Powerduino Hardware Overview

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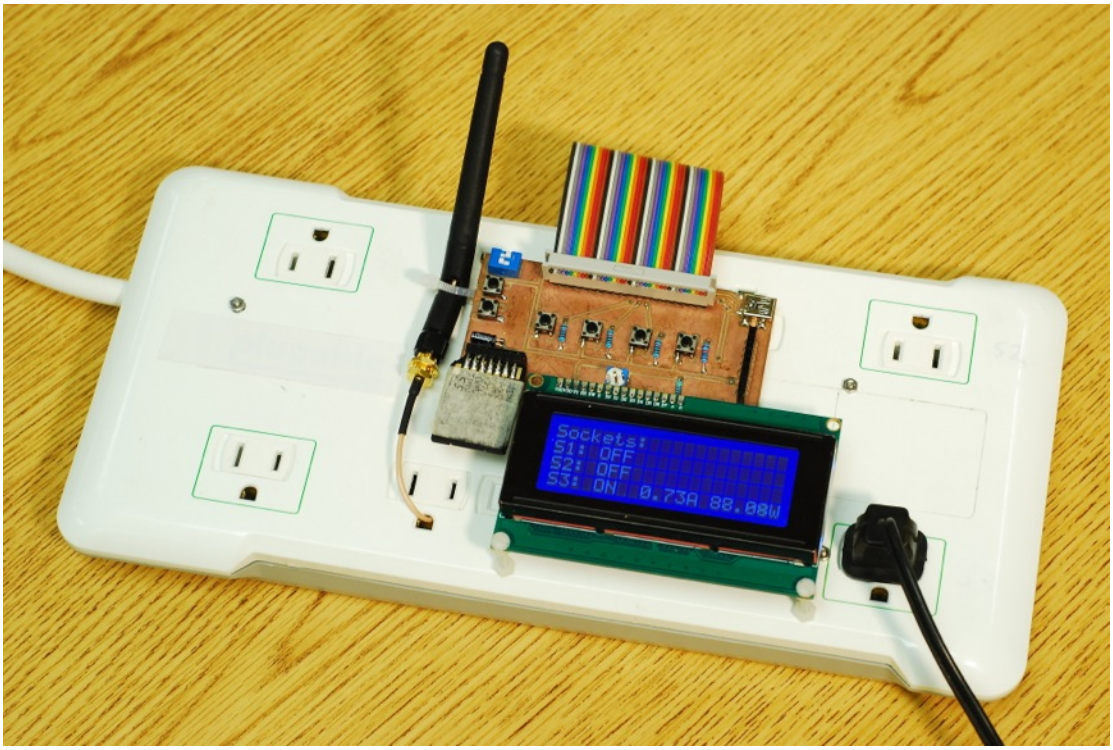
Contents

1. Project Overview 1
2. Design 2
  2.1 Block Diagram 2
  2.2 Circuit Overview 3
    2.2.1 Power Supply 3
    2.2.2 Relay Board with Current Sensor 3
    2.2.3 Main Board 3
    2.2.4 Front Panel 4
  2.3 Part List 5
3. Project Gallery 6
4. References 8

1. Project Overview



Powerduino is a power strip that has been enhanced with a Teensy 3.1 microcontroller, RTC, current sensors, relays, WiFi module, external digital/analog IO pins, LCD, SD card, USB connector, and buttons. With an arsenal of new sensors and components, along with its open source design and Arduino compatible microcontroller, users are able to wirelessly control and monitor each socket over WiFi, observe real-time current, power and energy consumption of individual sockets, perform energy usage logging on SD card, and upload custom programs to the power strip through Arduino IDE to perform any action they want on each socket. This enables a wide range of new applications within energy saving, safe and fast mains voltage home automation, and more.

For example, one can create an automatic lamp that turns on in the night by attaching a light sensor to one of the external pins, writing 4 lines of code, and plugging in a regular lamp in the designated socket. Similarly, with just a thermocouple, one can write a program to turn a $20 mini-oven into a reflow oven without modifying it in any way and being exposed to dangerous mains voltage. Want to turn off a socket when it has used more than 1kWh of power? Schedule a socket based on time? Limit the current that a socket can use? Implement a light dimmer right in the power strip? If you can code it, Powerduino can do it.

2. Design

2.1 Block Diagram

The construction of Powerduino is relatively straightforward, with microcontroller, WiFi module, power supply, and relay boards inside the power strip, and a front panel outside the power strip. A 2-row 40-pin ribbon cable connecting connecting them together.

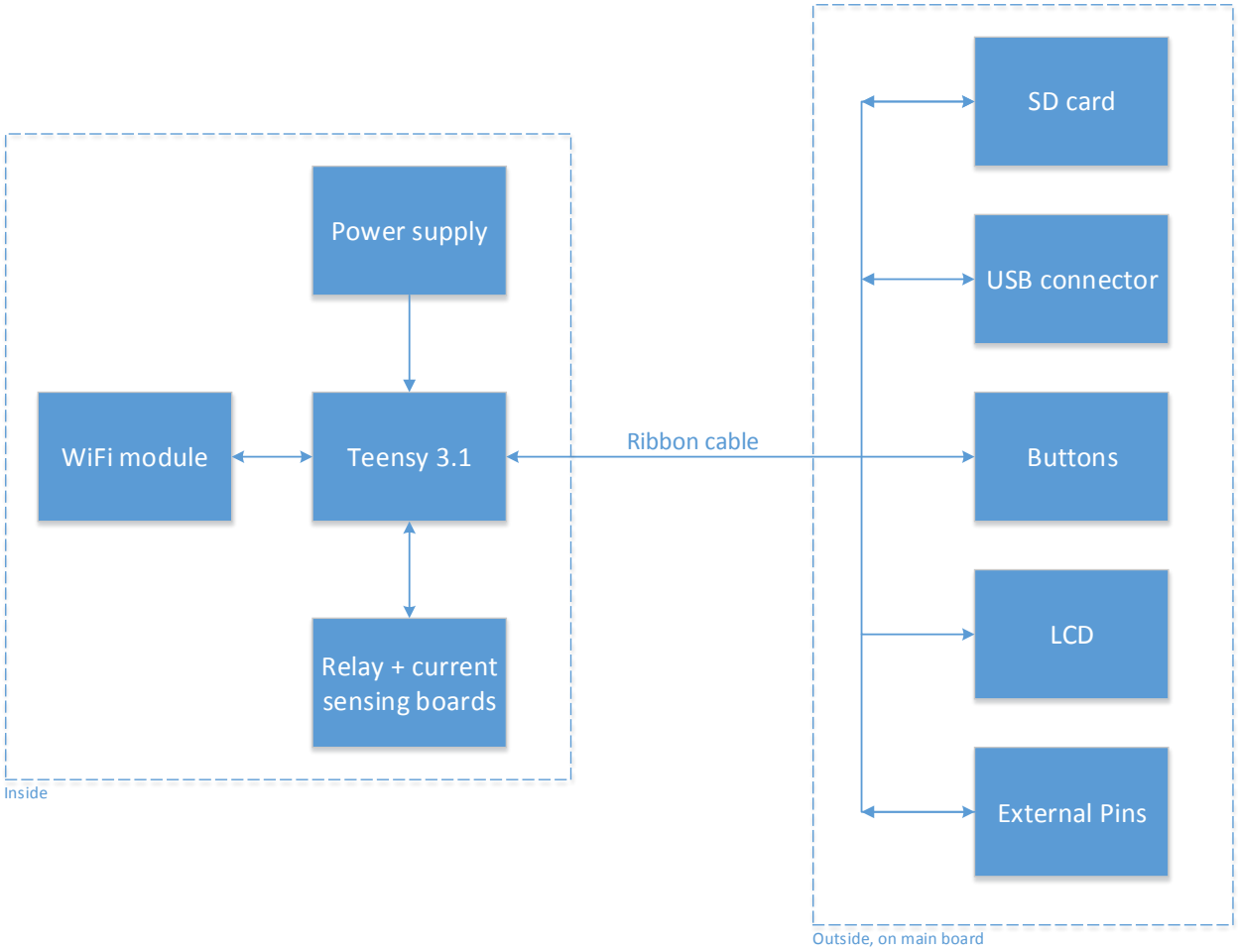


Figure 1. High-level block diagram

2.2 Circuit Overview

Please refer to corresponding Eagle file while reading the descriptions.

2.2.1 Power Supply

A simple linear power supply was designed for this project. The transformer(FP16-150) steps mains voltage down to 8V, which is then bridge rectified and regulated to provide 5V and 3.3V for various components. The half-wave of transformer's output have also been divided down to within 3.3V, intended for microcontroller's ADC, for zero-crossing detection. 400mA resettable fuses was used for protection. I only had 200mA fuses so I put two in parallel.

Feel free to use one of those miniature switch-mode 5V USB power supply in phone chargers, since it would be smaller than this design, and also more efficient. However you do need to implement your own 3.3V source and zero-crossing detection solution(if you need it).

2.2.2 Relay Board with Current Sensor

The relay board with current sensor is used to control each socket, as well as providing microcontroller with the information of how much current is passing through the relay. Two types of relay boards were designed for this project, namely solid state and mechanical.

The solid state relay was constructed with a MAC224 TRIAC controlled by a MOC3010 TRIAC driver. It provides very fast switching time, and noiseless operation. However, the TRIAC does generate a substantial amount of heat during operation, as much as around 9W when switching 10A of current. So adequate cooling is required if solid state relay are to be used continuously inside the confined space of an power strip.

The mechanical relay board is essentially the same as solid state relay board, apart from using a mechanical relay, in this case a T77S1D10-05. It produces much less heat when switching high currents compared to traic, but does produce some noise, along with slower switching times.

Both type of relay board contains a ACS712 Hall Effect current sensor to measure current. When no current is present, the output is 2.5V, while output is greater than 2.5V for current in one direction, and smaller than 2.5V in the other direction. The 0-5V output was divided down to 0-3.3V using a resistor divider for Teensy's ADC.

When assembling the relay board, make sure to insulate vertical resistors with heat shrink tubing to prevent them from touching and shorting out.

A LED can be connected to the 2-pin header at the bottom right corner of each board, which will light up when relay is on.

2.2.3 Main Board

The main board houses the microcontroller, WiFi module, 3V coin battery holder for the real-time clock, and various connectors to other modules, namely power supply, relay boards, and face panel.

The reset signal is a test point on Teensy 3.1, so solder a wire on it and connect the other end to the single TEENSY_RESET header near the top right of the PCB.

To use the USB connector on the front panel for uploading program, cut a micro-usb cable, plug the micro-usb side into teensy, and connect D+, D- and Vusb wires to the headers on the PCB.

Do not use 80-wire IDE cable as a ribbon cable to connect Main Board and Front Panel, some pins in the IDE cable are electrically connected together.

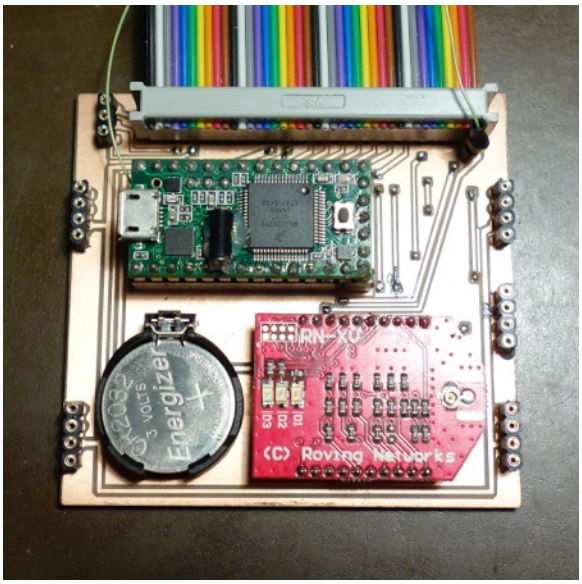


Figure 2. Main board

2.2.4 Front Panel

The front panel is located at the front of the power strip. It contains user-interface related components for the ease of use, namely LCD, buttons, SD card, external pins, mini-USB connector, as well as the connector to the main board inside.

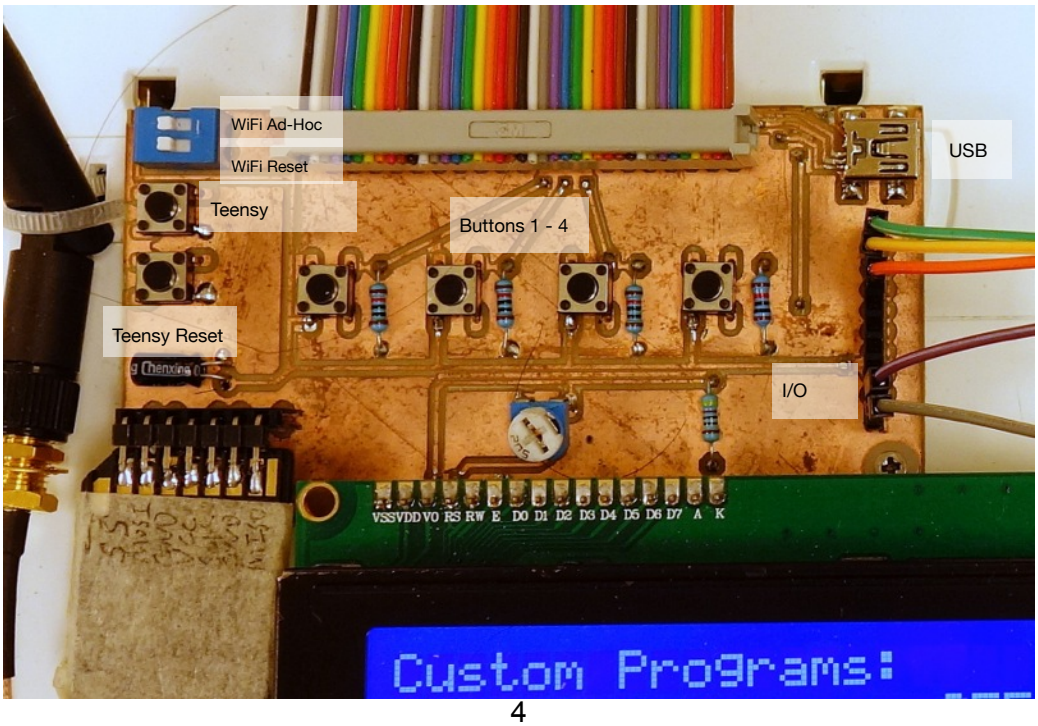


Figure 3. Front Panel

2.3 Part List

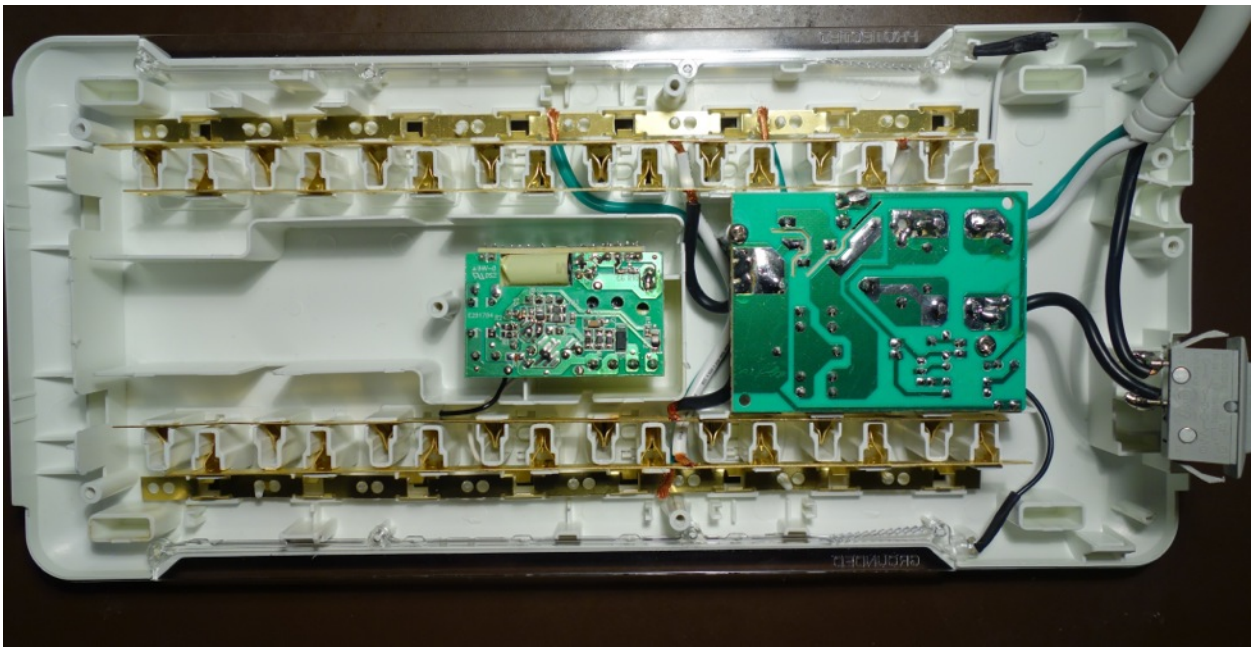
For those parts with a link to the product page, you don't have to buy it there, just make sure the part you get is the same.

Description	Part Number	Notes
WiFi module	RN-XV WiFly	https://www.sparkfun.com/products/10822
Power strip	Plugable 12 Outlet Power Surge Protector	Purchased from Amazon
LCD	20*4	https://www.sparkfun.com/products/256
SD card		Solder male pin header on Micro SD adaptor, plug into female pin header on front panel. The gold contact side facing buttons.
Microcontroller	Teensy 3.1	
TRIAC	MAC224	If you decide to use solid state relay board
TRIAC Driver	MOC3010	If you decide to use solid state relay board
Mechanical relay	T77S1D10-05	If you decide to use mechanical relay board
Pushbuttons		https://www.sparkfun.com/products/97
2-Bit DIP switch		http://i.imgur.com/cVnSq95.jpg
Assorted resistors		
Assorted capacitors		
Assorted pin headers		
Assorted wires		Including 40-wire ribbon cable
Resettable fuse	500mA	
Coin battery holder		https://www.sparkfun.com/products/783
Mini-USB connector		https://www.sparkfun.com/products/587
Transformer	TP16-150	
Diode bridge	W02G	
Voltage Regulators	7805, 7833	

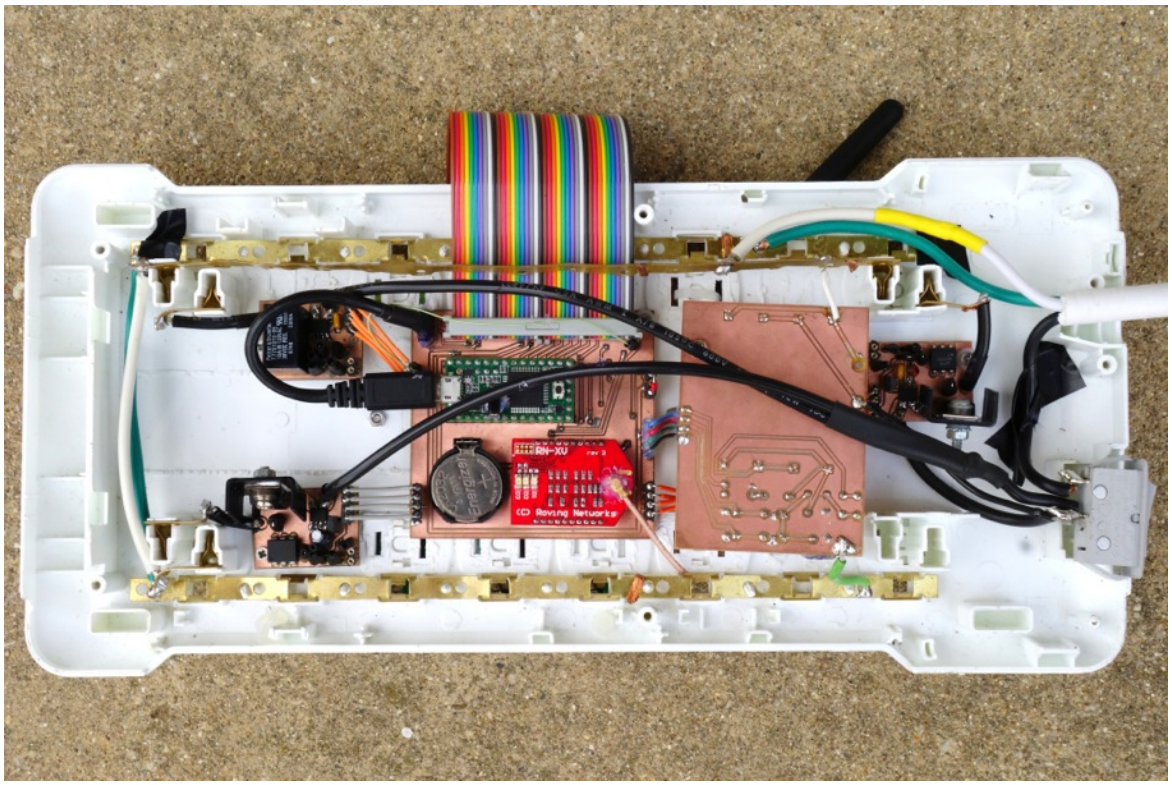
3. Project Gallery

The power strip before being modified, there is a total of 12 outlets.

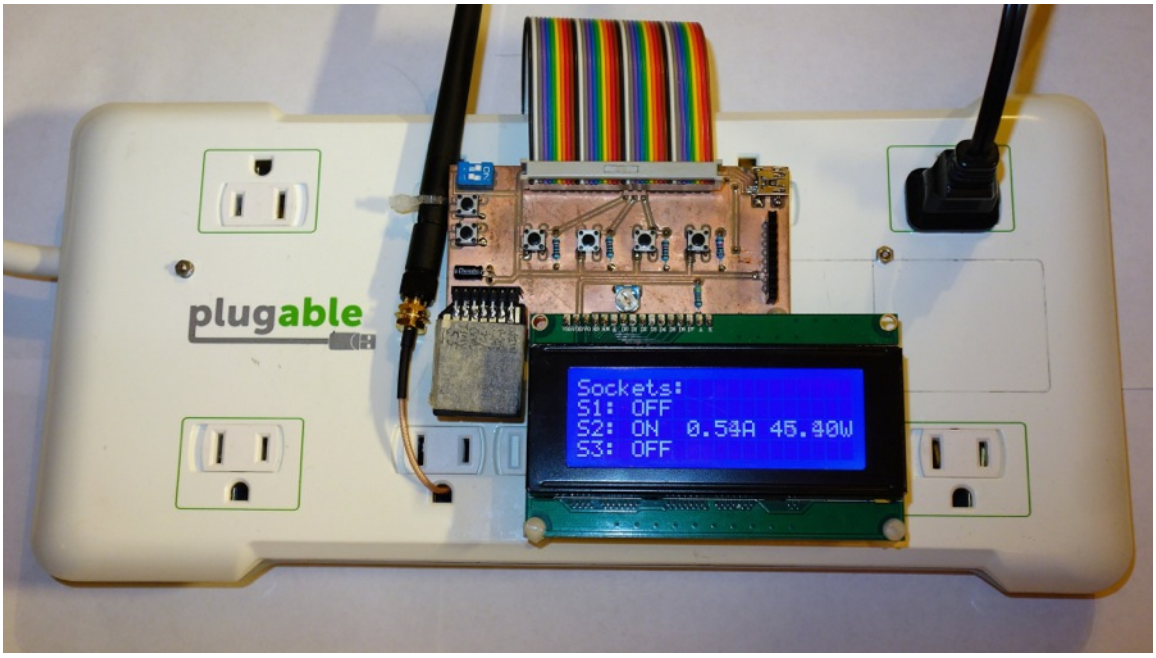
The inside of unmodified power strip, the PCB on the left is the USB charger, while the PCB on the right is surge protection circuit.



Assembled project, note that a large about of plastic was cut off to facilitate new circuit boards, only the sockets at corners are used.



View from front.



4. References

[1] *ACS712 Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor,* Allegro Microsystems, Inc., Worcester, MA, 2007.

[2] Application Note AN-3003, Applications of Non Zero Crossing TRIAC Drivers Featuring the MOC3011, Fairchild Semiconductor Corporation, 2003.