999,
"WO2S41 - WideO2 Voltage 4-1",	"Volts",	0.0,		7.999,
"EQ_RAT42 - WideO2 Equiv-Ratio 4-2",	"lambda",	0.0,		1.999,
"WO2S42 - WideO2 Voltage 4-2",	"Volts",	0.0,		7.999,
"WBEQ_RAT11 - WB-O2 Equiv-Ratio 1-1",	"lambda",	0.0,		1.999,
"WBO2S11 - WB-O2 Voltage 1-1",	"mA",	-128.0,		127.996,
"WBEQ_RAT12 - WB-O2 Equiv-Ratio 1-2",	"lambda",	0.0,		1.999,
"WBO2S12 - WB-O2 Voltage 1-2",	"mA",	-128.0,		127.996,
"WBEQ_RAT21 - WB-O2 Equiv-Ratio 2-1",	"lambda",	0.0,		1.999,
"WBO2S21 - WB-O2 Voltage 2-1",	"mA",	-128.0,		127.996,
"WBEQ_RAT22 - WB-O2 Equiv-Ratio 2-2",	"lambda",	0.0,		1.999,
"WBO2S22 - WB-O2 Voltage 2-2",	"mA",	-128.0,		127.996,
"WBEQ_RAT31 - WB-O2 Equiv-Ratio 3-1",	"lambda",	0.0,		1.999,
"WBO2S31 - WB-O2 Voltage 3-1",	"mA",	-128.0,		127.996,
"WBEQ_RAT32 - WB-O2 Equiv-Ratio 3-2",	"lambda",	0.0,		1.999,
"WBO2S32 - WB-O2 Voltage 3-2",	"mA",	-128.0,		127.996,
"WBEQ_RAT41 - WB-O2 Equiv-Ratio 4-1",	"lambda",	0.0,		1.999,
"WBO2S41 - WB-O2 Voltage 4-1",	"mA",	-128.0,		127.996,
"WBEQ_RAT42 - WB-O2 Equiv-Ratio 4-2",	"lambda",	0.0,		1.999,
"WBO2S42 - WB-O2 Voltage 4-2",	"mA",	-128.0,		127.996,
"CATEMP11 - Catalyst Temp 1-1",	"degC",	-40.0,		6513.5,
"CATEMP21 - Catalyst Temp 2-1",	"degC",	-40.0,		6513.5,
"CATEMP12 - Catalyst Temp 1-2",	"degC",	-40.0,		6513.5,
"CATEMP22 - Catalyst Temp 2-2",	"degC",	-40.0,		6513.5,

Appendix E: Error Codes and Troubleshooting Tips

Error Code	Error Message	Likely Root Cause	Fix
Error 1	Heater circuit shorted	<ol style="list-style-type: none"> 1. Short in cable 2. Short in sensor 	<ol style="list-style-type: none"> 1. Repair/replace cable. 2. Replace sensor.
Error 2	Heater circuit open	<ol style="list-style-type: none"> 1. Damaged sensor cable. 2. Cable connector not fully seated 3. Sensor Damaged 	<ol style="list-style-type: none"> 1. Inspect sensor cable for rips or tears. 2. Verify Sensor is fully seated into connector, make sure it 'clicks.' 3. Replace Sensor
Error 3	Pump cell circuit shorted	<ol style="list-style-type: none"> 1. Short in sensor cable 2. Short in sensor 3. Sensor overheating 4. EGT >1700° F 	<ol style="list-style-type: none"> 1. Repair sensor cable. 2. Replace sensor. 3. Move your sensor bung as far downstream as possible OR add a heatsink to isolate the sensor from the pipe.
Error 4	Pump cell circuit open	<ol style="list-style-type: none"> 1. Damaged sensor cable. 2. Cable connector not fully seated 3. Sensor Damaged 	<ol style="list-style-type: none"> 1. Inspect Sensor cable for rips or tears. 2. Verify Sensor is fully seated into connector, make sure it 'clicks.' 3. Replace Sensor
Error 5	Reference cell circuit shorted	<ol style="list-style-type: none"> 1. Short in sensor cable 2. Short in sensor 	<ol style="list-style-type: none"> 1. Inspect sensor cable for rips or tears. 2. Replace sensor.
Error 6	Reference cell circuit open	<ol style="list-style-type: none"> 1. Cable connector not fully seated 2. Damaged sensor cable 3. Damaged Sensor 	<ol style="list-style-type: none"> 1. Verify Sensor is fully seated into connector, make sure it 'clicks.' 2. Inspect sensor cable for rips or tears. 3. Replace sensor
Error 7	General System error (typically a software error).	Software error	Reboot LM-2 by cycling power. Reload firmware if necessary.
Error 8	Sensor Timing error (typically a damaged sensor).	<ol style="list-style-type: none"> 1. Sensor overheating. (The Bosch LSU4.2 is rated to operate at a sensor housing temperature of < 900 degrees (measured at the bung) for maximum accuracy and control. When this operating temperature range is exceeded, the sensor can no longer be accurately controlled.) 2. Sensor is damaged 3. Overly Rich condition 	<ol style="list-style-type: none"> 1. a. Perform sensor heater recalibration; b. Move your sensor bung as far downstream as possible. Right before the cat, or 2-3 feet from the end of the tailpipe are good locations; c. Add a heatsink to isolate the sensor from the pipe. The HBX-1 is an available accessory. 2. Replace sensor. 3. Correct Tune and recalibrate the sensor.
Error 9	Supply Voltage too low	Supply voltage too low for sensor regulation	Check your 12V connection for corrosion.

7 Revision History

1.0 6/23/2008
Initial Release

1.1 7/10/08
Added RPM setup and LM Programmer configuration screens.

1.2 8/27/08
Added sections 6.8 (Attenuating a Tach Signal), 1.5 (Playback), 6.9 (OBD II connection diagnostic trace), and 3.3 (Downloading Logs from Memory Card). Added references for Inverse screen display in sections 1.3 and 1.4.