

# **PLM-01 Power Line Modem**

**User's manual and assembly guide**

## **CAUTION!**

This device is intended to be connected to the mains via a coupling network. Be extremely careful and never work on the unit when power is applied. Also beware that capacitors can provide electrical shock even after the power is removed since they are charged.

We strongly recommend that you build in the module and other electronics in a fully isolated plastic case to prevent any risk of damages.

## 1.0 Introduction.

The **PLM-01** is a low cost and easy to build Power Line Modem capable to send and receive serial data over the power lines (mains) at speed up to 2400 bps. **PLM-01** lets you communicate with other devices around the house without running any wires since it uses the wires already available in every house.

**PLM-01** is designed to allow the engineer, technician or hobbyist to integrate it in new or existing designs with a minimum of interfacing required. **PLM-01** can easily be interfaces with any PC or micro controller (MCU) that are able to send and receive asynchronous data at 2400 bps or less. Perfect for use with BASIC Stamp's, SX, PIC, 8051, AVR, 68HC11, COP or standard Pac's.

You will require basic knowledge of electronics safety. Appropriate soldering skills will also be needed to successfully assemble the unit.

Good luck with your project!

### Features.

- Send and receive 110-2400 bps, half-duplex.
- At 2400 bps it's 40 times faster than X-10.
- Works over 230 VAC/50 Hz or 110 VAC/60 Hz.
- PLM-01 is protocol independent.
- Uses FSK (more immune to noise and other interfacing signals than ASK).
- Can co-exist with X-10 equipment and don't false trigger them.
- Small and easy to embed, PCB 54x38 mm (2.1x1.5 inch).
- +5V power supply @ 5 mA and +10V power supply @ 15 mA.
- Simple interface to a MCU or PC.
- Built in watchdog function.
- Rx sensitivity better than  $1mV_{RMS}$
- Carrier detection.
- Compatible with CENELEC EN 50065-1 (EU) and FCC (US) specifications.

### 1.1 What can PLM-01 be used for?

**PLM-01** can be used to build your own bi-directional home automation system where you can control lights, measure temperature, measure power consumption, query status of switches, turn on/off or control devices like stereos etc. Since it's bi-directional you can poll your house to see what modules you can currently have available or if anyone of them isn't responding you can take proper action.

Or you can use it to send and receive messages or data (files) between personal computers and their devices in a building without the need of cables. Use it as a low speed printer network for all in the building to share or run a speech recognition program on your PC to "talk" with your home!

Combine both together and top it with some **PLM-01** modules that have alarm sensors connected and you will have security system that is capable to dial up with your PC's modem and play a tune or send an fax or e-mail if something goes wrong or your house is visited by unknown people.

With **PLM-01** you have the communication medium the rest is up to you! Below is a short list of some doable things just to spark your imagination...

- Control lights and other devices
- Security systems
- Energy control and management
- Process control
- Environmental control
- Low speed PC networks
- Heating and air condition control
- Sprinkler/watering systems
- Connect your whole home to Internet
- PLM-01 <-> X-10 gateway
- Sophisticated HA systems
- Help for elderly and disabled people
- Chat system for whole buildings
- Measure temperature in rooms
- Small info terminals in rooms
- Close blinds if sunlight is too strong
- Let your PC control your home
- Stage control in home theaters
- ...

Since **PLM-01** is capable of both sending and receiving serial data over the power lines it's possible to implement a protocol that uses checksums or CRC to ensure that received data is correct and if it isn't ask for a re-transmission! The module itself is protocol independent so you can use how simple or complicated protocol you want (send ASCII or binary). Since the environment on the power line isn't very friendly it is wise to implement some way to check for errors and we highly recommend that that you do but it's not necessary.

By being protocol independent the **PLM-01** doesn't limits to any max. numbers of power line modems used in your network. You can have as few as two **PLM-01** up to millions if you ever need that.

## 2.0 Assembly Instructions.

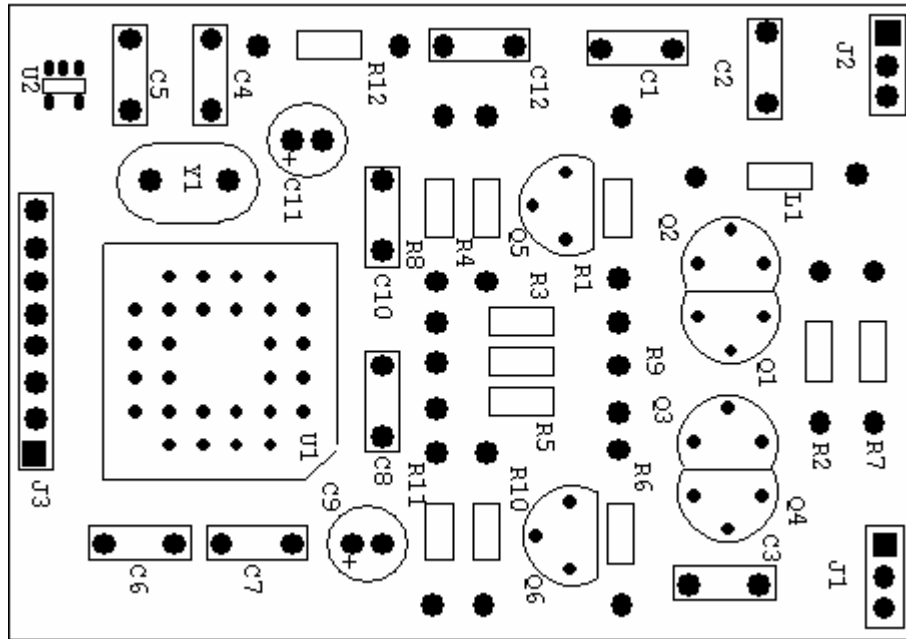
Below are suggestions and precautions for you to successfully build **PLM-01**.

- A basic knowledge of electronics and appropriate soldering skills are necessary.
- A soldering iron with fine tip, rosin flux core solder, solder paste (for the optional SMD part) and basic hand tools will be required for assembly. A multimeter will also be helpful for testing and troubleshooting.
- Read **all instructions before** beginning assembly.
- Double check all connections before applying power to the module.
- Always disconnect power, **both DC and mains power**, from the module before altering it.

### 2.1 Step-by-step instructions.

Except where noted otherwise, all components are installed on the component side and soldered on the solder side of the printed circuit board. Since semiconductors are sensitive to ESD handle all IC's with care and don't take them out their protecting bags until you shall install them. If possible use ESD safety equipment! Below is a step-by-step assembly guide and the rule of thumb is to mount the lowest component first and the tallest last.

Below is an overview of the component placing on the **PLM-01** printed circuit board and may act as an guide when you assembly the kit.



1. Before you start soldering any parts you should decide if you shall mount the optional on board oscillator (U2, R12 and C12) see section 2.5 on page 7 for more information about this before you proceed.
2. If you decided to mount the on board oscillator start to install U2 and since it's an surface mounted device (SMD) the easiest way to solder it is to use solder paste. If you don't have any experience at all with SMD parts we recommend you to ask someone for advise or at least practice on some other SMD components before you solder U2.  
U2 is mounted and soldered on the component side of the printed circuit board. In the following instructions we assume you decided to install the on board oscillator.
3. Install and solder all resistors, R1-R12.
4. Install and solder the inductor L1.
5. Install and solder the crystal Y1, be sure to leave some space (1-2 mm) under it so it won't short circuit anything via its metal case.
6. Install and solder the ceramic capacitors C4 and C5.
7. Install and solder the ceramic capacitors C1.
8. Install and solder the polyester capacitors C2, C3, C6, C7, C8, C10 and C12.
9. Install and solder transistors Q5 and Q6.
10. Install and solder transistors Q1 and Q2, note this pair of transistors shall be mounted as close as possible to each other with the flat side facing each other and at the same height.
11. Install and solder transistors Q3 and Q4, note this pair of transistors shall be mounted as close as possible to each other with the flat side facing each other and at the same height.
12. After installing above transistor use small strappers (or a bit of shrinking tube) on each transistor pair to fix their position "face to face". If you use shrinking tube be careful to not overheat the components and we recommend using a hot air blower special designed for this.
13. Install the 28-pin PLCC IC socket for IC U1. Don't insert U1 in the socket yet!
14. Install C9 and C11. The capacitor polarity should be noted, it's important to install them with correct polarity.
15. Now it's time to insert U1 in its socket. As mentioned before all semiconductors are sensitive for ESD so handle it with care. When inserting the IC in the socket is sure to note where pin 1 is (small dot on the IC) and the indication for pin 1 in the socket (often an

arrow but could be something else depending on manufacturer). Also one of the corners on the IC is cut to help you insert it in the socket correctly.

It can require pretty high pressure to insert U1 in the PLCC socket. Place the PCB on a flat surface and apply even pressure on the IC from above. If you don't place IC correctly the first time you will need a PLCC extractor to remove it again from the socket! Don't use any other tools since it will damage the IC.

16. Next you have to decide how you will connect **PLM-01** to your application. We recommend that you use the breakaway pin headers for J1, J2 and J3 and **mount them on the solder side**. This way you will get a small plug-in module that is easy to use on a bigger PCB by using female headers on that. By using this method there is room to place other components under **PLM-01** (approx. 10mm in height). **PLM-24** was designed with this in mind and our other products will interface with **PLM-01** this way.
17. Double-check **everything** before using it the first time! It's very easy even for an experienced user to misplace or misread something when mounting a PCB. Check the following and mark them off as you proceed.
  - Check component placement.
  - Check for any bad soldering.
  - Check so there isn't any short circuits between soldering pads.
  - Check again so U1 is correctly inserted in the PLCC socket.
18. Now your **PLM-01** Power Line Modem is ready, see section 4.0 for information on how to interface it to the coupling network and your MCU/PC.

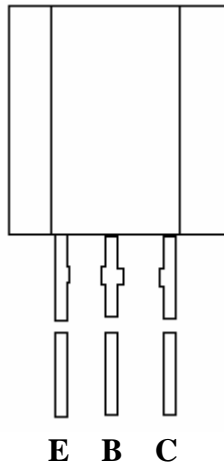
## 2.2 Parts list for PLM-01.

Below is the list of components required to build the **PLM-01** Power Line Modem and everything should be included in the kit. The column named RM indicates the components module size for capacitors, 1 module=2.54 mm (1/10 inch.).

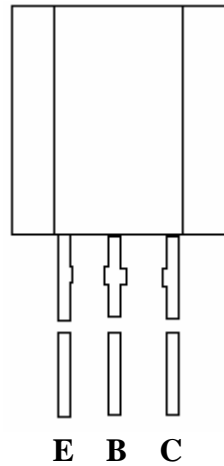
Qty.	Description	Reference	RM
2	1 Kohm, 1/4W Resistor	R7, R9	-
2	180 Ohm, 1/4W Resistor	R4, R6	-
4	2.2 Ohm, 1/4W Resistor	R1, R2, R3, R5	-
1	10 Kohm, 1/4W Resistor	R11	-
1	27 Kohm, 1/4W Resistor * optional see section 2.5	R12	-
2	47 Kohm, 1/4W Resistor	R8, R10	-
1	1 uF Capacitor (Ceramic)	C1	2
2	22 pF Capacitor (Ceramic)	C4, C5	1
1	6.8 nF Capacitor (Polyester 50V)	C2	2
6	100 nF Capacitor (Polyester 50V) * C12 optional see section 2.5	C3,C6,C8,C10,C12	2
2	2.2 Uf capacitor (Electrolyte 25V)	C9,C11	1
1	10 uH Inductor ( $R_{DC} < 1.5$ Ohm)	L1	-
3	PN2222A (TO-92) * see note below	Q1, Q2, Q6	-
3	PN2907A (TO-92) * see note below	Q3, Q4, Q5	-
1	11.0592 MHz Crystal	Y1	-
1	ST7537HS1 IC	U1	-
1	SN74AHCT1G14 IC (SMD) * optional see section 2.5	U2	-
2	3-pin header	J1, J2	-
1	8-pin header	J3	-
1	28-pin PLCC socket for U1	-	-
2	Straps to use around Q1, Q2 & Q3, Q4	-	-
1	PLM-24 Power Line Modem PCB	-	-

Note: Below is the pinout for the transistors.

**PN2222A**  
(Flat side facing you)



**PN2907A**  
(Flat side facing you)



### 2.3 Parts list for the coupling network.

Below is the list of components required for the coupling network to connect **PLM-01** to the mains. The references used in this table are taken from figure 1.0. This parts is not mounted on the **PLM-01** PCB and is sold separately or included in other products.

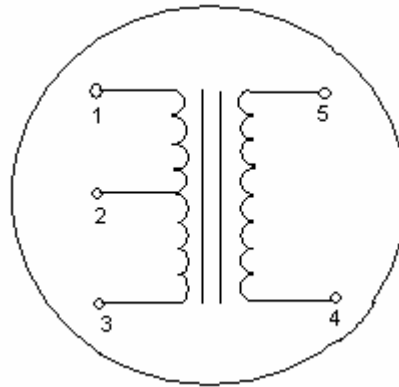
Qty.	Description	Reference
1	T1002 Transformer	TR1
1	Transil diode P6KE-6V8CA * see note below	D1
1	0.1 uF Capacitor (AC rated)	C1

Note: The transil diode D1 has no markings for anode and cathode since it's bi-directional and it doesn't matter how you connect it.

### 2.4 Transformer pinout.

Below is the pinout for the T1002 Transformer, the transformer is seen from above.

Winding 1-2      20 turns  
 Winding 2-3      120 turns  
 Winding 4-5      20 turns



## 2.5 What about the optional U2, R12 and C12?

The surface mounted U2 IC is optional and don't need for **PLM-01** to work but have been included for easier interfacing with BASIC Stamp`s and PC`s. U2 is a part of an on-board oscillator consisting of U2, R12 and C12 and the output is connected to the watch-dog input (WD) on ST7537HS1 IC (U1). Since ST7537HS1 need to receive a watchdog pulse on this pin to operate properly you have the choice to mount the on-board oscillator that provides that pulse automatically.

If you don't mount these components (U2, R12 and C12) you have to provide a watchdog pulse your self on pin J3.7. This is often no problem when using faster MCU`s since it is easy to implement a routine to toggle an I/O pin at the speed required. You will also benefit of the built in watchdog feature. If **PLM-01** doesn't receive a watchdog pulse within 1.5 sec. It will generate a reset pulse on pin J3.2 (RSTO) that you can use to reset your MCU or other circuits.

When using BASIC Stamp Rev. D (or BS1-IC) from Parallax Inc. you will use the SERIN and SEROUT command to send and receive data, while using SERIN on the BASIC Stamp there is no easy way to generate a watchdog pulse since the BASIC Stamp just sits and waits for serial data to receive. The on-board oscillator is also useful when connecting **PLM-01** to a PC`s serial port.

If you don't mount these components they are located such that they should be easy to add later (even if U2 is a surface mounted device) if you change your mind.

## 3.0 PLM-24 pin description

### Connector J1 (pin 1 to 3)

Connector	Name	Description
J1.1	+10V	+10V power supply input
J1.2	+5V	+5V power supply input
J1.3	GND	Ground

**PLM-01** needs stabilized +10 VDC power supply @ 150 mA and +5 VDC power supply @ 5 mA to operate correctly. Above power specifications are valid in Tx mode. In Rx mode **PLM-01** require less current, +10 VDC @ 30 mA and +5 VDC power supply @ 1 mA.



### Connector J2 (pin 1 to 3)

Connector	Name	Description
J2.1	I/O 1	To coupling network
J2.2	I/O 2	To coupling network
J2.3	GND	Ground

When connecting **PLM-01** to the coupling transformer (TR1) be sure to connect J2 to the correct windings according to figure 1.0. If not this may cause decreased functionality and may result in limited speed and higher packet loss when transmitting data over the mains.

### Connector J3 (pin 1 to 8)

Connector	Name	Description	I/O
J3.1	CTRL	Control (override the default 1 sec Tx limit)	Input
J3.2	RSTO	Reset Output	Output
J3.3	RxD	Received data out	Output
J3.4	TxD	Transmit data in	Input
J3.5	$\overline{CD}$	Carrier Detect	Output
J3.6	$\overline{Rx/Tx}$	$\overline{Rx/Tx}$ mode select	Input
J3.7	$\overline{WD}$	Watchdog	Input
J3.8	MCLK	Master Clock	Output

Note: all levels on above I/O pins are standard TTL/CMOS levels (i.e. HIGH=5V, LOW=0V)

#### CTRL

The CTRL input pin is used to override the default 1 second Tx limit built into ST7537HS1. If you pull this pin HIGH **PLM-01** is fully controlled by the Rx/Tx input. The input is pulled LOW by R11 so if not used you can leave the CTRL pin floating. However we recommend sending that less than 1 second transmit time due to several reasons.

#### RSTO

This pin is driven HIGH if the +10V supply voltage is lower than approx. 7.6V or when no negative transition occurs on the watchdog input ( $\overline{WD}$ ) for more than 1.5 second. When the reset occurs RSTO is held HIGH for at least 50 ms.

#### RxD

Received data output. Connect this output to your MCU serial input pin. If connected to RS-232C port an interface IC is necessary (i.e. MAX232 or via opto coupler).

#### TxD

Transmit data input. Connect this input to your MCU serial output pin. If connected to RS-232C port an interface IC is necessary (i.e. MAX232 or via opto coupler).

## $\overline{CD}$

The  $\overline{CD}$  pin goes LOW if a carrier is detected on the power line, this indicating that there is another unit already sending data on the power line. Use it to check that the communication medium is free before sending any data.

## **Rx/Tx**

The Rx/Tx mode input decides if your unit is sending or receiving data. Before you can send any data via the Tx pin you will have to pull this pin LOW and after sending pull it HIGH again to be able to receive data again. If CTRL=0 and Rx/Tx is held LOW for longer than 1 second then **PLM-01** switches automatically to receive mode.

## $\overline{WD}$

Watchdog input, this pin needs to receive a pulse (HIGH to LOW) with  $f > 1$  Hz for **PLM-01** to operate properly. See section 2.5 for more information about this and the optional on-board oscillator.

## **MCLK**

Master clock output provides you with the 11.0592 MHz oscillator clock used by ST7537HS1. You can use this signal to clock your external MCU and is especially useful for interfacing **PLM-01** with an 8051 MCU. If not used you should leave this pin floating.

#### 4.0 Connecting PLM-01 to the coupling network.

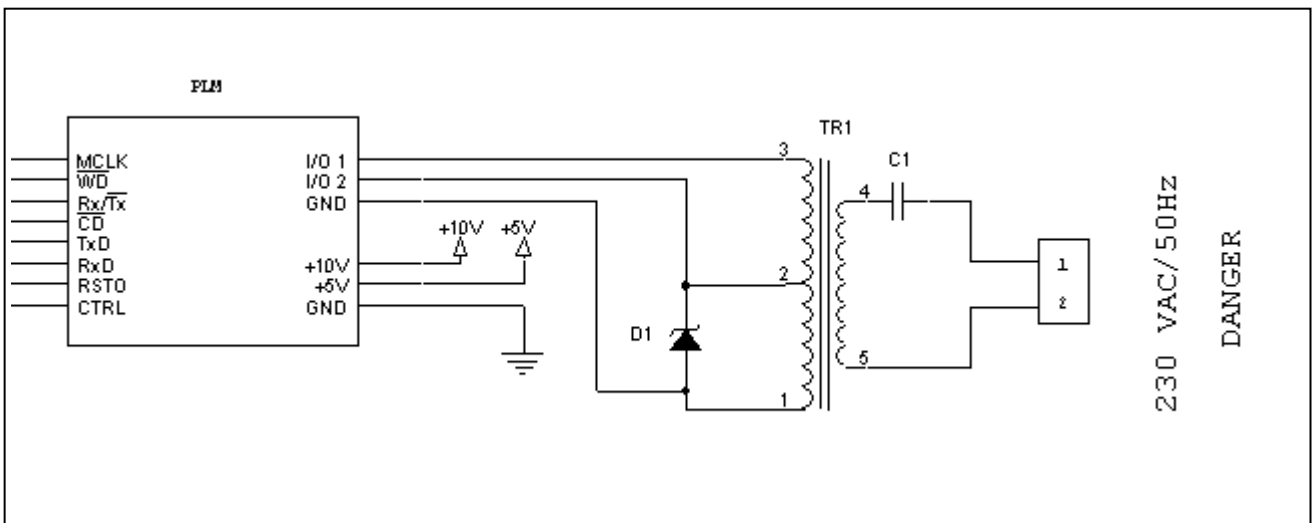


Figure 1.0 – Connecting **PLM-01** to the coupling network.

The above schematic shows how to connect **PLM-01** to the coupling network. In all the following examples it's assumed that you live in a country with 230 VAC/50Hz (if you live in the US you will have 110 VAC/60Hz instead).

When connecting **PLM-01** to the coupling transformer (TR1) be sure to connect J2 to the correct windings on the transformer (see section 2.4). Usually it's not needed to trim TR1 unless you experience low transfer rates or high packet loss. Since the core in the transformer is easy to break use a screwdriver made of plastic that fits and tune it optimal performance.

#### 4.1 Interfacing PLM-01 to MCU's and serial ports.

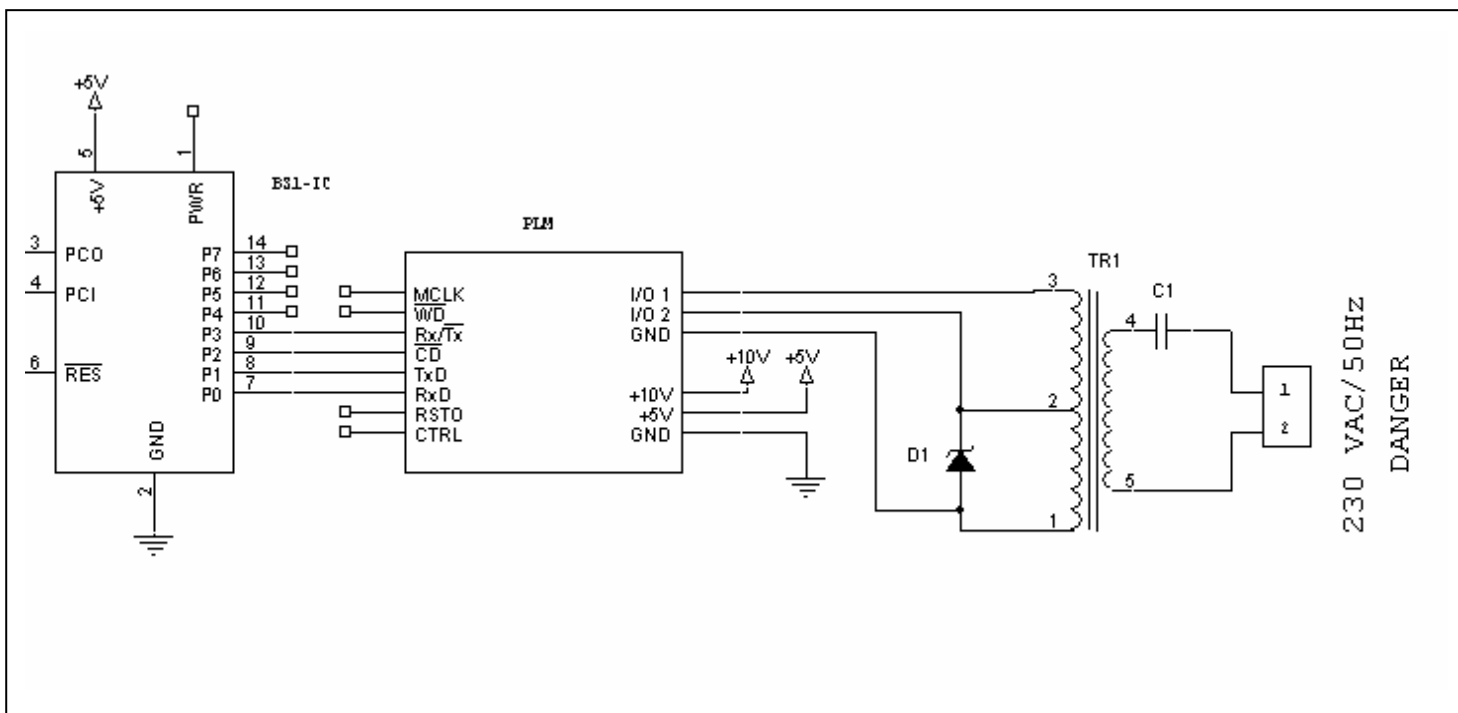


Figure 1.1 – Interface **PLM-01** with BS1-IC (on-board oscillator is mounted).

Figure 1.1 shows a BS1-IC connected to the **PLM-01** and has 4 I/O pins left (P4-P7) for general I/O. It's possible to not connect the CD pin but then the BS1-IC won't be able to check the communication medium to see if any other **PLM-01** is transmitting.

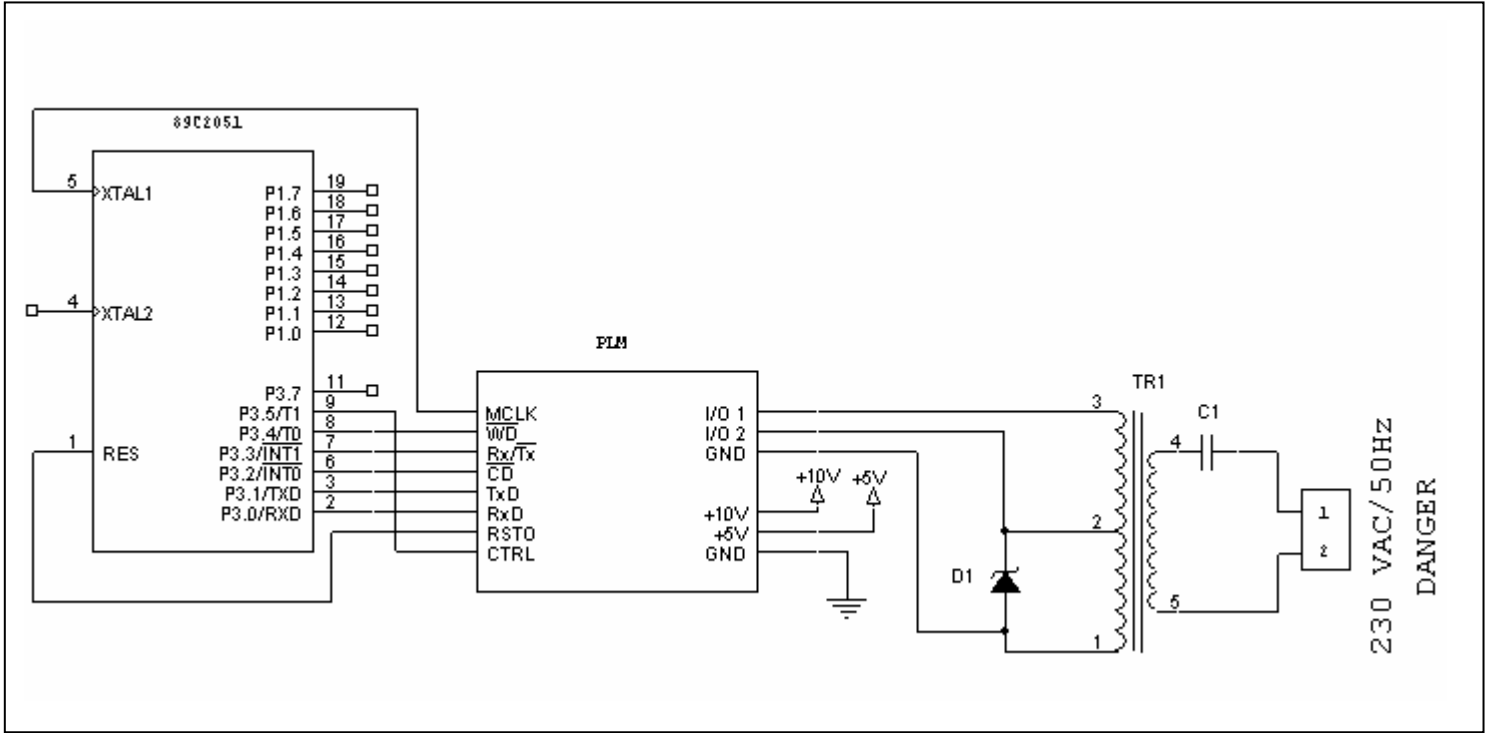


Figure 1.2 – Interface **PLM-01** to 89C2051 MCU (on-board oscillator is not mounted).

Figure 1.2 shows an Atmel 89C2051 connected to the **PLM-01** and has 9 I/O pins left (P3.7, P1.0-P1.7) for general I/O. Since the on-board oscillator isn't mounted the program running on the 89C2051 must provide a reset pulse on the WD input else the MCU would be reseted automatically. The above circuit also has full control over the transmitting time if the CTRL pin is pulled HIGH.

By connecting the MCLK output to XTAL1 on 89C2051 the MCU doesn't need any crystal since it receives the 11.0952 MHz clock from the **PLM-01**.

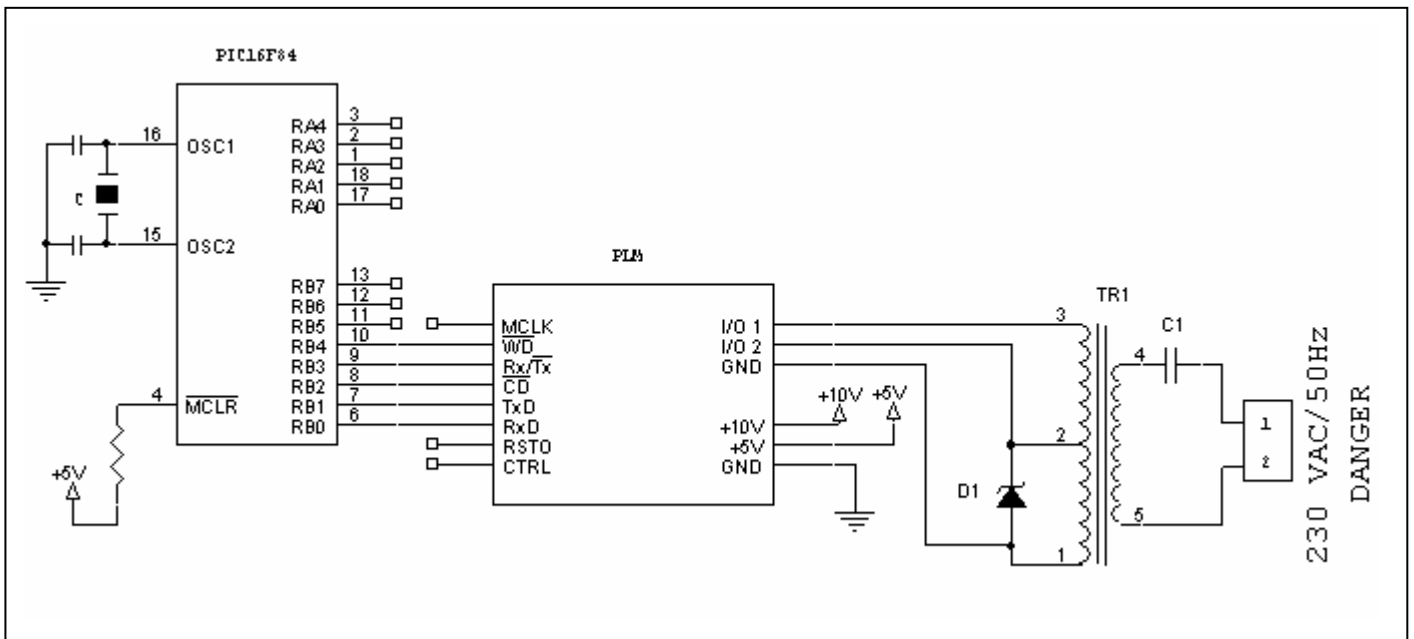


Figure 1.3 – Interface **PLM-01** to PIC16F84 MCU (on-board oscillator is not mounted).

Figure 1.3 shows a PIC16F84 connected to the **PLM-01** and has 8 I/O pins left (PB5-PB7 and PA0-PA4) for general I/O. Since the on-board oscillator isn't mounted the program running on the PIC16F84 must provide a reset pulse on the WD input.

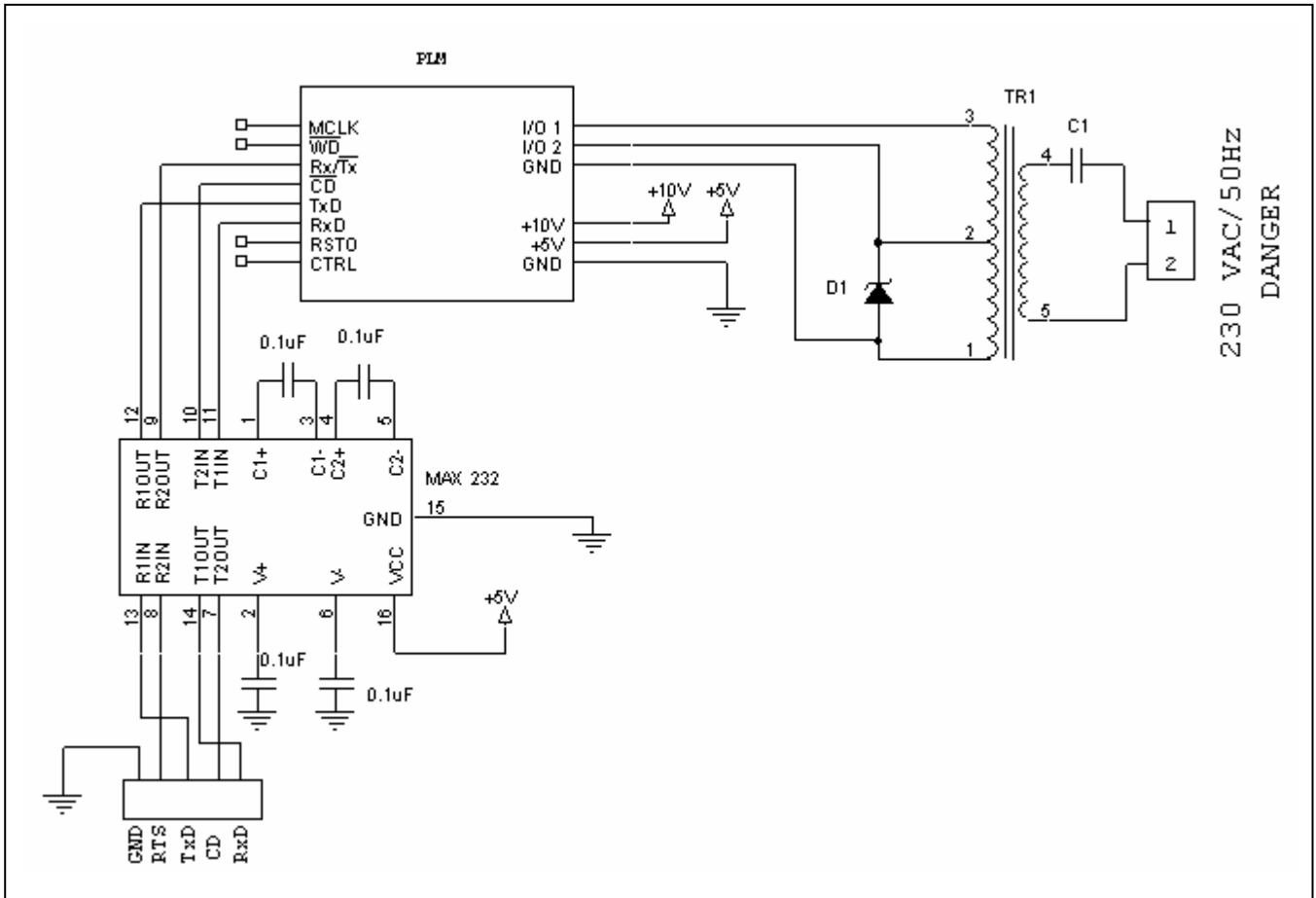


Figure 1.4 – Interface **PLM-01** to an RS-232C serial port (on-board oscillators mounted).

Figure 1.4 shows the PLM-01 connected to a MAX232 IC and provides an unisolated interface to your PC via the serial port. If the PLM-01 and the MAX232 IC is powered by an isolated source it provides sufficient protection for the PC from the power line. Warning, using unisolated power supplies referenced to one side of the line can damage your computer. To prevent damage from occurring the interface must be isolated via optocouplers.

When using the above interface the RTS (Request To Send) pin on the RS-232C port controls if the PLM-01 is in receive or transmit mode (in some software for PC is necessary close RTS to CTS pin 7 and 8 in the DB9 connector). If you are using communication program for testing you must be able to toggle the RTS pin to switch between send and receive mode. Lorix has a free test Windows program, Hyperterminal is not good for testing.

**Q1. Can I connect PLM-01 directly to an RS-232C serial port?**

Yes, but since the voltage levels on the RS-232C serial port is  $\pm 12V$  you have to use an interface circuit like MAX232 or similar (**PLM-01** uses standard TTL/CMOS levels).

**Q2. Do I need any special or expensive development tools?**

No. You can use the tools you already use for writing programs to your MCU or PC as long as its able to send and receive serial data at 2400 bps or less.

### **Q3. Do I have to use a protocol?**

No, you don't have to but we recommend you implement some way to find out if the data sent was received by the receiver and contains valid data. There are many ways to do this and our tip is to start simple and go from there.

### **Q4. Where can I read more about different protocols?**

There are lots of books available that describes different protocols. Go to your library and borrow a book about TCP/IP, IPX, AX-25 or another general network protocol to get an idea what a protocol is all about.

### **Q5. I get poor results when sending at 2400 bps, is something wrong?**

Not necessary, first of all you can try to tune the core in TR1 and see if that helps. If you experience times during the day while sending 2400 bps it may be that something in your house/building is generating noise on the power line (or blocking your signal) see Q&A number 9.

### **Q6. How many PLM-01 units can I have?**

Since **PLM-01** is protocol independent it is up to you. You can have as few as two up to several thousands if you need that.

### **Q7. How far does the signal go?**

It's a tricky question to answer but **PLM-01** is intended to be used within a house or building and the signal will not pass through any distribution transformers that may exist between houses or blocks.

Sending data over longer distance may force you to decrease the transmitting speed. The distance you can communicate is a factor of characteristics of your wires, loading and noise.

### **Q8. Can I use my existing X-10 equipment?**

Yes, you can still use your existing X-10 equipment and **PLM-01** will not false trigger any of the X-10 units. You can download schematics and source code for a **PLM-01** <-> X-10 gateway at our web-site.

### **Q9. Communication becomes poor when I plug in brand X in the outlet?**

Some appliances such as particular brands of televisions or other audio/visual equipment may have a capacitor across the AC line to filter out high frequency noise. **PLM-01** signals appear as high frequency noise to these capacitors and are thus attenuated.

Also some power strips that have filters in them to protect electronic equipment effectively filter out **PLM-01** signals. Try moving the **PLM-01** module from power strips to a standard outlet if they do not seem to be working. Cheaper power strips that protect against voltage spikes only do not affect **PLM-01** signals.

## 5.1 Feedback and suggestions.

LORIX is always working to improve our products. If you have any new ideas or suggestions for improvements please feel free to contact us by e-mail at [lorixvr@virgilio.it](mailto:lorixvr@virgilio.it)

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