Introduction to Solar Power, USB Charger - Spring 2017

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This class is designed to be a quick introduction to off-grid Solar power, covering basic electronic knowledge, hardware requirements, basic off-grid solar circuit design, and determining how much power you need.

The class is designed for artists/DIYer's/makers/basically anyone who isn't a "professional" with a very basic understanding of electricity and a willingness to experiment.

The class will culminate in building a tiny solar-powered usb power supply.

Introduction

Electrical Concepts

Our Solar Power System

Instructions

Determining your power needs

Larger Off-Grid Systems

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Introduction

What is solar power?

- Solar Panels generate electricity through the photovoltaic effect. Some material naturally absorbs photons of light and releases electrons.
- Variable i.e. dependent on available sunlight and to a lesser degree temperature.

Two types of solar power implementation

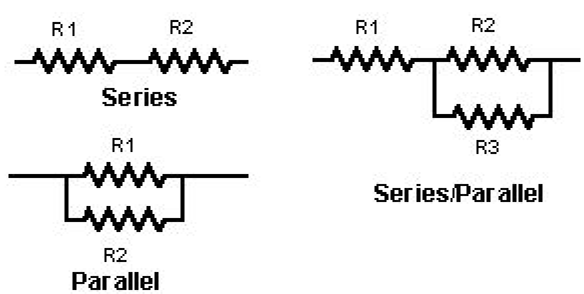
- On-grid (Connected to the public power grid)
- Off-grid (Not connected to the public power grid. This is what we're building.)

Ways to implement off-grid solar power

- Direct from solar panel to load
- Solar panel to capacitors to load
- Solar panel to batteries to load
- Our project combines the direct method with batteries.

Electrical Concepts

- A circuit is a circular path, which allows electricity to flow from an area of higher voltage to an area of low voltage.
- Series vs Parallel
- Ohm's Law V=I*R
- Watt's Law W=I*V
- Short Circuits (BAD!)



AC/DC

- There are 2 types of electrical currents. Direct Current, discovered by Edison, moves in one direction. This is used in batteries. Alternating Current, discovered by Tesla, switches directions and is used in the national power grid.
- Inverters are used to switch from DC to AC.
- Rectifiers are used to switch AC to DC.
- Do not directly attach AC and DC supplies and loads without the use of the proper hardware.

Safety

- DON'T CONNECT ANYTHING TO A WALL OUTLET (unless you really really know what you're doing).

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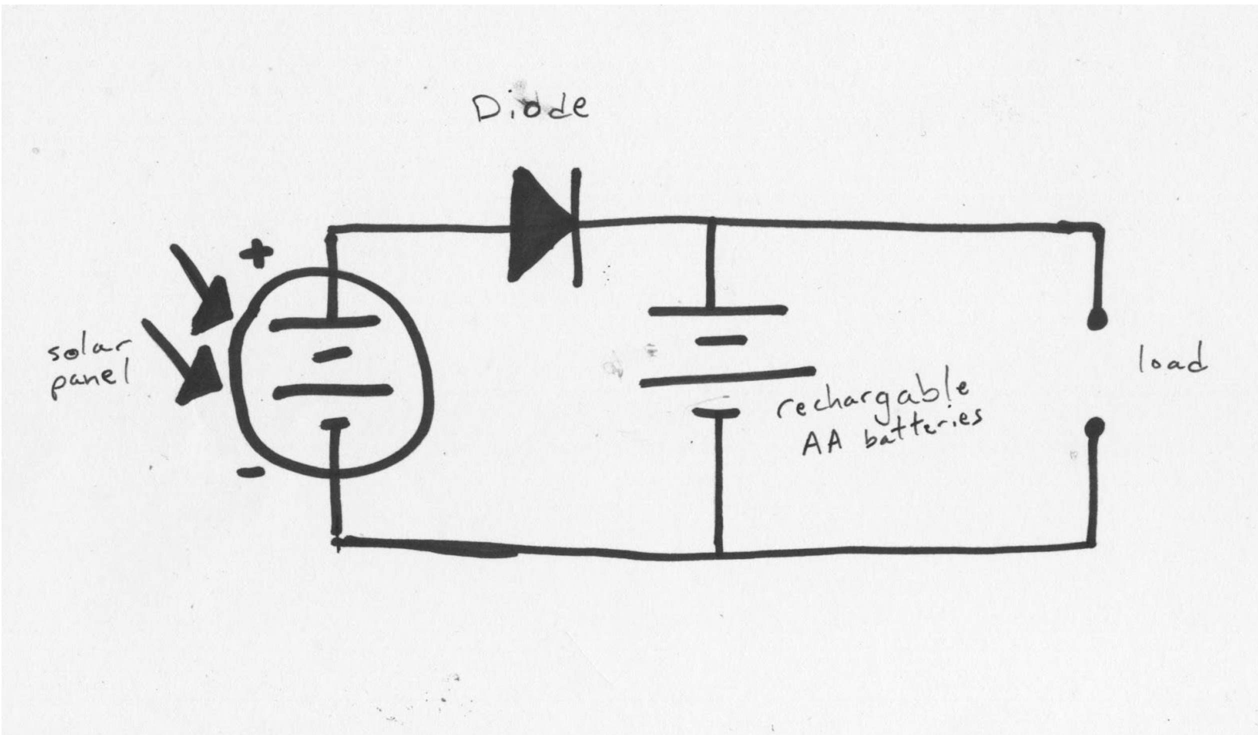
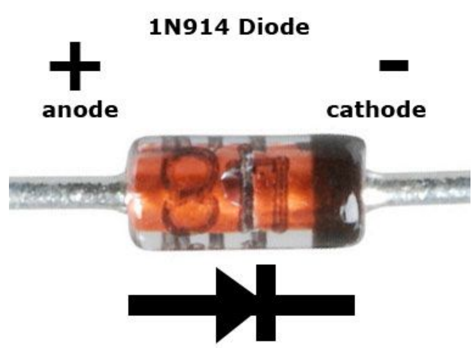
- In larger solar power systems fuses should be used to protect components.
- Never mix different battery types (AA, AAA, etc.), different brands, or different capacities in a single charger.

Our Solar Power System



Solar charger schematic (fig. 1)

Material specifications



1W 5V solar panel

- 200mA output

1N914 diode

- This protects the solar panel by controlling which direction electricity can flow.
- Diode drops about 0.2V from the system.
- The direction of diode is important. Note the black line indicating the cathode side of the diode.

Two rechargeable 1800mAh NiMH AA batteries

- Our battery chemistry is nickel–metal hydride (NiMH)

- Battery capacity is measured in amp hours (Ah).
- We will be "trickle" charging our batteries. When using a "smart" wall adapter you can safely charge batteries at a high speed. Our charger is a passive, "dumb" charger so we use the 10% rule to safely charge the batteries. This method will avoid over charging.
- Battery voltage is a nominal measurement. A fully charged battery rated at 1.2V actually begins closer to 1.4V and drops below 1.2.

DC voltage booster (transformer)

- input = 1.8-5V
- output = 5.2V, 500mA
- This DC to DC boosting circuit outputs ~5V 500mAh, which is the standard for USB. The circuit board included with this project is a PowerBoost 500, made by Adafruit. A very detailed spec sheet can be found on their website. Similar, cheaper boards can be used, however they may not be compatible with Apple products.

Battery holder

- Ours has an on/ off switch, but it's not necessary.

Project enclosure

- Repurposed from a cheap Bed, Bath, and Beyond travel case

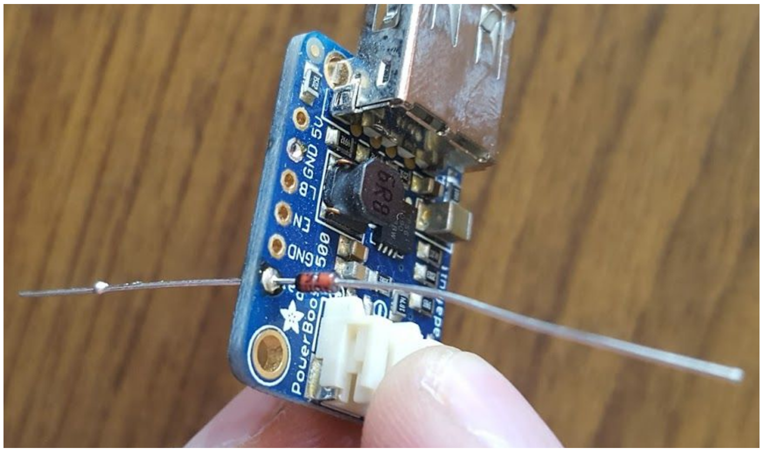
Instructions

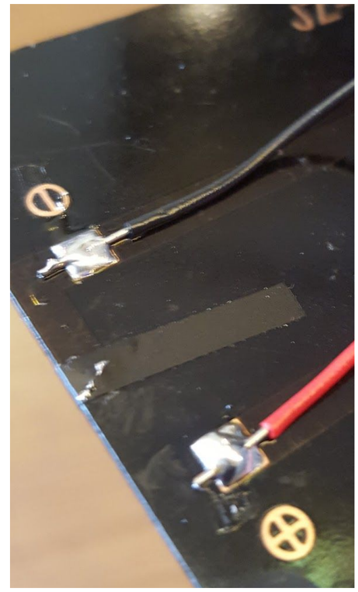
1. Test the solar panel
    a. Set your multimeter to the DC voltage setting above 5V. This will most likely be the 20VDC setting.
    b. Attach the multimeter to the contacts on the panel. Use alligator clips if necessary.
    c. The multimeter should display the voltage being generated by the solar panel. In direct sunlight it should be about 5V. If the reading is negative, reverse the polarity of the multimeter.
    d. Try covering the solar panel with your hand and observe the voltage output.
2. Prepare the project enclosure
    a. Mark the holes on your enclosure before cutting.
    b. Drill a hole on one side of the enclosure
    c. Cut a rectangular hole on the bottom of the enclosure. This hole should be big enough to fit the USB port into.

3. Assemble the circuit board
    a. Solder the usb port on to the board

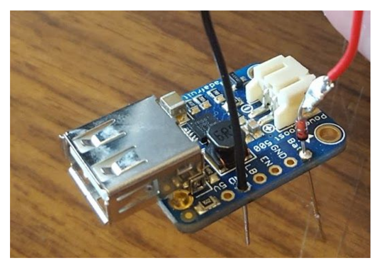
i. Use the continuity setting on your multimeter to confirm that there is not a short between any of the 4 pins on the USB port.

b. Solder the diode on to the board. Place the cathode side of the diode through the **BAT** hole on the board. The black line on the diode should be facing the board. Position the diode in such a way that one wire sticks out on the other side.





4. Wire the solar panel
   a. Determine the solar panel's polarity. This is usually indicated with + and - symbols. If those are absent, use the multimeter to determine polarity.
   b. Strip about ¼'' off each end of both wires.
   c. Solder one end of the red wire to the + side.
   d. Solder one end the black wire to the - side.
   e. Hot glue over the solder joints. Hot glue the wires together onto the back of the panel. This helps relieve tension from the solder joints.
   f. Run both wires through the hole on the side of the enclosure.
   g. Solder the red (+) wire to the anode side of the diode.
   h. Solder the black (-) wire to the **GND** hole on the board.



At this point the circuit board should turn on in direct sunlight. There are 2 LEDs on the board. The green LED indicates power. The red LED indicates the input voltage is below 3.2V.

5. Wire the battery pack (fig. 5) **note: remove the batteries before soldering**

   a. Solder the red (+) wire on the battery pack to the **BAT** hole. If you assembled it in the identical way as pictured, you should be able to connect this wire to loose end of diode protruding from the bottom of the board.
   b. Solder the black (-) wire on the battery pack to the **GND** hole. If you assembled it in the identical way as pictured, you should be able to connect this wire to the loose end of the negative solar panel wire protruding from the bottom of the board.
6. Final placement (fig. 6a-d)
   a. Before glueing, place the battery pack and the circuit board into the enclose with the USB port slightly sticking out of the rectangular hole on the bottom to ensure they both fit. Place a dab of hot glue on the bottom of the circuit board.
   b. Place the battery pack in enclosure. Do not glue the battery pack into place. You may want to change the batteries or turn them on or off at some point.

Additional notes:

- The two **GND** holes on the Power Boost 500 circuit board are connected. We will use the one farther away from the **BAT** hole to minimize the chance of shorting.
- By using the diode to connect the red (+) wires to the panel we can cut down on the amount of jumper wires needed. We will also place the black (-) wire from the panel through the hole in such a way that the black (-) wire from the battery pack can be soldered to it. This method cuts down on the total amount of wires required and makes the project slightly more elegant.
- Batteries will only charge if the battery pack is turned on.
- This project is not waterproof, however you can make it slightly more water resistant by plugging the hole for the solar panel wires with hot glue.

Determining your power needs

Battery capacity and capability

- 1Ah means that we can theoretically draw 1 Amp for 1 hour. This can be misleading. A 1Ah battery probably cannot provide 1A for an hour, but can provide .01A for 100 hours.
- As the rate of discharge increase, battery capacity decreases.
- 1Ah = 1000mAh

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The capability of a battery (i.e. the ideal charge and discharge current of a given battery) is measured C's.

C = Ah/1 hour
Ex. 1C of 7Ah battery is 7A.

The ideal trickle charge rate for Ni-MH batteries is .1C. Ni-MH batteries can be discharged at a rate as high as .2C.

1C of 1800mAh = 1800mA
ideal battery charge rate: .1C = 180mA
ideal battery discharge rate: .2C = 360mA

When wiring identical batteries in series the voltage is added, but the Ah's stays constant.
When wiring identical batteries in parallel Ah is added, but voltage is constant.
2xAA NimH 1.2V @1800mAh in series = 2.4V 1800mAh

Calculating solar panel output
1W/ 5V = .200A output rate (Watt's Law)

200mA = ~.11C

Our project's charge rates
1800mAh (battery capacity)/ 200mA (charge rate) = 9hrs
9hr x 1.2 (20% efficiency loss) = 10.8 hrs to fully charge AA batteries.

Calculating the ability of a battery to power a load (using an Arduino as an example)

Arduino Power Basics

- There are multiple ways to connect power to an Arduino. The safest way is through the barrel jack, because it has a diode in place to protect against reversing the polarity.
- The recommended input voltage through the barrel jack is 7-12V
- Absolute max current per pin 40mA (recommended max is 20mA).
- Max total current of all IO pins is 200mA.
- The 5V and 3.3V output pins can supply higher amperage than the IO pins.

Ex. 1 rechargeable 12V 7Ah marine Battery powering an Arduino Uno with no load.

Arduino with no load consumes ~50mA.

7Ah = 7000mAh
7000mAH/50mA = 140 hours of power

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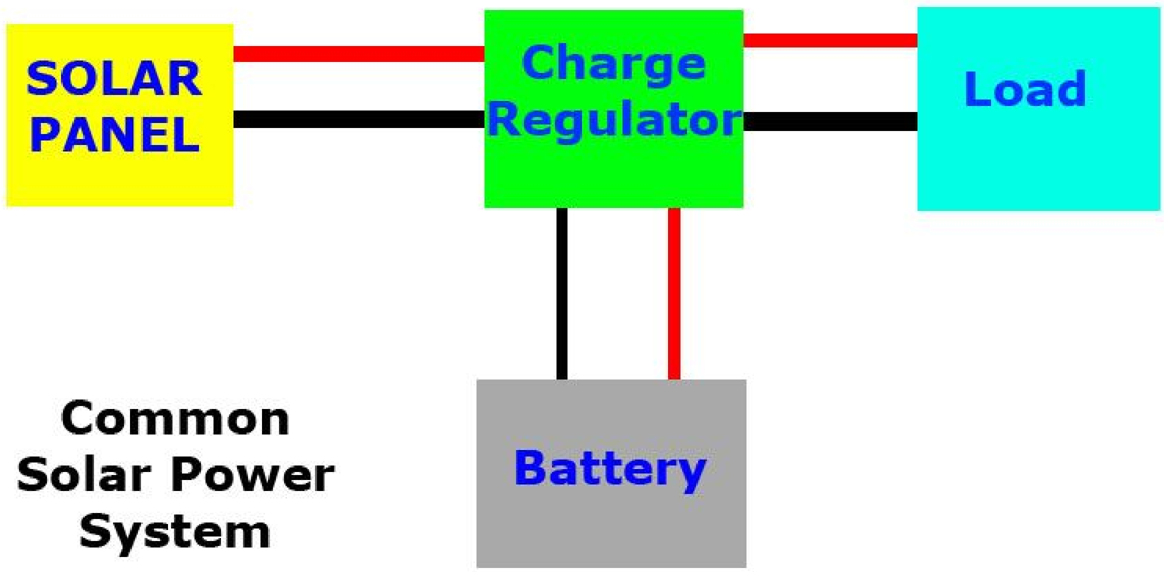
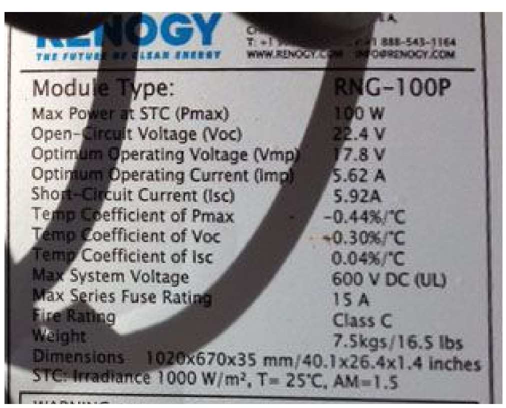
Larger Off-Grid Systems

Main hardware components of an off-grid solar power system



Solar Panels



Batteries

- Solar power batteries look similar to car batteries, but have very different characteristics.
- Car Batteries, also known as starter batteries, are meant to be discharged and charged very quickly. These can work for solar in a pinch, but are not ideal.

- A typical battery engineered for solar power will be called a deep cycle battery. Sometimes these are called marine batteries. These are designed for gradual charging and discharging.

Charge controllers

- Charge controllers range from as low as $30 to thousands of dollar.
- Charge controllers manage the battery power and provide some amount of voltage control.
- Knowing the maximum amperage of your solar power system and matching it to the amperage rating of your charge controller is key.
- Higher end charge controllers will have LCD displays and provide you with a lot of information about your system.

Placing fuses between components on a larger scale solar project is highly recommended.

Additional Resources

http://www.eforaging.com/links.html