LMA-3 Multi-sensor Auxiliary Input Device
User Manual

1. 1. Overview

The LMA-3, also called AuxBox is a peripheral to the LM-1 digital Lambda meter. The LM-1 has 5 auxiliary inputs. The LMA-3 populates these inputs with either built-in sensors or user-connectable external sensors. Each of the five inputs of the LMA-3 can be user configured for different functionalities.

The following table shows the functionality of each of the 5 inputs of the LMA-3:

Table 1: Input Functions

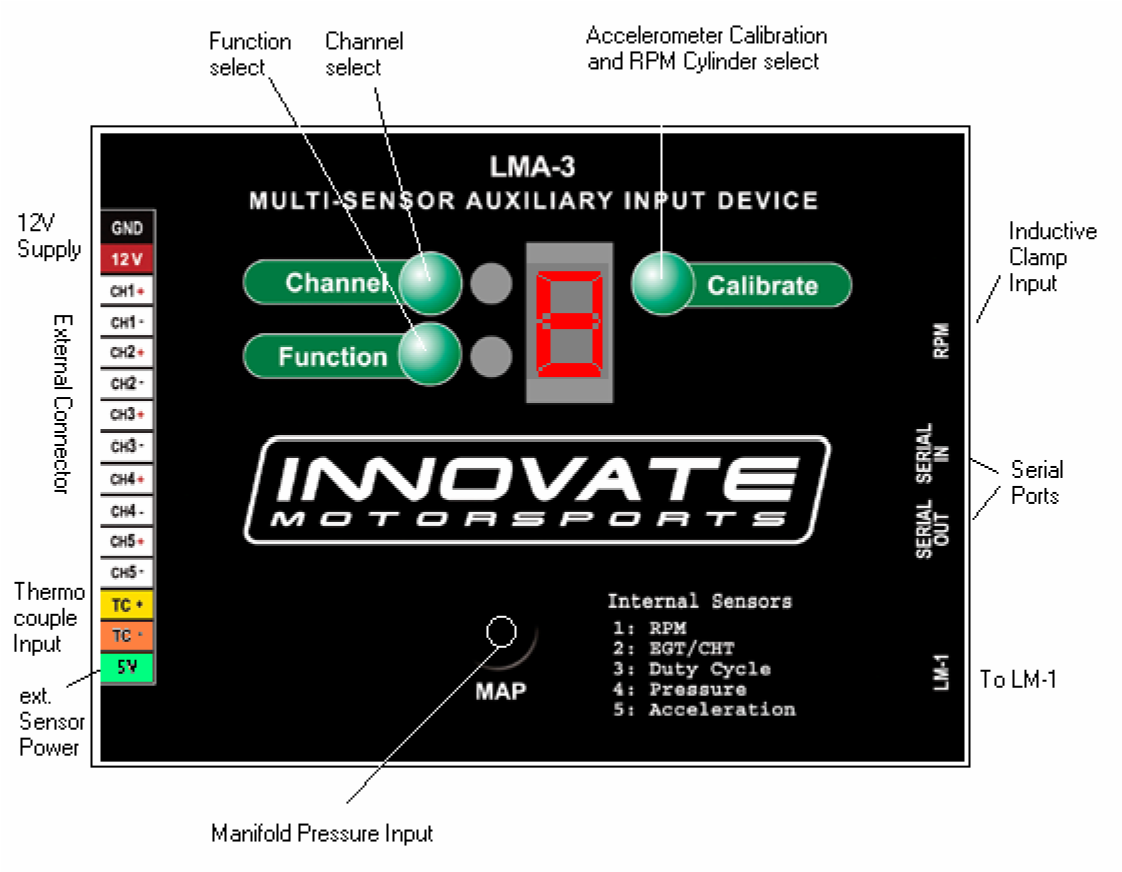
Input	**Function 1**	**Function 2**	**Function 3**	**Function ext**
1	RPM (0..10230)	RPM (0..20460)		External (0..5V)
2	EGT (0..1093 ^{o}C)	CHT (0..300 ^{o}C)		External (0..5V)
3	Duty Cycle (DWELL) (0..100%)			External (0..5V)
4	Absolute Pressure (0..14.7 PSIA)	Absolute Pressure (0..44.1 PSIA)		External (0..5V)
5	Acceleromete r (+- 2 g)	Acceleromete r (+- 1 g)	Acceleromete r (+- 0.25 g)	External (0..5V)

The LMA-3 also can act as a power supply for user supplied external sensors. The 5V output of the LMA-3 can supply up to 300mA of current. For this functionality the LMA-1 must be connected to a switched 12V source in the car. It converts the 12V to 5V to power the sensors.

When no external sensors need to be supplied with 5V power, the 12V connection can be left open.

2. Connecting the LMA-3

The LMA-3 looks like this:



Plug the supplied Mini-DIN8 to Mini-DIN8 cable in the LM-1 port of the LMA-3. Plug the other end of the cable into the AUX-IN port of the LM-1.

The LMA-3 is now operable and is powered by the LM-1.

2.1 Connecting external sensor signals

For each external connection you can connect the external sensor's output to the CHx+ connection. Connect the CHx- connection to the ground of the sensor. Make sure the sensor output signal does not exceed 5V. The LMA-1 is protected if sensor signals exceed that (up to 40V for most inputs), but it can not measure beyond a 5V signal.

2.2 Powering external sensors

If you want to power external sensors, connect a switched 12V supply (switched on when the cars ignition system is on) to the connection marked 12V on the left side. Connect the connection marked GND to the cars chassis ground. At the connection marked 5V you can connect external sensors. External sensors don't HAVE to be powered by the LMA-3. The 5V output is a convenience for external sensors when no 5V supply is available. The 5V supply can power sensors with a total power consumption of up to 300mA.

2.3 Connecting an RPM signal

For RPM measurement you can either connect a tach signal to the CH1+ input or plug an inductive clamp into the 3.5 mm stereo socket marked RPM. See chapter 5 for RPM measurement details.

2.4 Connecting Type K Thermocouples

Thermocouples are used to measure temperatures by relying on the phenomena where a junction of any two different metals (Copper and Iron, for example) will generate a small voltage. This voltage is dependant upon which two metal are used, and the temperature of the junction. This phenomena is known, formally, as the "Seebeck Effect". Because every junction of different metals contributes its own voltage into the measurement, it is important to have as few junctions between dissimilar metals as possible in order to record an accurate measurement. This is why thermocouple wire is made completely of two different metals. The "Type K" thermocouple included in the LMA-3 kit is composed of Copper and Constantan; one lead being made of each (the red and yellow leads). ***Do not look in the box for a thermocouple sensor to put onto the end of the thermocouple wire. The wire IS the sensor.***

To use a thermocouple, strip approximately 3/4" of insulation form one end of the thermocouple wire. Twist the two exposed metal ends together. You may optionally solder them, also. But twist them first. Do not solder them in parallel. This will form what is called the "Hot junction". This "Hot junction" is what you will connect to the surface that you want to measure. This is usually either: a) under the copper gasket of a sparkplug for cylinder head temperature (CHT) or, b) clamped to a primary header tube for exhaust gas temperature (EGT).

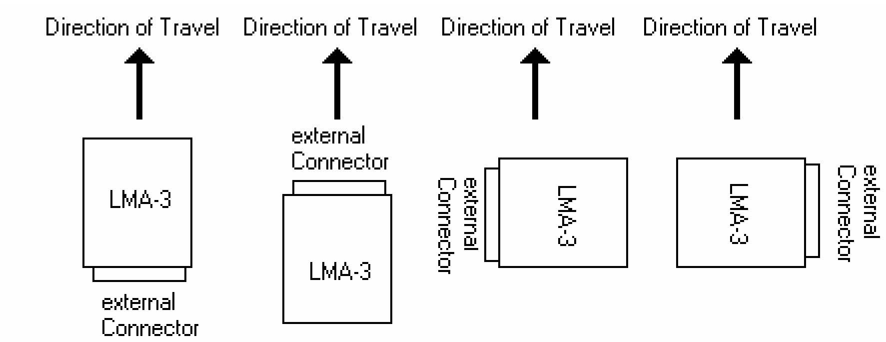
There is also the "Cold junction." This is where the 2 leads of the thermocouple come together again at the LMA-3 terminals. The LMA-3 has an internal temperature sensor at the T/C input terminals. It uses this sensor to "offset" the effect of the "Cold junction" in the measurement. This is called "Cold junction compensation". Once the effects of the cold junction are neutralized, the LMA-3 can accurately read the temperature of the "Hot junction" which is the twisted lead pair at the opposite end of the thermocouple wire.

One thing that is counter intuitive for many people is that the *negative side of a thermocouple wire is always red.* There are many different types of thermocouple wire; types K, J and T being the most popular. All have a red negative lead and a yellow, black, or blue positive lead respectively. **When connection the thermocouple to the TC terminals on the LMA-3, be sure to connect the yellow lead to the + and red lead to the - terminals.**

Several manufacturers offer EGT "thermocouple probes" which are actually inserted into the exhaust gas stream through a hole in the headers or exhaust manifold. These provide a more accurate measurement of exhaust gas temperature. They are commonly available in types K and J. Only type K will currently work with the LMA-3. To use a thermocouple probe, connect the red and yellow leads of the thermocouple wire to the yellow and red leads of the thermocouple probe. The junction is inside the probe. **You can not use normal copper wire to connect the thermocouple probe to the LMA-3.** You must use thermocouple wire to connect the probe. If you do not, there will be an extra two-metal junction where the Copper wire meets the Constantan wire of the probe. This extra junction will cause a large error in the temperature readings.

3. Mounting and calibrating the LMA-3

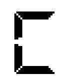
In order to use the acceleration sensor of the LMA-3, care must be taken to mount the LMA-3 correctly on a horizontal surface in the car. The LMA-3 MUST be aligned with the direction of travel. The following pictures show the four possible mounting positions.



The mounting position should not deviate more than 3 degrees from horizontal.

3.1 Calibrating the Acceleration Sensor to the mounting position

Lay the LMA-3 down on the mounting surface, but don't mount it yet. Switch the LM-1 on to power the LMA-3 or switch the 12V supply to the LMA-3 on if it is powered from a switched 12V supply.

Press the 'Calibrate' button until the digit display shows a blinking C 

If the mounting surface is not within the 3 degrees of horizontal, the acceleration sensor can't be calibrated for zero g and the LMA-3 shows a blinking E for Error: 

After the zero g acceleration calibration is performed, hold the LMA-3 such that the side of the LMA-3 pointing in the intended direction of travel points vertically up. Then press the Calibrate button again until the blinking C shows up.

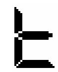
You can now mount the LMA-3.

4. Setting up the input channels

The LMA-3 can be programmed directly through the setup buttons on the LMA-3. After the release of the forthcoming LM Programmer software version 2.1 (or later) you will be able to program the LMA-3 via the LM Programmer software.

4.1 Programming the LMA-1 with the setup buttons

To program an input channel, repeatedly press the ‘Channel’ button until the channel number to program appears on the LMA-3 digit display. Then repeatedly press the ‘Function’ button until the digit display shows the intended function. The digit display will switch rapidly between indicating the input channel number and the set function. The LEDs next to the channel and function buttons will indicate which value is being displayed.

If the function selected is EGT measurement the digit display shows a ‘t’ like this: .

If the function selected is External input, the digit display shows a ‘=’ sign like this: 

Refer to Table 1. for the different functions for the inputs.

5. RPM measurement

5.1 RPM Measurement basics

Most RPM measurement methods use the ignition system of the car as a convenient source of RPM dependent pulses. Other methods use a TDC sensor (one pulse per rotation), cam sensor, or fuel injection pulses (number of pulses/rotation is dependent on the fuel-injection system). Some actually measure the AC frequency created by the car's alternator.

Because the number of pulses per crank rotation is dependent on the ignition system and engine type, a universal RPM measurement method must be adaptable to the different environments encountered. The typical ignition system consists of an ignition coil, a coil driver that switches current to the coil on and off, and a distributor. When current is switched on to the coil, the coil stores energy in its magnetic field. When the current is switched off, that energy gets discharged at a very high voltage pulse on the coil’s secondary winding, creating a spark.

A capacitive discharge ignition system (CDI) uses a capacitor to store the spark energy. The capacitor is charged to about 400V and then rapidly discharged over the ignition coil's primary winding. The coil thus only acts as transformer and does not store energy (and can therefore be smaller). The advantage of a CDI system is a very high and fast rising spark voltage (less susceptible to spark fouling). The weakness of the CDI system is the very short duration spark, which might not be long enough to ignite the mixture. Multispark ignition systems try to overcome the inherent weakness by creating multiple spark pulses over some degrees of crank rotation to increase the likelihood of igniting the mixture. The distributor switches the spark voltage to the appropriate spark plug.

5.1.1 Four-Stroke Engines

On a typical 4-stroke engine each spark plug fires once for every two crank rotations. The coil on a distributor-equipped 4-stroke has to create sparks for every cylinder. The number of ignition pulses per crank rotation in this case is the number of cylinders divided by 2.

Some engines have one coil for every 2 cylinders instead of a distributor. The coil fires two spark plugs at the same time. One spark is wasted because it fires one cylinder at the end of its exhaust stroke. Therefore, this system is called a Waste Spark System. Each coil of a Waste Spark System fires once for every crank revolution.

Other distributor-less 4-stroke engines use one ignition coil for every spark plug. This ignition system fires each coil once for every 2 crank revolutions.

Coil-on-Plug ignition systems actually incorporate the ignition coil in a module that plugs directly onto a spark plug and do not have a spark plug wire.

5.1.2 Two-Stroke Engines

On a 2-stroke engine there is a spark for every crank rotation, so the spark frequency doubles compared to a 4-stroke.Very few multi-cylinder 2-strokes have distributors. For those that do, the number of ignition pulses per crank rotation is equal to the number of cylinders. Most two-stroke engines have one coil for every cylinder. The coil fires once for every crank revolution, the same as on a 4-Stroke Waste Spark system.

5.1.3 Rotary Engines (Wankel Engine)

A rotary engine consists of a roughly triangle shaped rotor rotating in a roughly elliptical chamber. The three spaces left between the chamber and the rotor go through the four cycles of a four-stroke engine for each rotation of the rotor. A single (or dual) spark plug at a fixed position in the chamber ignites the mixture of each space in sequence. Therefore, a rotary engine requires 3 sparks for every rotation of the rotor. The mechanical power from the rotor is coupled to an eccentric gear to the output shaft. This gear has a 3:1 gear ratio and the output shaft therefore rotates 3 times faster than the rotor. The output shaft is the equivalent of the crankshaft on a piston engine. Because RPMs are measured conventionally as the rotations of the crankshaft, the rotary engine requires one spark for every 'crankshaft' rotation, the same as a two-stroke engine.

5.2 Programming the RPM input

- Determine the number of ignition pulses per crank rotation. Refer to Table 2 or 3 for guidance.
- Press the 'Channel' button until it shows channel 1.
- Press the 'Function' button until it shows 1 or 2. Use 1 if your engine's redline is below 10000 RPM. Otherwise use 2.
- Press the 'Calibrate' button until the selected Cyl. Number apears

Table 2: 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	8	
10	10	A	
12	12	C	

Table 3:: 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	A	
6	6	C	

5.3 Using the LMA-3 with the Inductive Clamp

The inductive clamp measures the magnetic field created around a spark plug wire when spark current flows. If a metallic shield covers the spark plug wire, the inductive clamp may not work because the shield would short out the magnetic field. Like all inductive clamp rpm pickup devices, some ignition systems like Capacitive Discharge Ignition (CDI) or multi-spark ignition systems may not work properly with the inductive clamp pickup because the pulses created may be too short in duration. Multi-spark systems confuse the ignition timing measurement because the RPM converter cannot distinguish which ignition pulse belongs to which crank rotation**. The LAM-3 will work only on the tach output of the ignition system in this case.**

The inductive clamp must be clamped around ONE lead only. Clamping it (for example) around all wires of a coil-on-plug pack does not allow it to work because the magnetic fields of the wires most likely cancel each other out.

5.3.1 Inductive Clamp Usage

- Plug the inductive clamp's 3.5mm audio plug into the RPM socket of the LMA-3.
- Clamp the Inductive Clamp on the spark plug wire of one cylinder so the wire is completely surrounded by the clamp.
- Make sure the clamp is completely closed.
- Start the engine.
- Switch on the LM-1 unit.

The decimal point of the digit display of the LMA-3 should light up steadily. This indicates when a valid RPM signal is detected. If it does not light up, or lights up intermittently, reposition or reverse the clamp (try clamping it upside down). If the decimal point out only occasionally, that is OK. The RPM converter will still convert, though its output might be noisy. A noisy output has spikes or lengthy flat areas in the data log. *[Note: to work properly with the inductive clamp pickup the LMA-3 must be set up for the appropriate number of pulses per crank rotation.]*

- For a 4 stroke engine without waste spark ignition, this would be 1 pulse per 2 crank rotations. This is the factory setting.

- For a 4 stroke engine with waste spark ignition, or a 2 stroke engine, this would be 1 pulse per crank rotation.

- For a rotary engine, this would be 1 pulse per rotation. This is the same as for a 1-cyl 2-stroke motor.

Note: On any distributor-less ignition system you can alternately clamp the inductive clamp around one of the power wires on the primary side of the ignition coil or coil-on-plug module.

5.4 Using the RPM-Converter with pulsed RPM input (Tach) signals

- Unplug the inductive clamp from the LMA-3 if connected.
- Connect the RPM signal to the CH1+ input screw terminal.

The decimal point of the digit display of the LMA-3 should light up steadily. This indicates when a valid rpm signal is detected. If it does not light up, check your connections.

DO NOT CONNECT A PULSED RPM SIGNAL TO THE INDUCTIVE CLAMP INPUT. THIS MIGHT DAMAGE THE LMA-3 OR LM-1. Again, this should just result in an error code, not mechanical damage.

6. Using the LMA-3 with LogWorks

When using LogWorks 1.1 (or 1.11), some of the AuxBox default settings are different from the actual LMA-3. For those input channels on the LMA-3 that are not correctly handled, use the Custom setup function of LogWorks to set the channel up correctly. The following table shows how.

Input Channel	Function 1	Function 2	Function 3	Function E
1	0..10230 RPM (LogWorks is correct)	0..20460 RPM (LogWorks is correct)		User defined custom settings
2	0..1093 deg C or 32..2000 deg F Thermocouple EGT range (LogWorks is correct)	0..300 deg C or 32..572 deg F Thermocouple CHT range (LogWorks is correct)		User defined custom settings
3	Dwell 0..100% (LogWorks is correct)			User defined custom settings
4	Manifold absolute pressure (normally aspirated) 0..101 kPa or 0..14.7 PSI or 0..1 bar (LogWorks is correct)	Set as Custom 0 kPa = 0V 304 kPa = 5V Or 0 PSI = 0V 44.1 PSI = 5V Or 0 bar = 0V 3 bar = 5V		User defined custom settings
5	Set as Custom -2g = 0V +2g = 5V Or -19.62 m/sec^2 = 0V +19.62 m/sec^2 = 5V Or -64.37 ft/sec^2 = 0V +64.37 ft/sec^2 = 5V	Set as Custom -1g = 0V +1g = 5V Or -9.81 m/sec^2 = 0V +9.81 m/sec^2 = 5V Or -32.18 ft/sec^2 = 0V +32.18 ft/sec^2 = 5V	Set as Custom -0.25g = 0V +0.25g = 5V Or -2.45 m/sec^2 = 0V +2.45 m/sec^2 = 5V Or -8.05 ft/sec^2 = 0V +8.05 ft/sec^2 = 5V	User defined custom settings

7. Updating the LMA-3 firmware

This requires LM Programmer Version 2.1 or later (not yet released at time of writing).

To update the firmware, connect a free serial port of your computer with the supplied 2.5mm Stereo to DB-9 cable to the port marked ‘Serial Out’ of the LMA-3.

Plug the supplied 2.5 mm terminal plug in the port marked ‘Serial In’ of the LMA-3.

Connect the LMA-3 to the LM-1 as described in chapter 1. Or connect the LMA-3 to a 12V supply as described in chapter 2.

Start the LM Programmer software.

The LM Programmer software scans through all serial ports of your computer until it finds a compatible programmable device.

The LM Programmer software then shows in its first page the type and version number of the firmware of the device. Click on the ‘Update Firmware’ button. You will be presented with a file dialog box that allows you to select a firmware file. Firmware files end with the file extension .dld. LMA-3 firmware file names start with: AUXB1 for AuxBox 1. The first part is followed by a dash, then a V, then the version number without dots.

Example: LMA-3 firmware version 1.00 alpha release would have the file name AUXB1-V100A.dld LAM-3 firmware version 1.00 would have the file name AUXB1-V100.dld

After you opened the firmware file, this new firmware will be downloaded in the LMA-3 device.

8. Revision History

1.0 -- 8/23/04
Initial release.

1.1 -- 8/31/04
Corrected miscellaneous typographical errors.

1.2 -- 9/1/04
Corrected table 1 and section 6.

1.3 -- 9/20/04
Corrected miscellaneous typographical errors.