



**LM-1 RPM Converter (Aux. Input Cable #2)**

**USER MANUAL**

# LM-1 Aux Input Cable and RPM Converter

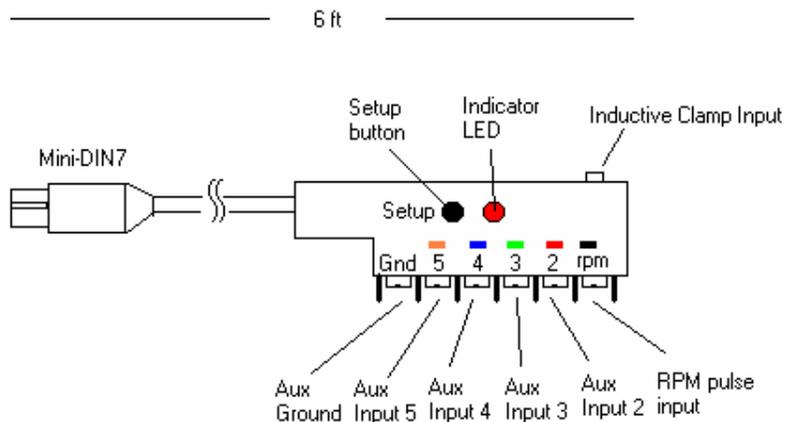
## 1. Introduction

The LM-1 Aux Input Cable #2 (RPM-converter) is an auxiliary device for the LM-1 Lambda Meter. The Aux Input Cable allows the connection of up to 5 analog inputs for data logging to the LM-1. The RPM converter converts RPM pulses from various sources to an analog 0-5V voltage and allows the connection of up to 4 additional analog inputs for data logging to the LM-1. For details on the analog signal inputs see chapter 7.

The RPM-converter can either be used with an inductive clamp (similar to an ignition timing light clamp) or with a pulsed RPM signal from other sources (like tach output signals from ECU's or electronic ignition systems).

As set up by the factory, the RPM-converter is programmed for 1 pulse for every 2 crank rotations as can be expected when using the ignition clamp on the spark wire of one cylinder (non waste-spark ignition).

The RPM-converter can be user-programmed for different numbers of pulses per crank rotation, as described below.



**Figure 1. Aux Input Cable #2 (The RPM converter)**

The Setup button on the RPM converter is used to program the RPM-converter for different pulse numbers per crank rotation as described in chapter 6. The Indicator LED will be steadily on when the RPM-converter detects a valid RPM signal. The Aux 2-5 screw terminals allow the connection of other sensors from your car.



***You can only hook up Aux-input signals whose voltage never exceeds 5V and does not go below ground. Failure to heed this warning may cause damage to either the LM-1 or the RPM-converter.***

The RPM pulse input is used when using an RPM-pulsed signal other than the inductive clamp. See chapter 2 for specifics about the RPM pulse input.

The RPM pulse input can be hooked up to the switched terminal of the ignition coil, provided the ignition system is not a capacitive discharge or multi-spark type.



***Be very careful when connecting to the ignition coil. Some ignition systems retain a high voltage at the ignition coil for a long time even when the engine is off. This high voltage can kill. Always short the terminal to ground before you work on it.***

## 2. 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.

### 2.1. 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.

## 2.2 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.

## 2.3 Rotary Engines (Wankel Motors)

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.

## 3. Using the RPM-Converter 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 RPM converter 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.**

### 3.1 Inductive Clamp Usage

- Plug the inductive clamp's 3.5mm audio plug into the inductive clamp input of the RPM converter.
- 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.
- Plug the RPM-converter in the LM-1 unit.
- Start the engine.
- Switch on the LM-1 unit.

The indicator LED on the RPM-converter should light up steadily. The indicator light 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 LED goes 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 RPM converter 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 3 pulses per rotation. This is the same as for a 6-cyl 4-stroke before the distributor.

***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.***

### 4. Using the RPM-Converter with pulsed RPM input (Tach) signals

- Unplug the inductive clamp from the RPM converter if connected.
- Connect the RPM signal to the RPM pulse input screw terminal.
- Plug the RPM-converter into the LM-1 unit.
- Start the engine.
- Switch on the LM-1 unit.

The indicator LED on the RPM-converter should light up steadily. The indicator light 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 RPM-CONVERTER OR LM-1. Again, this should just result in an error code, not mechanical damage.***

In most cases the ground connection of the RPM converter is required only if the other Aux Inputs (2-5) are used.

## 5. Setup of the RPM-Converter for different rpm pulses/rotation

During the setup procedure the RPM converter measures the number of pulses for 5 seconds. Then it selects from a table the closest matching engine setup. If the measured pulses cannot be found in the table, the RPM converter retains the previous setting. The table covers the following engines:

# of Cylinders	Type of Engine	Pulses/Crank Rotation	Notes
1	4 Stroke	1/2	
1	2 Stroke	1	Or waste spark ignition connected to one spark wire or coil
1 Rotor	Rotary	1	
2	2 Stroke	2	
4	4 Stroke	2	
4	2 Stroke	4	
5	4 Stroke	2 1/2	
5	2 Stroke	5	
6	4 Stroke	3	
6	2 Stroke	6	
8	4 Stroke	4	
8	2 Stroke	8	
10	4 Stroke	5	
12	4 Stroke	6	
12	2 Stroke	12	

So the table consists of engine/ignition types of:

1/2, 1, 2, 2-1/2, 3, 4, 5, 6, 8 and 12 pulses per crank rotation

### 5.1 Setup using the audio output of your computer (preferred method)

Required:

- A computer with a sound output.
- A 3.5mm (1/8") Stereo cable to connect the sound card speaker or headset output to the inductive clamp Input of the RPM converter.
- LM Programmer PC Software Version 2.0 or later (LMConfig Version 1.21 or later.) (Available at <http://www.innovatemosports.com/support/download.php> ).

Preparation:

- Connect the RPM-Converter to the LM-1 unit.
- Connect the serial cable of the LM-1 unit to your computer.
- Connect the stereo cable between the speaker or headset output of your computer and the inductive clamp Input of the RPM-Converter.
- Make sure no background sound is playing on your computer. No CD or MP3's playing to the RPM-Converter, please.
- Switch on the LM-1 unit.
- If your computer has a sound volume control, make sure it is set all the way up.
- Start the LM Programmer application (LMConfig prior to version 2.0).
- Click the RPM Tab. The RPM-Converter setup page looks like this:

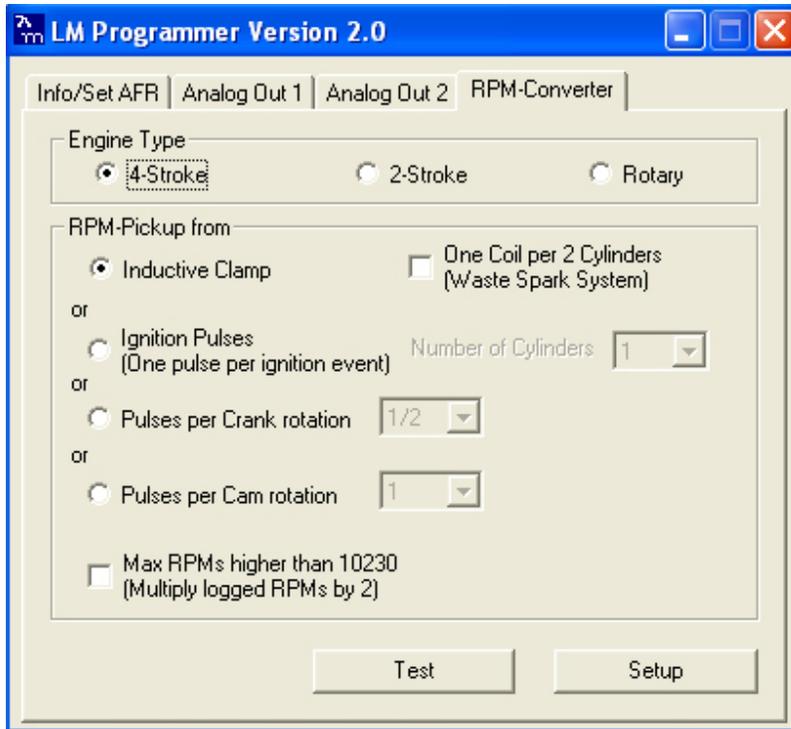


Figure 3. RPM-Converter Setup Page

Select the engine type and number of pulses per crank rotation. Then press the setup button. Follow the instructions provided on screen. After the setup is complete, the LED on the RPM-converter should light up steadily. To test your setup, press the 'Test' button. The LED on the RPM-Converter should light up for about 4 seconds.

To test your sound output, connect the regular speakers back to your computer. Then select '4-Stroke', uncheck 'Waste Spark', select Ignition Pulses and set the number of Cylinders to 12. Then press the 'Test' button. You should hear a loud tone of about 440 Hz (Middle A). The output frequency is set to simulate 4400 RPM for the selected engine type.

## 5.2 Auto-configuration using your engine

- Connect and power up the LM-1 and RPM-Converter as described in Chapter 4.- Make sure the Indicator LED is lighting up steadily at 2000 RPM.
- Press and hold the Setup button on the RPM-Converter until the Indicator LED on the RPM-Converter blinks rapidly.
- You have now 10 seconds to rev up your engine to 2000 RPM while the Indicator LED blinks rapidly.
- Hold the engine at 2000 RPM ( +- 200 RPM) while the Indicator LED blinks. When it starts to blink slowly it is taking measurements.
- After a total of 15 seconds the Indicator LED will light up steadily.
- Relax, you are done.

The RPM Converter accurately tracks RPM signal up to a limit of 10230 RPM. If your engine is expected to rev higher than 10230 RPMs in operation, hold the engine at 4000 RPM (+- 400 RPM) instead of 2000. The datalog will still be showing 0-10230 RPMs, just double the values in the data log or change the setup using the custom setup procedure as described in the LM-1 manual. This procedure works only for pulsed rpm signals of up to 6 pulses per crank rotation.

## 6. RPM Converter Specification

	Min	Typical	Max	Unit
Measurable RPM ( <i>Note 1</i> )	100		10,230	RPM
Input frequency	0.8		1100	Hz
Input Pulse Amplitude	1.5		250	V
Input Impedance (RPM input)		10		kOhm
Input Impedance (Aux inputs)		2		MOhm
Minimum Input pulse width	0.1			usec
Measurement error ( <i>Note 2</i> )			1.0	% of indicated
Resolution ( <i>Note 3</i> )		10		RPM
RPM-output rise/fall time		0.04		sec/1000 RPM
Overswing		20		RPM
Power consumption (5V)	10			mA
Cable Length		6		ft.
Housing Size (LxWxH)	4.175 x 1.75x0.6			in.

*Note 1: When calibrated with 4000 RPM instead of 2000 RPM, max RPM is 20,460.*

*Note 2: or 50 RPM, whichever is greater.*

*Note 3: When calibrated with 4000 RPM instead of 2000 RPM, resolution is 20 RPM.*

## 7. Auxiliary Inputs

The Auxiliary Inputs of the RPM-Converter cable or the Aux Input cable are used to connect other signals from the car to the LM-1 for data logging. The procedure is the same for all inputs. When connecting signals to the Auxiliary inputs, connect the Ground of the Aux Input Cable (or RPM converter) as close as possible to the sensor from which you want the highest resolution. Ground differences between sensors can falsify the results. Ground differences can be as large as 0.5V, which is 10% of the input range. The Auxiliary inputs have an input impedance (static) of greater than 1 MOhm.



**You can only hook up Aux-input signals whose voltage never exceeds 5 V and does not go below ground. Failure to heed this warning may cause irreparable damage to either the LM-1 or the RPM-converter.**

Typical sensors like MAP sensors or TPS sensor output signals vary with the measured quantity. If the Aux Inputs are used to measure switched signals involving coils like solenoids or relays, special protection devices should be added. The following example describes using an Aux Input to record the state of a NOS solenoid. The same protection method can be used for other solenoids or relays or other switched signals that exceed the 5V input limit of the Aux inputs.

## 7.1 Recording the state of a NOS solenoid

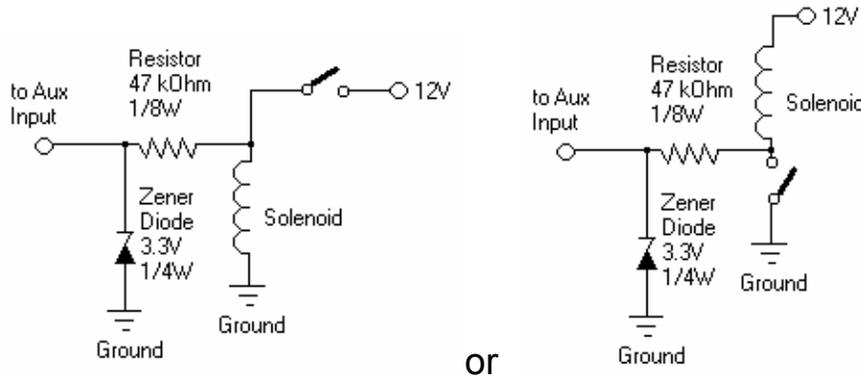


Figure 4. Solenoid Interface (High Side Switch, Low Side Switch)

In the left case the solenoid is grounded on one side, the other side is switched to 12V when the solenoid is on. The LM-1 will record 3.3V when the solenoid is on, and record 0V when the solenoid is off. In the second case the solenoid is connected to 12V on one side and the other side will be grounded when the solenoid is on. The LM-1 will record 0V when the solenoid is on and 3.3V when the solenoid is off. The same method can also be used to detect other signals like clutch switch and so on.

## 7.2 Recording Battery voltage or a signal between 0 and 12V

This circuit creates a load of 330 kOhm on the signal. If your measured signal has a high output impedance ( $> 33 \text{ kOhm}$ ), increase the resistor values in the circuit proportionally.

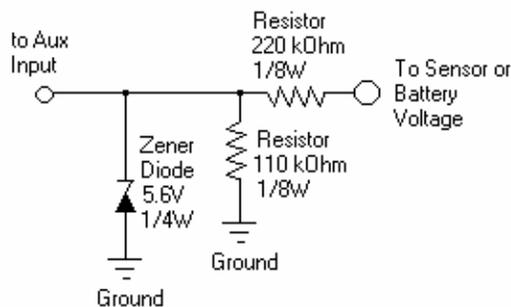


Figure 5. Battery Voltage or high signal amplitude interface

The measured signal is divided by 3. The maximum battery voltage that can be measured is 15V. The recorded voltage will be 1/3 of the actual voltage. Either multiply the measured voltage in the log by 3 or set up the appropriate input as custom as described in the LM-1 manual.

## 8.1 Revision History

**Version 1.0-** November 20, 2003- Initial Release

**Version 1.1** – December 10, 2003

**Version 1.2** – May 12, 2004 –Update LM Programmer screen shots and references