Power Analyzer 20A

Harware Manual

Rev. 2r0 Edited to described latest board version

The Power Analyzer 20A Is the third generation of the series, and is now fitted with Hall Effect current sensor to extend its current range all the way to 20A (from 8A). That more than doubled the load capacity to 4400VA at 220V source. Although the Hall effect current sensor can measure the DC component of the current as well, drift and sensitivity of hall effect sensor to magnetic fields sorounding it can easily mess up your readings. Hence this module was programmed to respond to AC contents only. Usage and programming is essentially identical to its predecessor; you can use the same code you used with the old power analyzer kit without the need to modify anything.

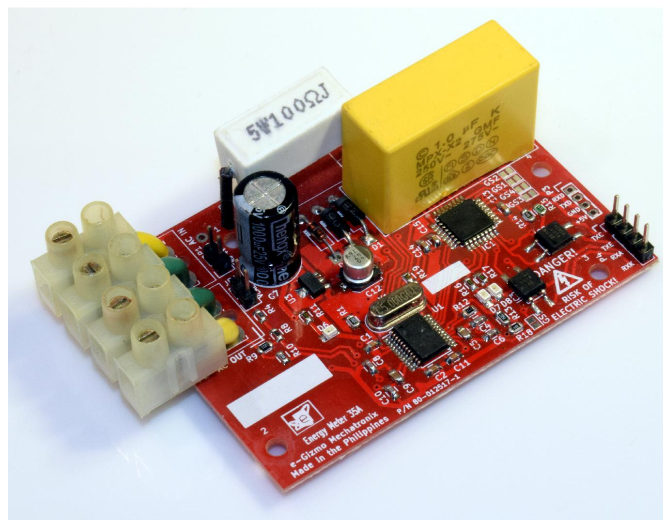
This kit can be used to measure and monitor accurately electrical energy usage. It is designed for easy interfacing with any UART equipped microcontroller circuit and modules, such as the gizDuino line.

Watt-Hour

Real Power

Power Factor

Apparent
Reactive
Fundamental
Harmonic
Fundamental Reactive
POWER



SAFETY WARNING:

The Power Analyzer module directly taps its DC power source from the AC mains. Hence the whole assembly is an electrical hazard once plugged in a live outlet.

- Never touch any part of the PCB assembly while the circuit is plugged and powered through the AC line.

- Do not connect any other component in any part of the circuit other than the opto-isolated serial I/O port. The opto-isolated port is the only electrically- safe access port in the Power Analyzer module.

Usage Precautions:

The Hall Effect current sensor accuracy can be affected in a bad way by strong magnetic fields. Keep the module away from magnets, speakers, transformers, and other metal objects that can induce strong magnetic interference.

FEATURES:

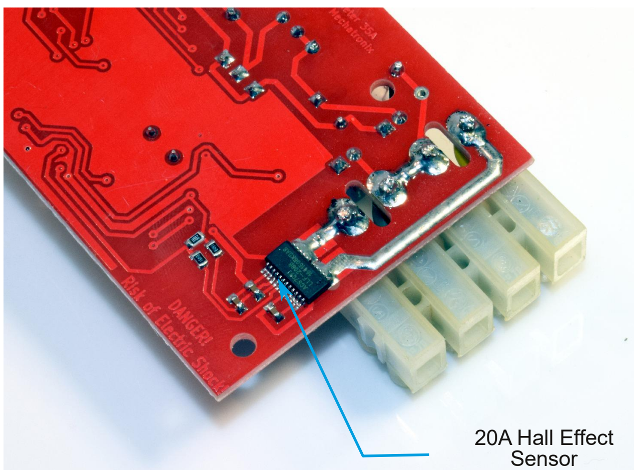
Measurements:
- Volt RMS
- Amp RMS
- Real Power
- Apparent Power
- Reactive Power
- Fundamental Power
- Fundamental Reactive Power
- Harmonic Power
- Power Factor
- Watt-Hour

Electrical:
- Operation Voltage: 100V- 240V AC, 60Hz
- Current Capacity : 20A continous

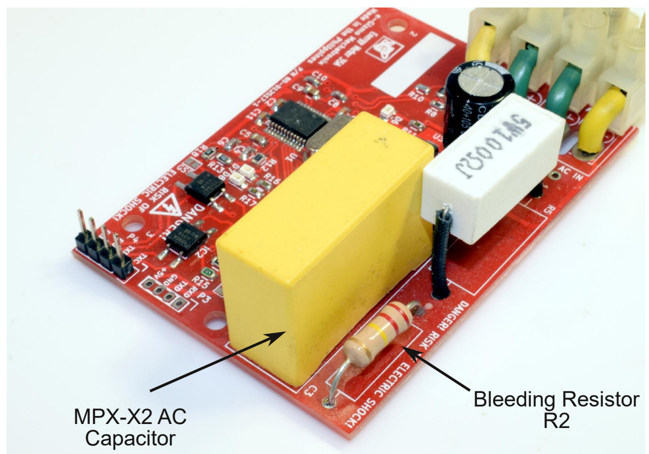
Opto isolated Interface Port:
- UART TX
- UART RX

Non-isolated Interface Port:
- UART TX
- UART RX
- +5V

Future Version:
- Current Transformer Version



(a)



(b)

Figure 1. The latest AC Power Analyzer module now uses a hall effect current sensor (a). A bleeding resistor R2 (b) is added to quickly discharge the AC capacitor when power is removed. Due to the increased ampacity, the board is no longer equipped with a fuse. For increased safety, you must include a suitably rated external fuse in your wirings. As always, MPX-X2 safety qualified AC capacitor is used for the critical capacitive AC voltage divider and power supply circuit.

1. COMPONENTS LOCATOR GUIDE

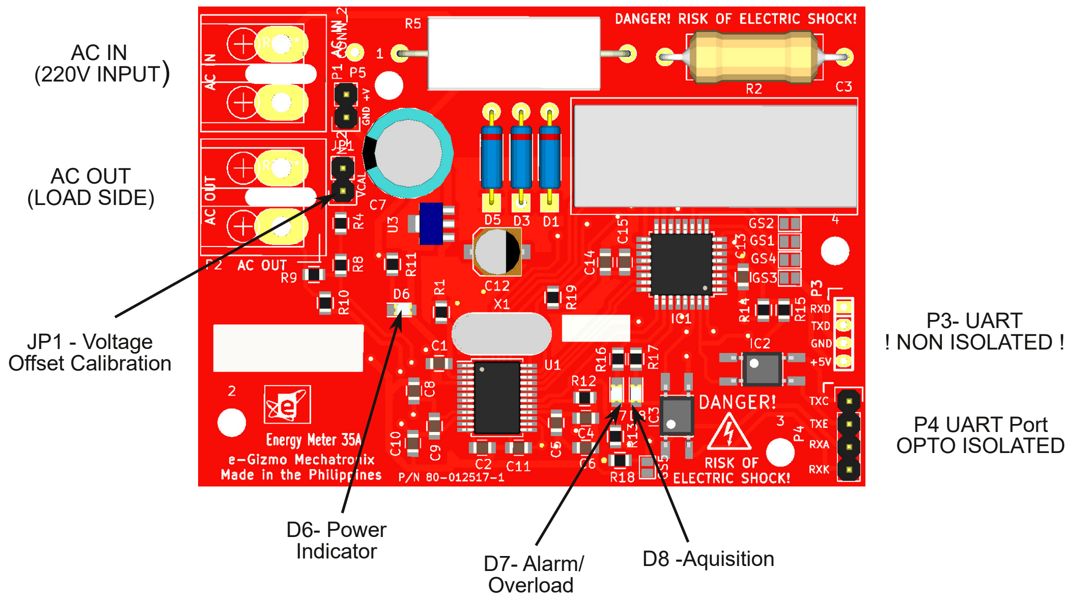


Figure 2. Location of connectors and major components. Note that under normal use, the 0V Voltage Offset Calibration jumper must be installed. Once connected to AC, dangerous voltage appears to all components in the circuit, except P4. P4 is the only port considered safe for connecting your circuits.

Table 1. P3 UART Non-isolated Port

Warning: This UART port is not galvanically isolated from the mains connected portion of the circuit and should be used with reasonable caution.

20A Hall Effect Sensor

Pin	ID	Description
1	RXD	UART Receive pin TTL level
2	TXD	UART Transmit pin TTL level
3	GND	Circuit Ground
4	+5V	Low Current +5V Output

Table 2. P4 UART Opto-isolated Port

This is an electrically safe port that is amply isolated from the AC mains. This is the only electrically safe port of the circuit, hence, any electrical wirings connecting outside components and circuits must be done through this port only.

Pin	ID	Description
1	TXC	TX Transistor Collector Pin
2	TXE	TX Transistor Emitter Pin
3	RXA	RX LED Anode (+) pin
4	RXK	RX LED Cathode (-) pin

Table 3. LED Indicators

ID	Description
D6	Power Indicator. Normally ON
D7	Alarm, indicates input overload condition when ON
D8	Acquisition Link indicator, normally flashing at 1Hz rate

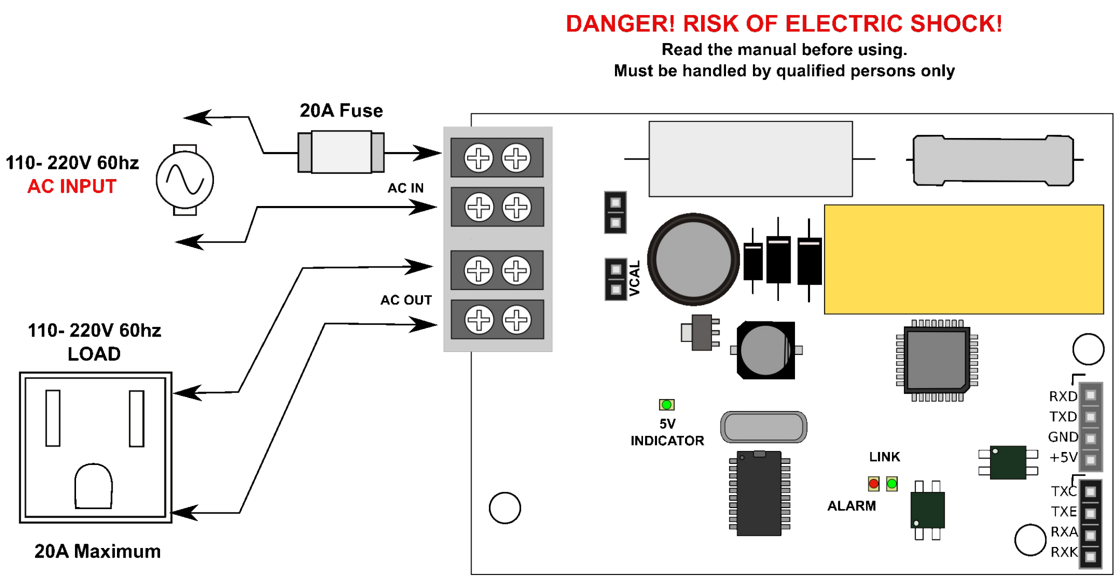


Figure 3. AC source and load side wiring. Note the inclusion of a fuse in the AC wiring. Make sure all wires are securely fastened into their correct connectors. Heavy AC power may pass through this circuit, any loose wiring will pose a hazard.

2. AC WIRINGS

To minimize risk of AC wiring errors, a couple of terminals are provided that clearly separate the source and load side wiring. Connect only as shown in Figure 3. Connecting the AC wiring any other way may result in fire, injury to persons, and permanent damage to the circuit board.

2.1 Connecting wires to the AC terminals

Use AWG 12 or heavier insulated stranded wires for all AC source and load connections.

1. Strip off about 8mm length of insulation from the AC wires.

2. Loosen the terminal screws and gently insert fully inward the stripped portion of the wire between the clips of the terminal. Make sure no wire strands are left free. Loose strands might bridge to the other terminal and results in nasty short circuits.

3. Tighten the screws just enough torque to securely fasten the wires.

4. Test the connections with a slight pull in the wire to ensure a tight and secured wiring installation.

KEEPING THINGS SAFE

AC Capacitor - Low voltage DC supply is tapped from the AC mains through the AC capacitor C3. The kit uses MPX-X2 type AC capacitor verified by various safety agencies as suitable for direct AC mains circuits. In the unlikely event that this component fails, replace with the same type only.

Although the DC voltage at various points in the circuit may be low, it is not isolated from the AC mains, and poses a real risk of electrocution. Never touch any part of the circuit while in operation. This basic safety reminder cannot be overstated.

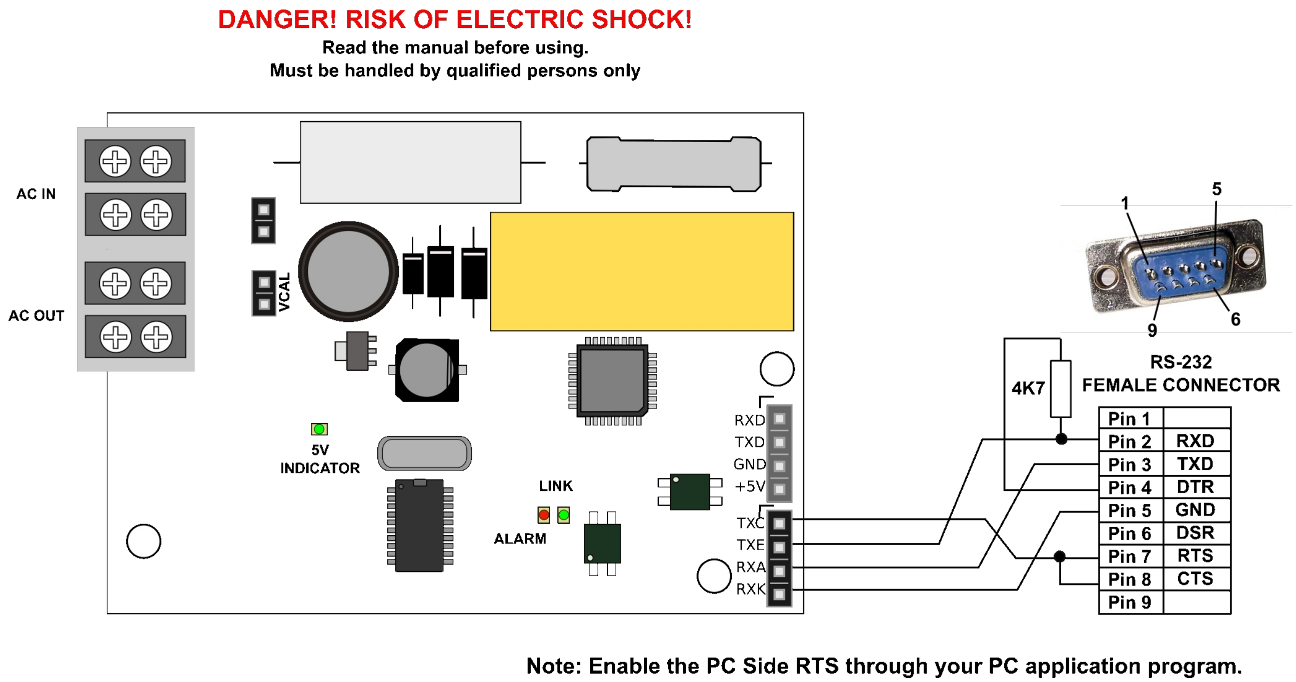


Figure 4. Interface wiring to a PC RS-232 COM port is surprisingly simple. Measurements can be displayed on a PC using terminal programs such as Terminal by Br@y++ (see section 5.2). If you can write your own PC app, then, you can customize your own display and functions. A sample program written in VB.net can be downloaded for free from the corresponding product page of this kit @ e-gizmo.com.

3. APPLICATION

The Power Analyzer Module is a general purpose AC power data acquisition module. To make it do useful function, additional components are necessary.

3.1 Connecting to a PC

The quickest way to monitor and display data from the Power Analyzer module is probably with the use of a PC. But of course, there are several even more important reasons why you want to connect it with a PC.

You can program your PC using your favorite programming IDE (e.g. Visual Basic Express) to not just display the measurements, but to log, analyze, maybe even manage and automate your electrical energy usage. The source code for a simple visual basic program that displays all measurements is available as a free download at e-gizmo.net. You can use this to jump start your development and add as many functions as you like.

If your desktop PC has a COM port, you don't need any extra interface circuit to connect it with your Power Analyzer. You can make your own interface cable as shown in Figure 4 using just a DB-9 connector, a 4k7 resistor, and a 4-wire header connector. Your PC program must enable the RTS line of your COM port to use this simple interface.

Laptops, unfortunately, are no longer fitted with COM port. A USB to Serial TTL conversion kit is required. The connection is identical to the wiring scheme recommended for MCUs as shown in Figure 5.

Future options will include a Bluetooth adapter for an even better still wireless link between your PC and Power Analyzer.

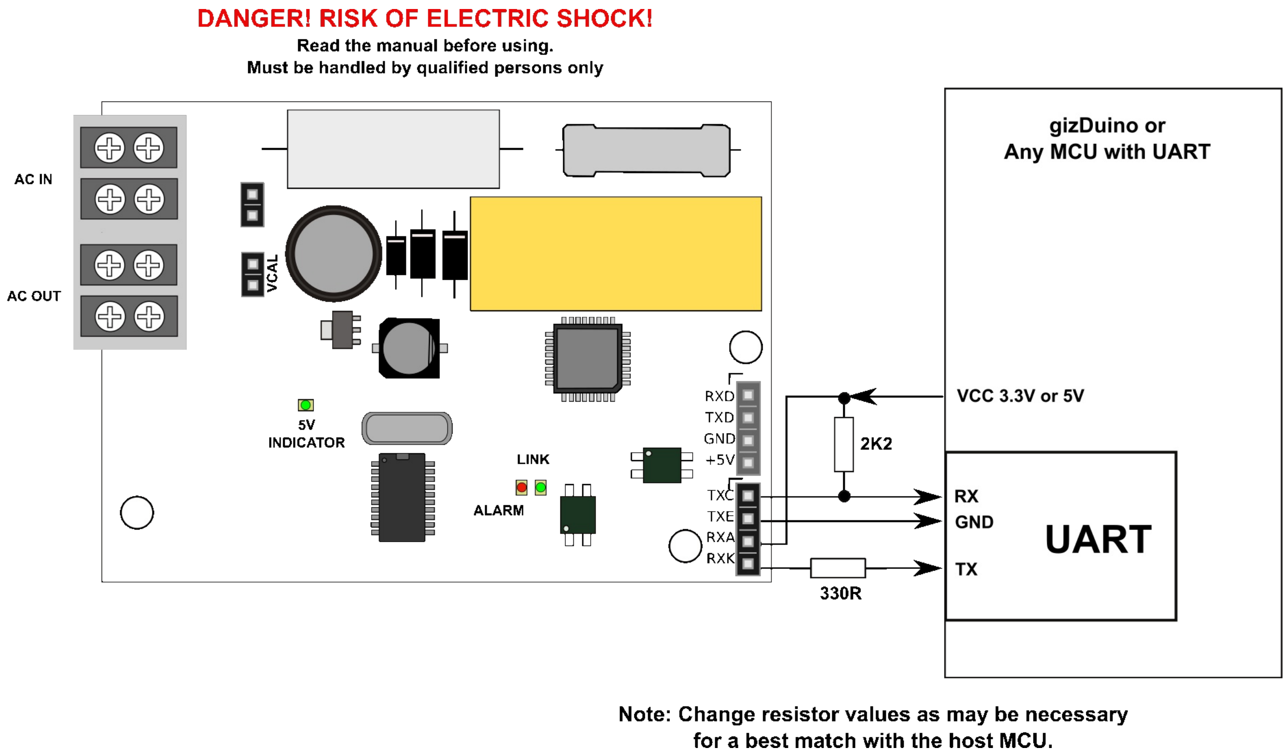


Figure 5. Interfacing the Power Analyzer with an MCU or gizDuino/Arduino controller. Any MCU equipped with a UART may be used. Resistor values shown are for reference only, and may need to be changed as the application circuit may so require.

3.2 Connecting to an MCU

The Power Analyzer can be connected to any microcontroller MCU circuit and module with UART port. MCU boards, such as Arduino and gizDuino, will allow you to construct application specific functions for the Power Analyzer. For example, use it with a Wi-fi equipped gizDuino combo, and you can program and build a powerful internet enabled power monitoring system.

Here are a few more project ideas you can build by combining the Power Analyzer with a microcontroller:

- Prepaid power cutoff device
- Electrical energy monitor/ Energy usage
- 3-phase load balancing
- Stand alone Power Analyzer
- Power Scheduling, etc.,

3.3 Power Analyzer Instrument

You can actually build a fully functional Power Analyzer instrument without writing a single code. The Power Analyzer has a built-in output function that allows it to connect to a 4x20 Serial LCD 2 kit. Set up the output mode to LCD display mode as described in section 4.

The Watt-Hour integrator timer is free running. You can reset Watt-Hour and integrator anytime to zero by pressing the Watt-Hour reset button.

The Watt-Hour timer is somewhat limited by the LCD display to 99:59:59. Past this, the LCD may display an erroneous time, but the integrator timer will continue with the correct time.

Note the safety reminders enumerated in the caption.

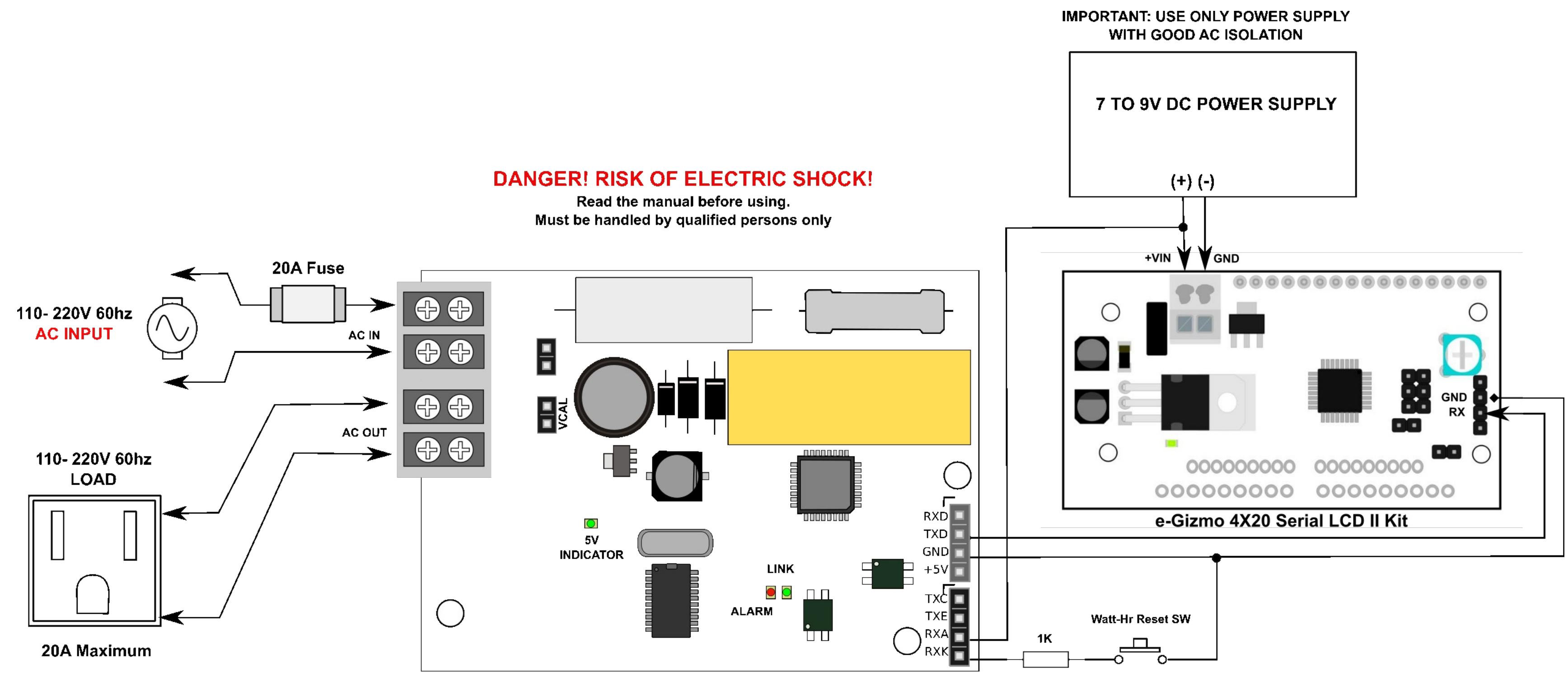


Figure 6. It is very easy to build an AC Power measuring instrument using the Power Analyzer kit. You only need to add a 4x20 Serial LCD2 kit as a display unit powered by a separate DC supply. A transformer type AC-DC adapter with good AC isolation is recommended for the Serial LCD2 kit. Note that the Serial LCD2 is now connected to the non-isolated port, and makes it an electrical hazard as well. Make sure everything is enclosed in an insulating case.

4. SERIAL OUTPUT MODES

The Power Analyzer serial data output can be configured in four different modes:

- Readable Format streaming
- ASCII CSV Format streaming
- Data on Demand
- Serial LCD streaming

4.1 Setting the serial output mode

The serial output mode can be configured two ways, one is through serial port command, and the other is by bridging a set of solder pads. The solder pads settings takes the priority and cannot be overriden by the serial port command.

4.1.1 Serial port command

Use the M command to set the serial output mode to the desired settings. Details of the command can be viewed in the Communications Section 6 of this manual. Settings are stored in a non-volatile memory of the Power Analyzer, and will be in effect, even after power cycling, until a new mode is set.

4.1.2 Solder pads settings

The serial output mode can be changed at anytime by applying a solder short on a corresponding solder pad. Obviously, a soldering iron is needed for this endeavor.

Short one pad only corresponding to the desired configuration. The Power Analyzer will assume the solder configured role regardless of the settings made with the serial port M command.

GS1 - ASCII CSV streaming
GS2 - Serial LCD streaming
GS4 - Readable Format streaming

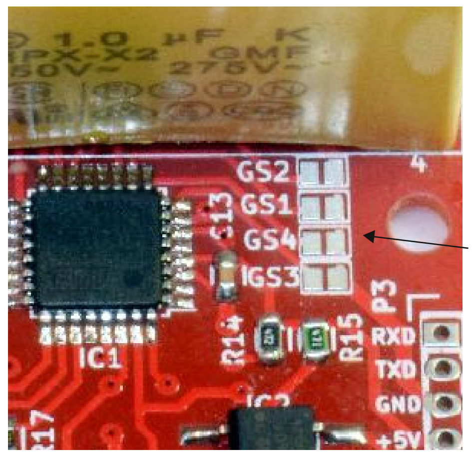


Figure 7. Solder pads locations. By applying a solder to bridge a pair of pads (left to right), the serial output mode can be set to a desired mode. Leaving these pads unsoldered will allow the display mode to be set using serial port command.

[STX]STAT,VERSION,VRMS,IRMS,PREAL,VA,QAVERAGE,QINSTANT,PF,TEMPERATURE,PHARMONIC,PFUNDAMENTAL,PQFUNDAMENTAL,
WATTHR,INT[ETX]

Example CSV output stream:

Figure 8. Comma Separated Value CSV transmission format. The third line displays an example CSV stream. [STX] and [ETX] are non printable ASCII characters and may be displayed by the terminal program using various symbols (e.g. a blank box character).

4.2 ASCII CSV Streaming

In this mode, the Power Analyzer will dump all measurement data in Comma Separated Value CSV format in the order shown in Figure 8.

[STX] - STX marker
See communications section for more detail.

STAT - Status
"OK" - Normal Operation
"OVF-V" - Voltage Range exceeded
"OVF-I" - Current Range exceeded

Any OVF condition results in invalid readings.

VERSION - 4-digit Firmware Version Stamp

VRMS - AC Voltage, Voltage RMS

IRMS - AC Current, Ampere RMS

PREAL - Real Power, Watts

VA - Apparent Power, Watts

QAVERAGE - Average Reactive Power, Watts

QINSTANT - Instantenous Reactive Power, Watts

PF - Power Factor

TEMPERATURE - Chip Temperature ºC

PHARMONIC - Harmonic Component Power, Watts

PFUNDAMENTAL - Fundamental Component Power, Watts

PQFUNDAMENTAL - Reactive Fundamental Component Power, Watts

WATTHR - Watt-Hour Integration

INT - Integration Time

[ETX] - ETX marker

See communications section for more detail

4.3 ASCII Readable Format Streaming

The Power Analyzer, in this mode, basically dumps everything in ASCII human readable format. The whole stream is wrapped in [STX][ETX] marker.

Example readable format output:

Volt RMS: 231.46 Amp RMS: 0.22 Real Power: 34.73
VA: 50.04 Q Power: -37.49 Q Instant: -17.76
PF: 0.6940 Temperature: 41.88
Harmonic: 0.03 Fundamental: 34.69 Fundamental Reactive: -37.49
Watt-Hour: 3.122
Integration Time: 0:23:46

4.4 Serial LCD streaming

Power Analyzer output stream will be in the Serial LCD2 format. A 4x20 Serial LCD2 kit is required as shown in Figure 6 to use this feature. Because of the obvious limitation in displayable capacity, not all measurements will be displayed. Following is a list of measurements that can be viewed with a Serial LCD2 kit display:

- AC Voltage, Voltage RMS
- AC Current, Ampere RMS
- Real Power, Watts
- Power Factor
- Apparent Power, Watts
- Chip Temperature ºC
- Integration Time
- Average Reactive Power, Watts
- Watt-Hour Integration

5. COMMUNICATIONS

Baud Rate: 9600
Data: 8 Bit
Parity: none
Handshake: none

5.1 Summary of Functions

Mn - Set Serial Output mode
Dnn - Transmit Requested Data
R - Reset watt-hour
V - Firmware Version
O - Offset Calibration

5.2 Communications Format

Important:

Every packet of data transmission are wrapped inside an [STX] and [ETX] marker.

[STX] – Start of transmission marker, ASCII value = 0x02
[ETX] – End of transmission marker, ASCII value = 0x03

The first character after the [STX] marker is a single character function specifier. Each transmission may contain just a function specifier only, or may contain a series of data in addition to the function specifier. End of transmission is signaled by the [ETX] marker.

[STX] and [ETX] are data packet markers and should not be transmitted as literal string. They should be send in their ASCII representation. The correct way of transmitting the [STX] and [ETX] markers are as shown in the following example:

Example 1: Reset Watt-hour Integrator

Transmission Format: Format: [STX]R[ETX]

This should be transmitted in their ASCII code representation as shown in the following table:

Symbol	STX	R	ETX
Hex	0x02	0x52	0x03

Visual Basic:

Correct:

```
' correct way to send [STX] & ETX  marker
Serial1.print(chr(2)+"R"+chr(3))
```

Wrong:

```
Serial1.print("[STX]R[ETX]")   'WRONG!
```

Arduino:

Correct:

```
Serial.write(0x02);     // correct way to send [STX]
Serial.print("R");      // ASCII equivalent of 'R' 0x52
Serial.write(0x03);     // [ETX] marker
```

Wrong:

```
Serial.print("[STX]R[ETX]");    // WRONG!
```

Alternately, you can use the C/Arduino "\" operator to send the ASCII code of STX and ETX, together with the function and data:

```
Serial.print("\002R\003");     //"\002"=STX, "\003"=ETX
```

Notice that in the example, only the STX and ETX marker need to be manually converted to their ASCII code, for the simple reason that they have no equivalent printable characters. The three line implementation (long format)may make your program longer, but is more human readable. Hence, for clarity, all example codes given are shown in the long format. We leave it up to you if you want to convert and code it in short format.

5.3 Function Description

5.3.1. **M** – Set Serial Output mode

Format: [STX]Mn[ETX]

Where n= Mode setting 1-4

1 - Transmit all readings in readable format at 1 sec refresh rate
2 - Transmit all data in ASCII CSV format at 1 sec refresh rate
3 - Data on demand

4 - Transmit selected data using e-Gizmo Serial LCD II protocol

See section 4 for details.

5.3.2. **D** - Transmit Requested Data

To prevent confusing results, use this function with the Serial Output Mode set to 3 (Transmit on Demand). D function will cause the Power analyzer to transmit the requested data regardless of the settings of the Serial Output Mode.

Format: [STX]Dnn[ETX]

Where nn= Data 0-0B
Note: nn should always be entered as two digits

00 - Volt RMS
01 - Amp RMS
02 - Real Power
03 - Apparent Power S
04 - Reactive Power Q
05 - Power Pactor
06 - Chip Temperature
07 - Harmonic Power
08 - Fundamental Power
09 - Fundamental Reactive Power
0A - Watt-Hour
0B - Integration Time (secs)

Example (Arduino): Get Real Power

```
Serial.write(0x02);     //STX code
Serial.print("D02");    //Transmit Real Power
Serial.write(0x03);     //ETX code
```

5.3.3 **R** - Restart Watt-hour Integrator

This function will reset the watt-hour and integrator to zero.

Format:[STX]R[ETX]

5.3.4 **V** - Display Firmware Version

Returns a four digit Firmware Revision stamp.

Format:[STX]V[ETX]

5.3.5 Vofst, Iofst - Offset Calibration

For best accuracy, offset calibration may be done periodically. See section 5 for details.

6. OFFSET CALIBRATION

The Power Analyzer is sold pretested and calibrated in the configuration as when it was sold. Replacing the current sensors will require a full recalibration, and this can be done only with proper calibration equipment. Full recalibration is therefore something not to be done by the end user.

With usage, it is possible that the zero point of the Power Analyzer kit may have shifted to a value other than zero. This drift is usually not significant enough to cause an appreciable error with most measurements but in the low range region (less than 10W).

If you so desire, error in the low power range region can be further minimized by performing offset calibration before doing measurements. User offset calibration are not permanent adjustments and are in effect only until the board is powered off. ***Power cycling will return the offset calibration to its factory settings.***

6.1 Equipment Required

- A PC with COM port running "Terminal by Br@y++" program.
- Serial cable to connect to PC as described in Figure 4.

6.2 About the Terminal by Br@y++

Terminal is a freeware developed by, guess who, Br@y++. This program allows you to use your PC as a dumb terminal, very much like the HyperTerminal that was once bundled with your Windows OS. But there is a huge difference. This terminal program allows you to do more than just transmit and receive a stream of characters. For example, it allows you to setup the hardware handshake lines of the COM port, this is a required feature to enable our use of the simple cable interface. It allows us to transmit non printable characters, such as the [STX] [ETX] markers required for each message transmission block. It is a program made for experimenting geeks.

Download and learn more about the program by visiting their site:

http://sites.google.com/site/terminalbpp/

6.3 Terminal Offset Calibration Setup

Launch and set up the Terminal program by clicking ON the following options:

COM Port - COM port where your Power Analyzer is connected. Our example used COM1.

Baud Rate - 9600
Data bits - 8
Parity - none
Stop bits - 1
Handshaking - RTS/CTS

With the Power Analyzer connected and powered, measurement data from the Power Analyzer should start streaming-in. If no data is displayed, try typing:

$02M1$03

from the transmit window, and then click [SEND].

$02- [STX] marker. This cause the Terminal to send STX (ASCII code = 2)

$03- [ETX] marker. This cause the Terminal to send ETX (ASCII code = 3)

You should see the measurement readings at this point.

6.4 Current Offset Calibration Procedure

The Hall effect current sensor is DC coupled to the Power Analyzer engine, but the chip is configured to ignore the DC components. Hence AC current offset is not likely. But there may be conditions where DC offset may have gone too much that it already badly affects the accuracy of your AC current measurements. If you suspect that problem, then the Current Offset calibration may help mitigate the problem.

Following is the recommended procedure:

1. Disconnect all devices appearing on the load side terminal.

2. Type $02Iofst$03 at the Terminal transmit window and then click [SEND]. This will initiate the offset calibration procedure. Wait until the Power Analyzer completes the procedure. This should take less than 30 seconds.

3. Reconnect load devices.

6.5 Voltage Offset Calibration Procedure

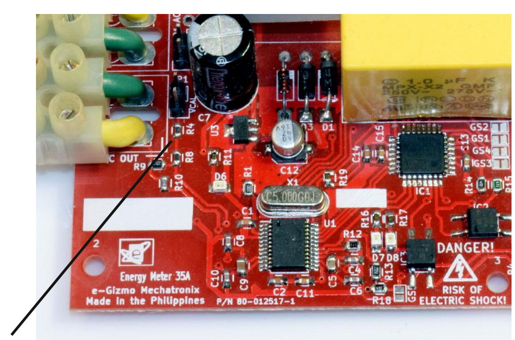
It is highly unlikely that the zero voltage offset would drift enough to introduce a significant error in the measurements. Nevertheless, the procedure is listed just the same in case you find a need for it.

1. Remove the Offset Calibration jumper (Careful!) and unplug/disconnect any load in the P1 AC OUT side.

2. Find the portion in the displayed measurements that indicates Volt RMS. Make sure it displays a value of less of than 5 VAC.

3. Type $02Vofst$03 at the Terminal transmit window and then click [SEND]. This will initiate the offset calibration procedure. Wait until the Power Analyzer completes the procedure. This should take less than 30 seconds.

4. Reinstall the jumper removed in step 2.



Offset calibration jumper location shown with the jumper already removed.

7. USEFUL INFORMATION

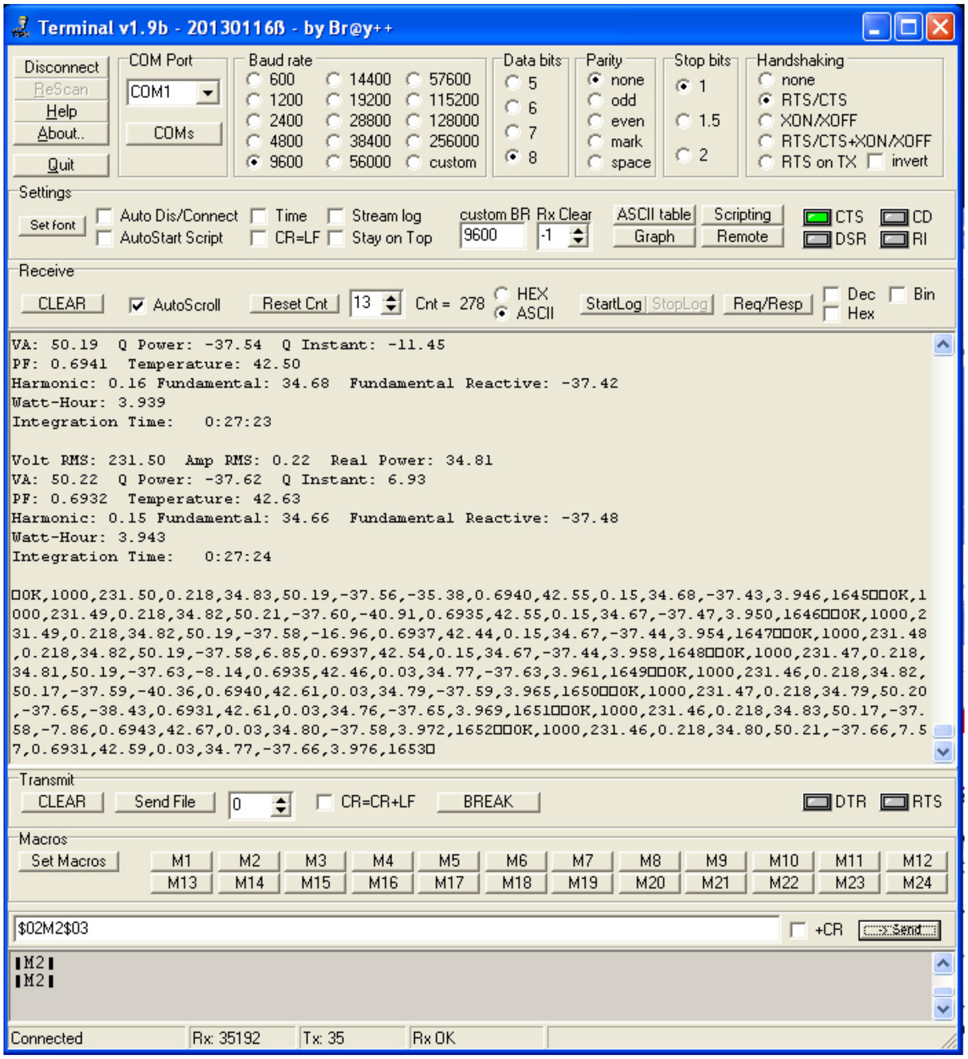


Figure 10. Screen capture example of a Terminal program session. Note the communication interface setup.

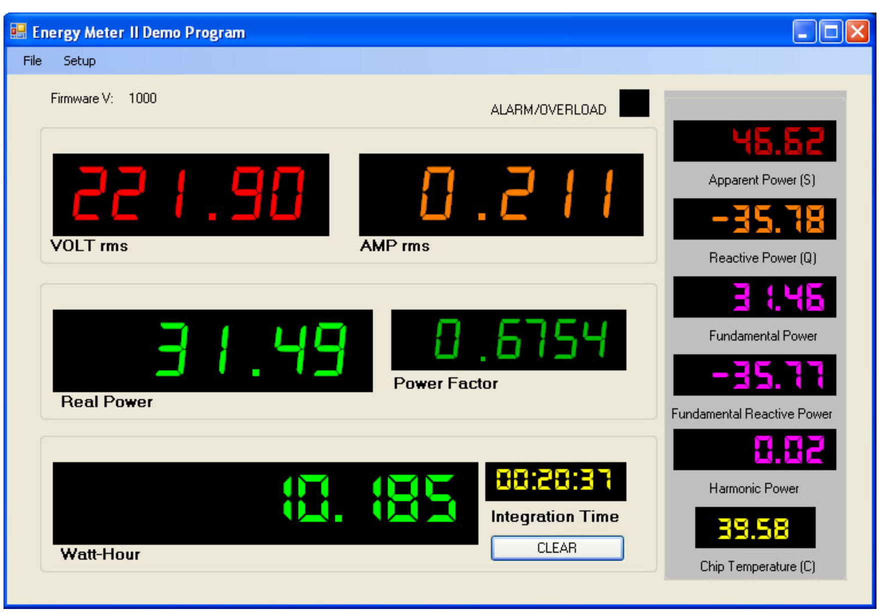


Figure 11. Visual Basic example program showing all measurements. If you can develop your own PC app, then you can customize your PC functions and display in any way you want.

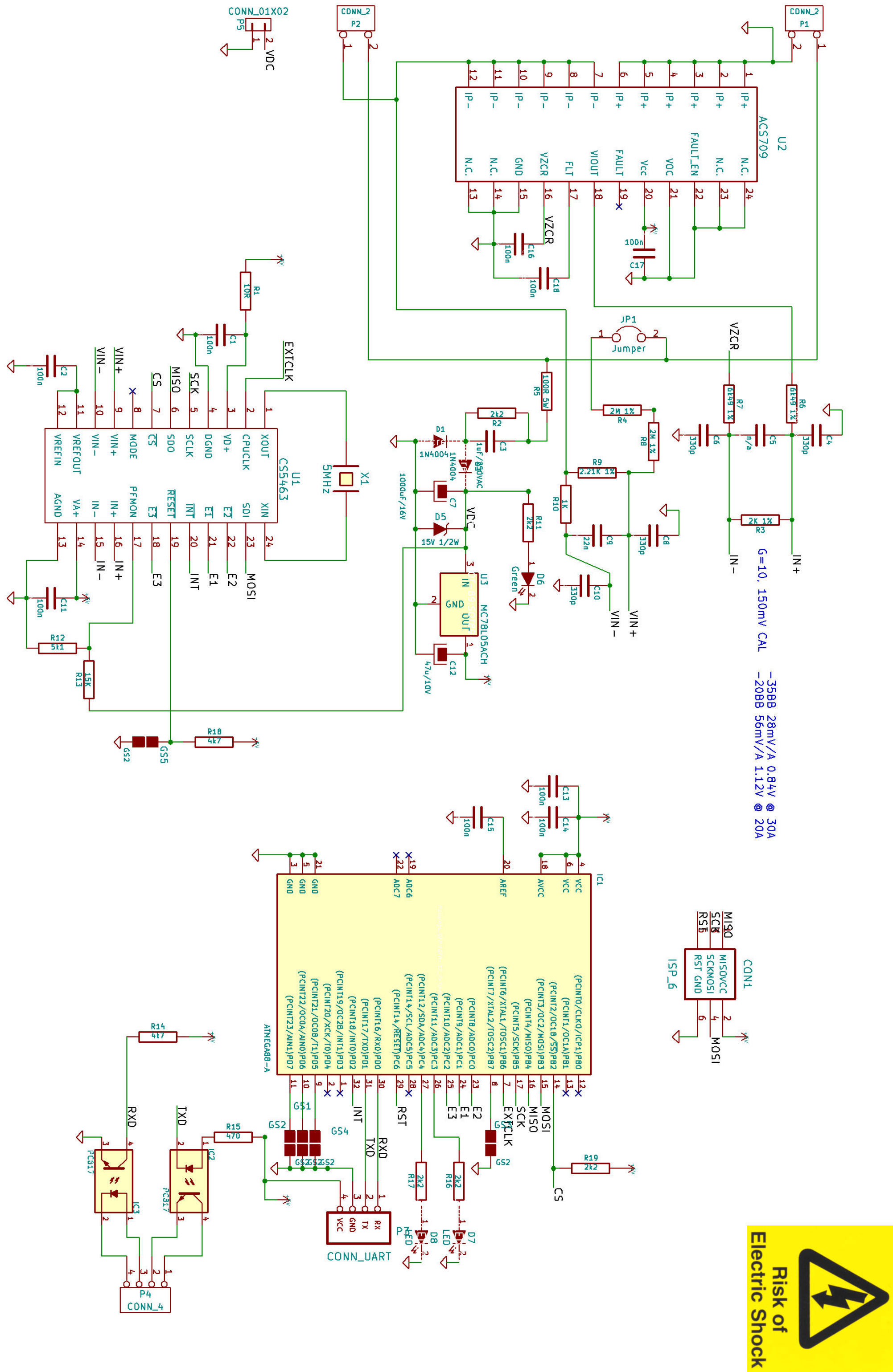


Figure 12. The Power Analyzer 2 complete schematic diagram. The Power Analyzer uses the same CS5463 analyzer chip as before. The on board MCU, on the other hand, uses a ATMEGA168, which made it possible to pack in more functions and features.