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3D-PRINTED SINGLE-AXIS SOLAR TRACKER WITH ENERGY STORAGE AND BLUETOOTH MONITORING

Technology (/technology/) > Arduino (/technology/arduino/) by nicolasfg (/member/nicolasfg/) Follow

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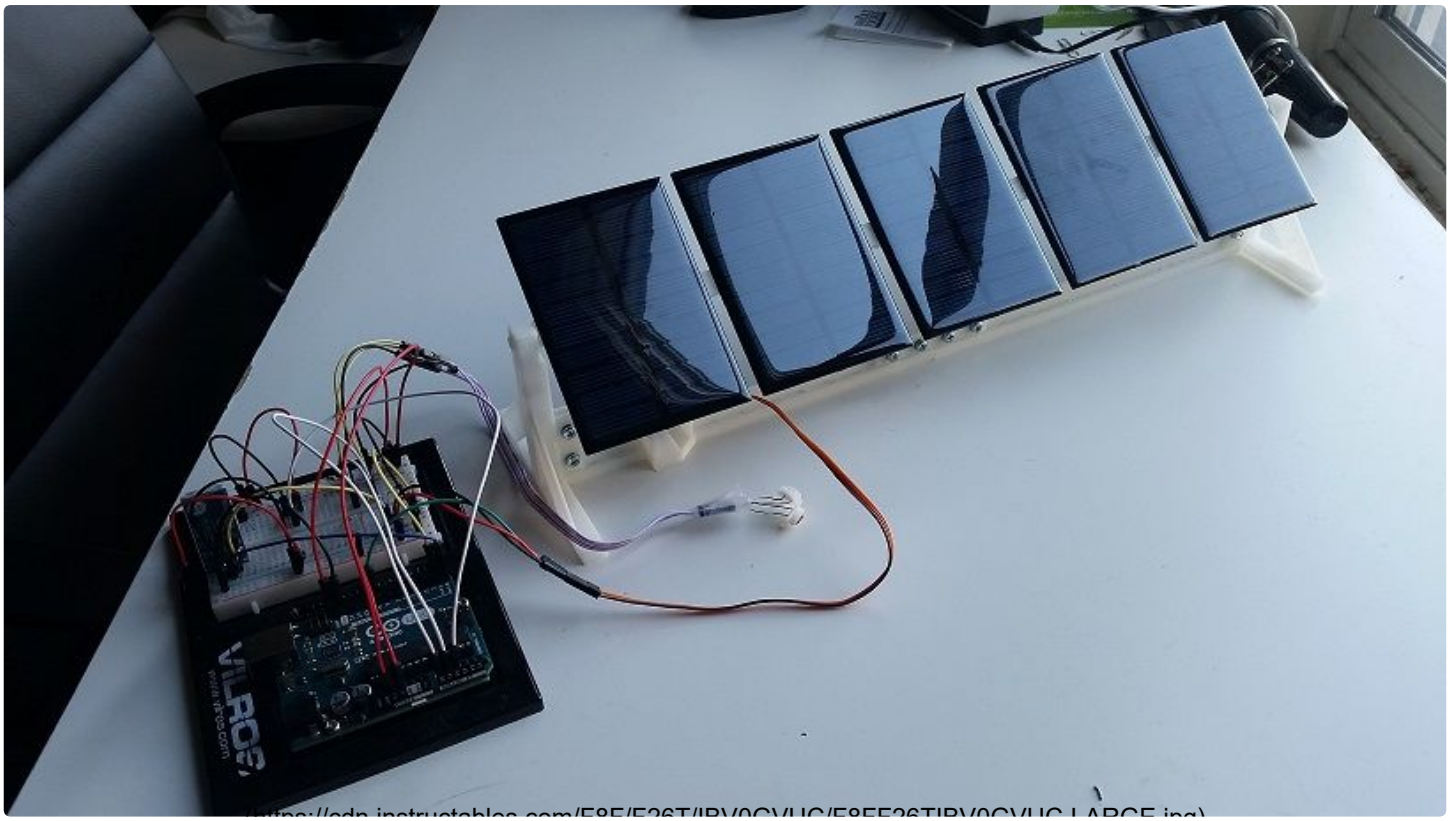

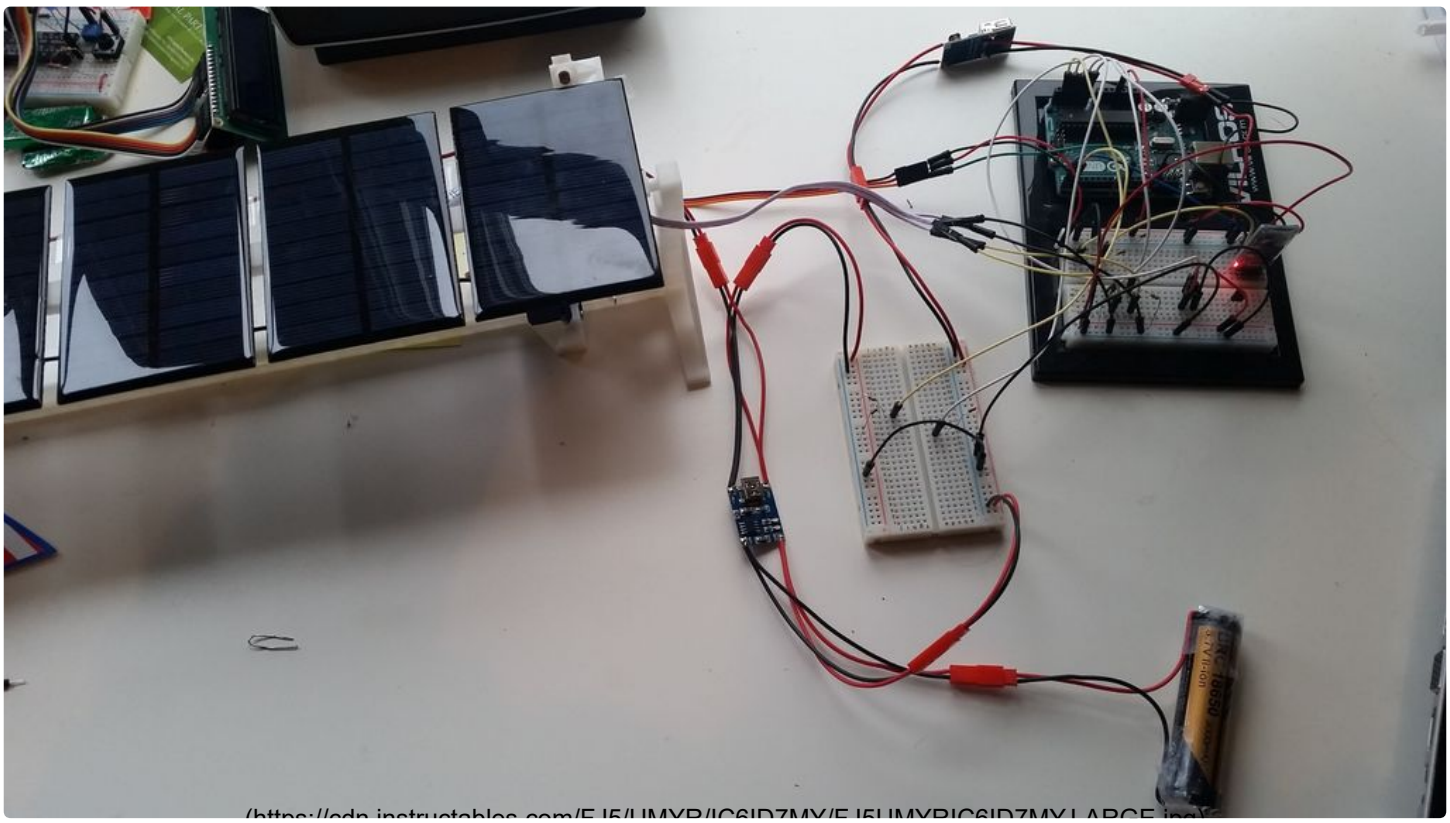

Motivation:

I am a Mechanical engineer with background in Mechatronics and few years of professional in solar project management. Wanted to create my own prototype to understand better blablabla.... Must be educational (everything is apparent) but also functional and useful (charge a smartphone or a tablet).

General principle:

This is a typical closed-loop position control system. The solar energy is converted by the solar array and charging the Battery pack. The Battery pack is supplying a controller which optimize the orientation of the solar array towards the sunlight, based on the light sensor attached to the solar array. In addition to power to the control system, the battery pack has enough capacity to concurrently charge a smartphone or a tablet entirely. It takes approximately about 10 hours (under STC) -or about 1.5 day- to charge the battery pack completely.

Overall technical Specs:

- Solar Array: 5Wp (= 5 x 1W solar panels in parallel)
- Energy Storage: 1 x 3000 mAh Lithiun Ion battery
- Controller: Arduino Uno Rev3, featuring a sun-tracking algorithm
- * Input: light sensor (2 LDR mounted at 45 degrees)
- * Output: servo motor (9g, 1.5? kg.cm)
- Monitoring: Bluetooth communication protocol (serial UART?), sending data every 10 seconds
- Mounting system: 3D printed structure, featuring a fixed structure (the "base") and a moving structure (the "axis")

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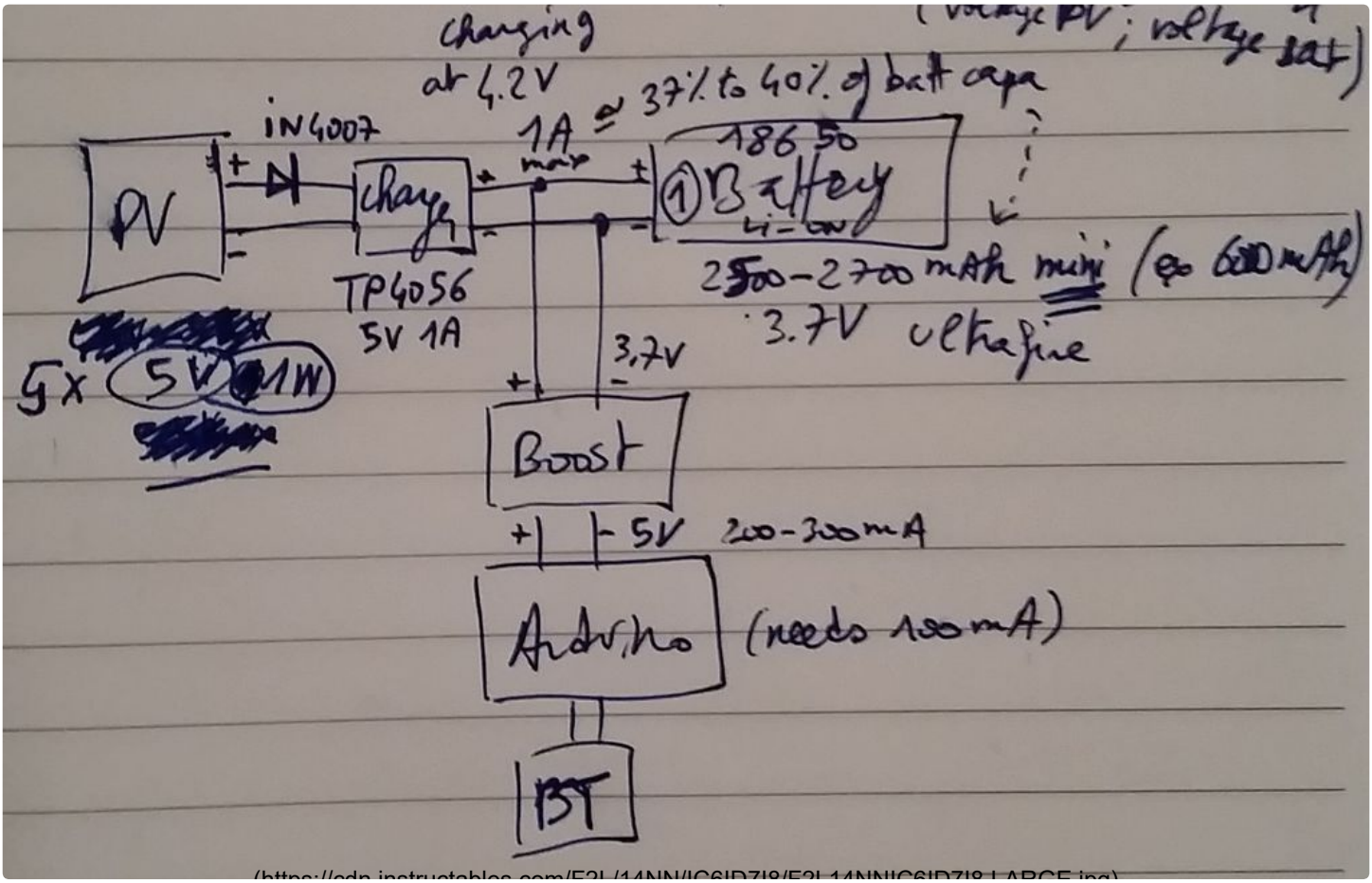
Step 1: Description of the Component Sizing Process



Step 1: Evaluate the consumption of the control system and monitoring system

The consumption of the Arduino + Servo + BT is assumed to draw 100 mA in total (probably 50 mA?).
Need to find literature.

Step 2: Sizing of the battery
In order to supply the system for at least an entire day (24 hours): 100 mA x 24 h = 2,400 mAh. This allows to restart a new solar cycle the next day.
To reach that objective, we choose a battery 3,000 mAh at 3.7V, coupled with a DC-to-DC power Boost to supply the control system.

Step 3: Sizing of the battery charger

We use here the charger XXXXXX as proposed in Instructables XXXX. The characteristics are:

* Input: 1 A max / 5 Volts (or 5W)
* Output must be less than 30% of the battery capacity. Here, it will be 300 mAh max. Which charge the battery in 10 hours

Step 4: Sizing of the PV array

In order to provide 1 Amp at 5 V (or 5W) for the charger to work properly, we are connecting five 1W solar panels in parallel. Show here the panel tech specs. Each solar panel would produce a maximum of 200 mA at 5V. The parallel association allows to sum the current from each solar panel (5 x 200mA = 1 A) and keep a constant voltage (5V)

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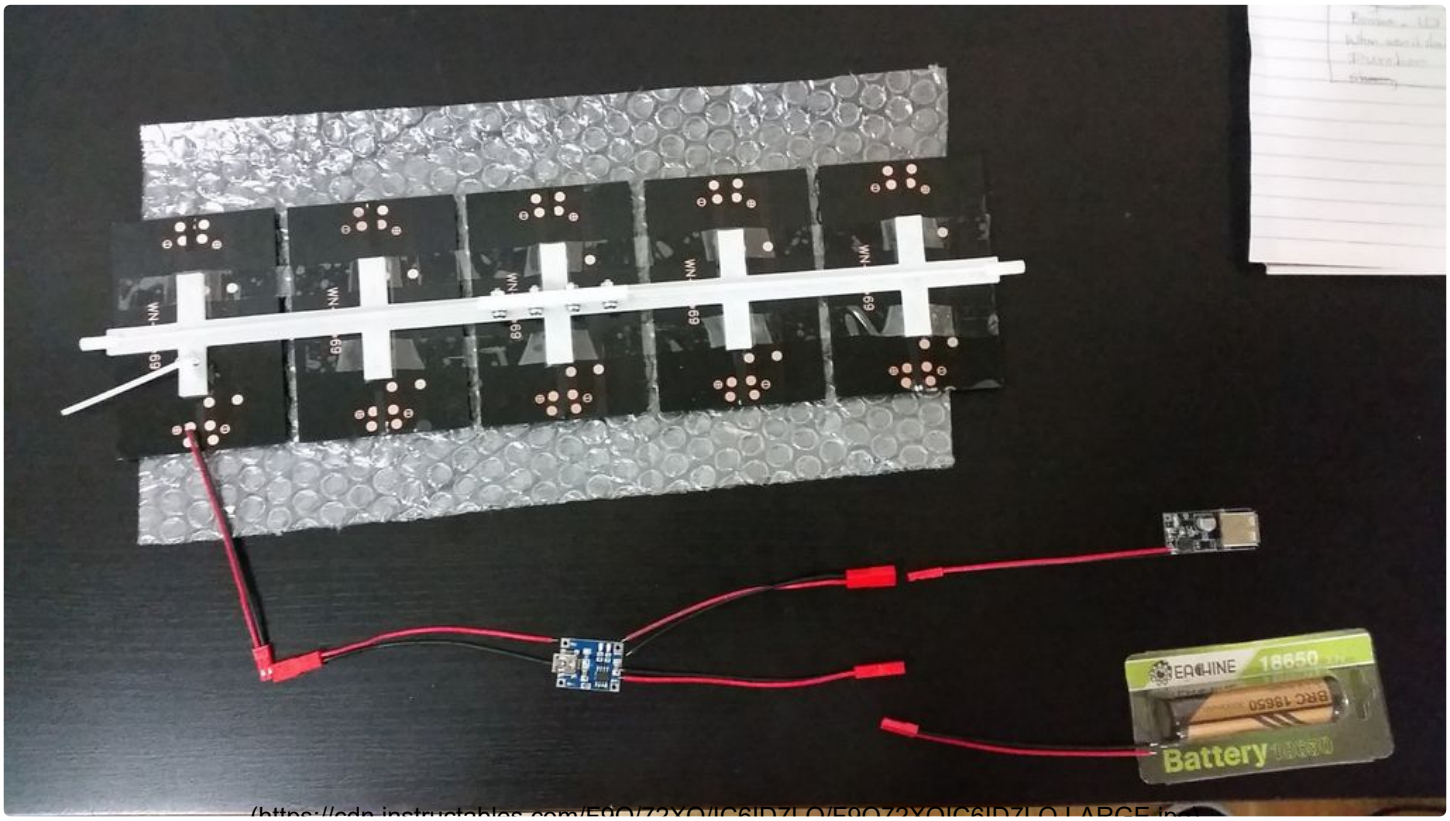
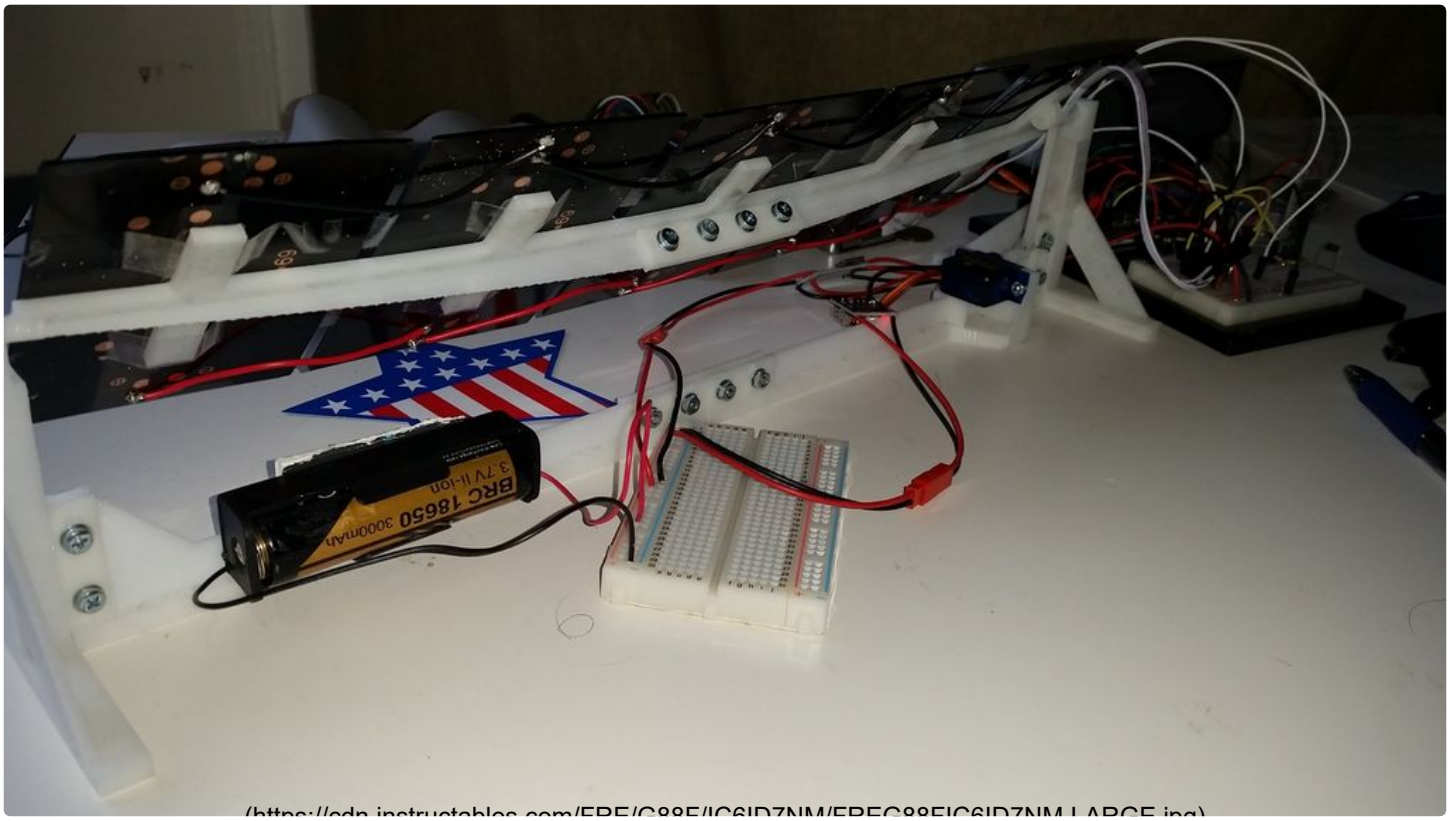
Step 2: Sizing the Li-Ion Energy Storage System





Based on Instructables XXX, a 3.7V 18650 Li-Ion battery would

be compatible with the CC-CV linear charger aforementioned.

Then the battery capacity depends on:

- the load (Arduino + BT module): how many mA

- and the local insolation: San Francisco, CA

Consequently, the selected battery capacity was 3000 mAh.

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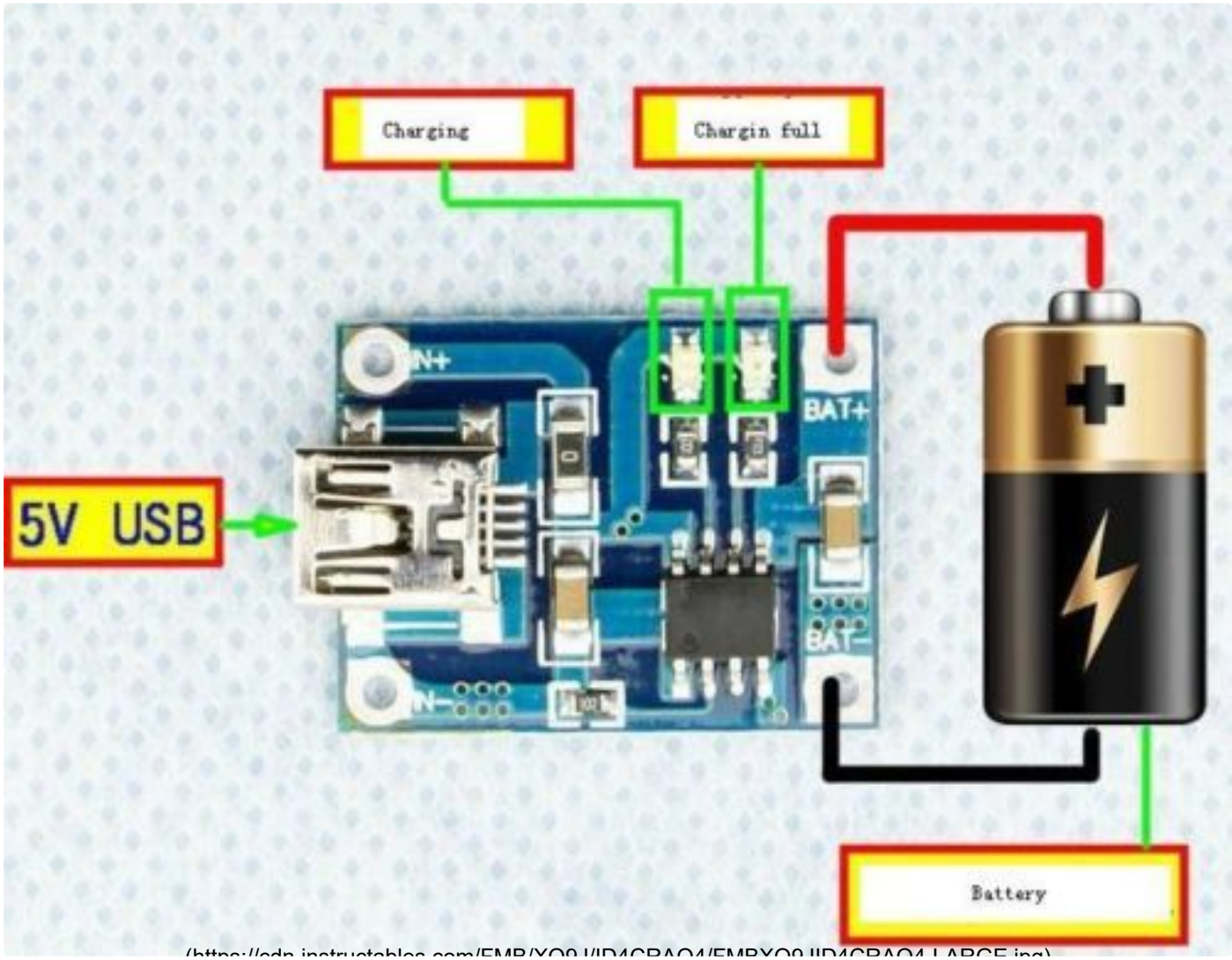
Step 3: Sizing the Battery Charger



(https://cdn.instructables.com/FMB/XQ9J/ID4CBAQ4/FMBXQ9JID4CBAQ4.LARGE.jpg)

Using a CC-CV linear charger for a lithium-ion battery (*see Instructables XXX*) that can receive a maximum of 1A as 5V DC input.

Specs of the 5V Mini USB 1A Lithium Battery Charging Board Charger Module:

method: linear charge 1%

Charging current: 1A Adjustable

Charge Accuracy: 1.5%

Input voltage: 4.5V-5.5V

full charge voltage: 4.2V

Charging indicator: red green full charge

Charging input interface: mini USB

Working temperature: -10 Degree to +85 Degree

Reverse: NO

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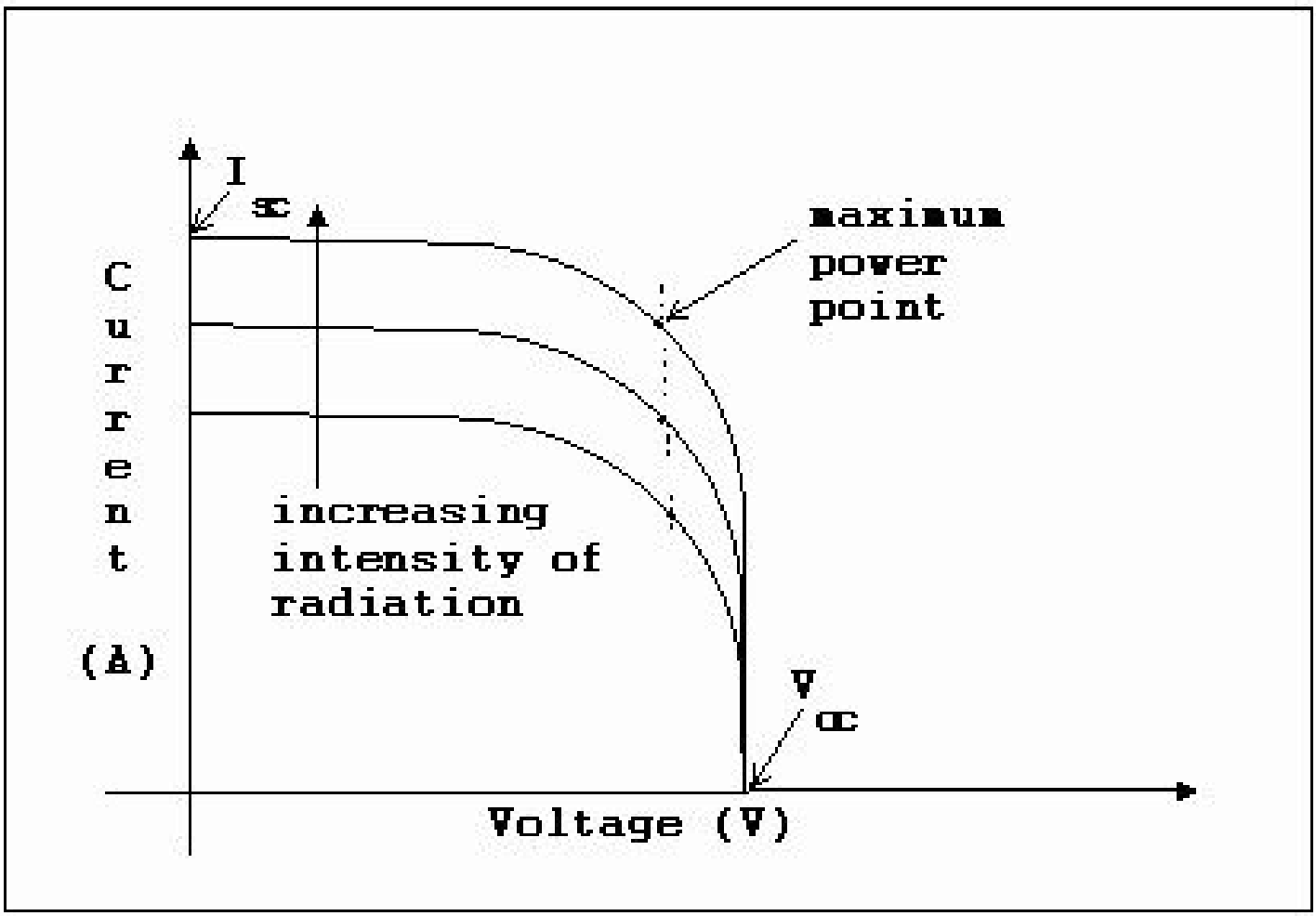
Step 4: Sizing the Solar Array



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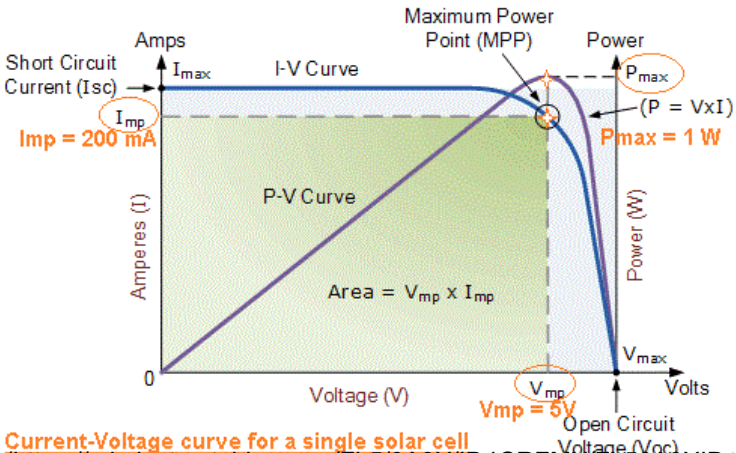
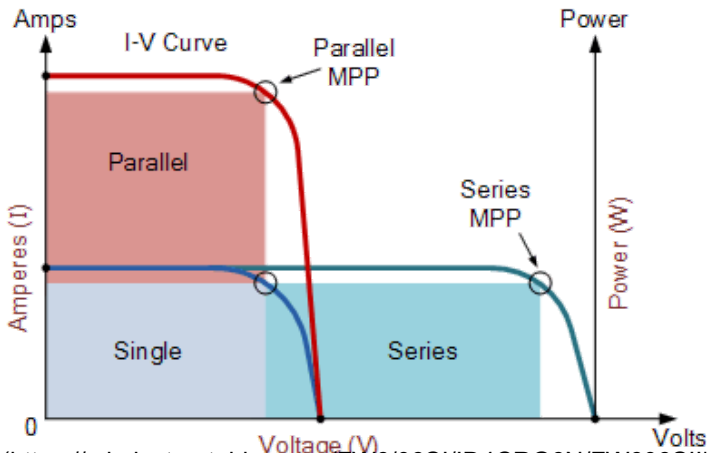


Current-Voltage curve for a single solar cell

(https://cdn.instructables.com/FL5/0A9X/ID4CRFMX/FL50A9XID4



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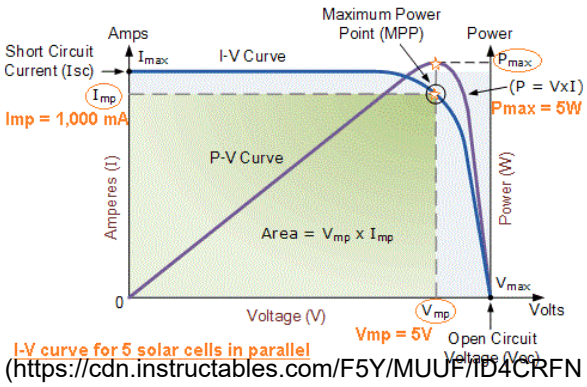

(https://cdn.instructables.com/F5Y/MUUF/ID4CRFN


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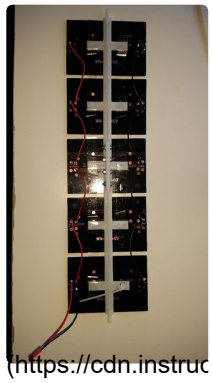
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Using 1W mini solar modules (5V, 200mA, 1W maximum at MPPT). Requires 5 modules to reach a maximum of 1A at 5V.

Possibility to add a DC-DC voltage regulator (Boost or Buck converter) in order to emulate MPPT tracking.

Product features

Voltage at Maximum Power output: 5V.

Max Power Output: 1W.

Material: polysilicon.

Size: 9.9cm x 6.9cm x 0.2cm.

Additional information:

- Solar cell can be compared as a current generator. The more intense the sunlight, the more intense the current. See diagram.

- Per the Current-Voltage (I-V) curve (see diagram),

- Wiring in // to increase the current and limit the voltage to 5V. See the diagram.

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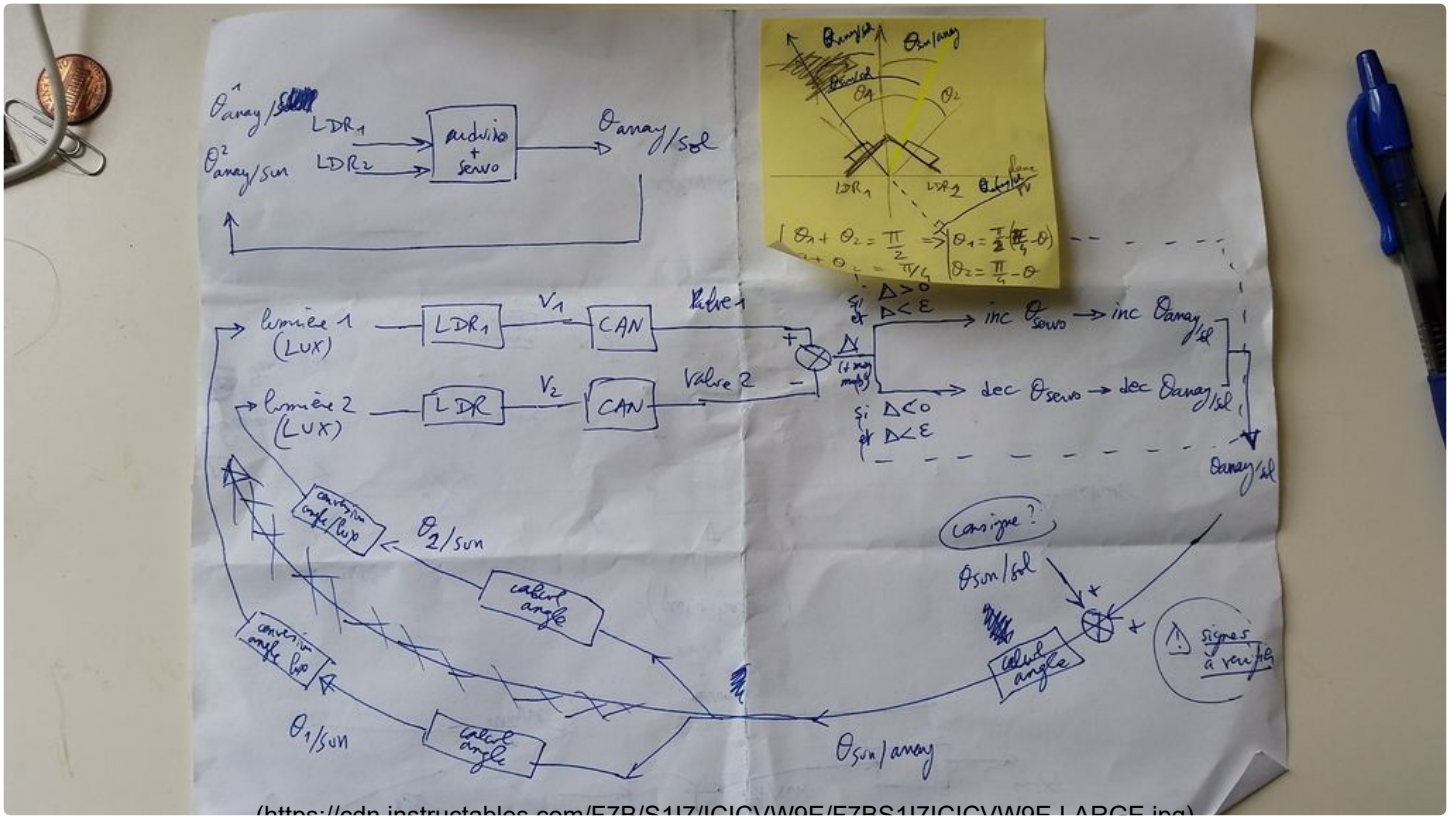
Step 5: The Solar Tracker Algorithm



The solar tracker algorithm

```
if ((abs(average_diff) >= epsilon) || (abs(-average_diff) >= epsilon))

{

if (average_diff > 0)

{

angle += servo_step;

if(angle < 148) { myservo.write(angle); }

else { angle = 148; } // low limit -- high number is lower -- modify the design of structure to allow lower

}

else

{

angle -= servo_step;

if(angle > 53) { myservo.write(angle); }
```

```
else { angle = 53; } // high limit -- small number is higher

}

prog_speed = 200; // faster response to a light change

}
```

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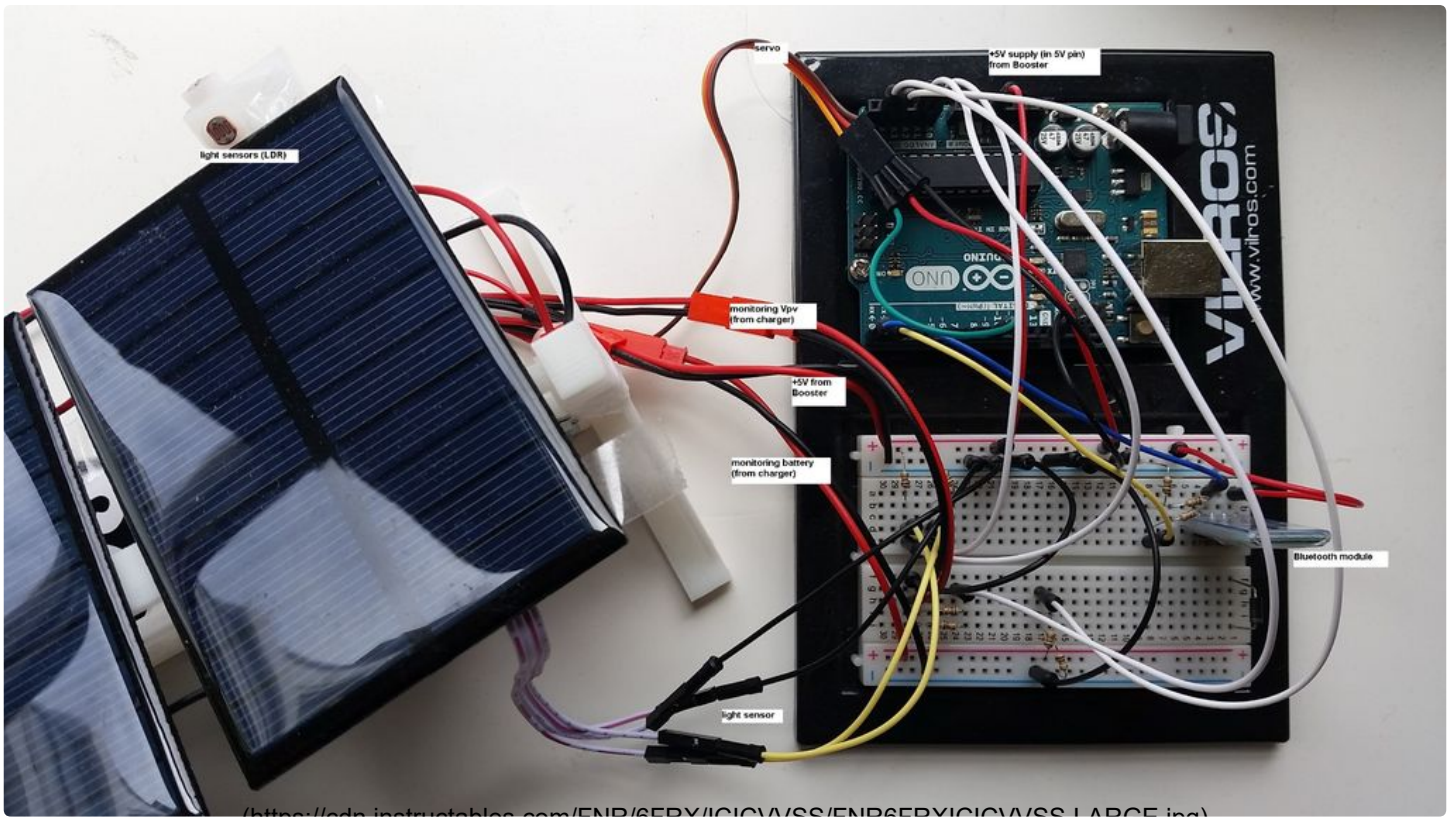
Step 6: Designing the Control System With an Arduino



Inputs:

- Two Light Sensors (two LDR mounted at 45 deg from the normal to the plane of the array)

Outputs:

- Angle of servomotor

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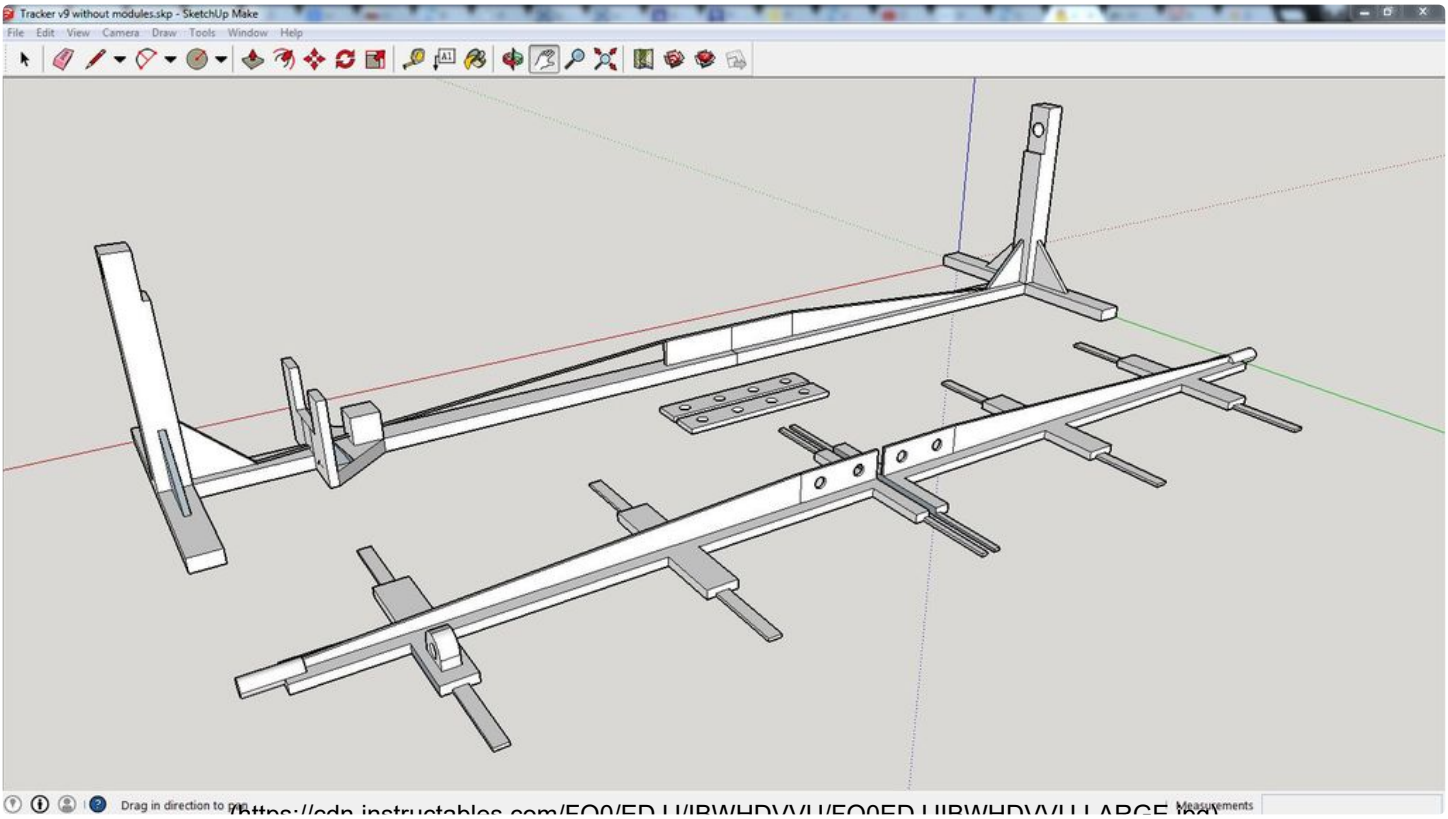
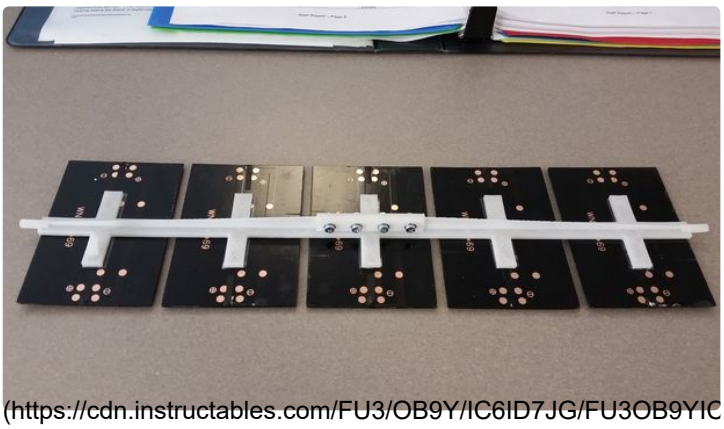
Step 7: 3D Printing the Structure





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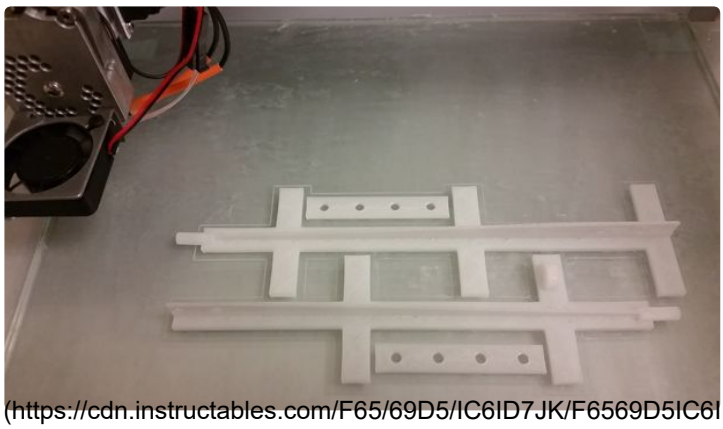

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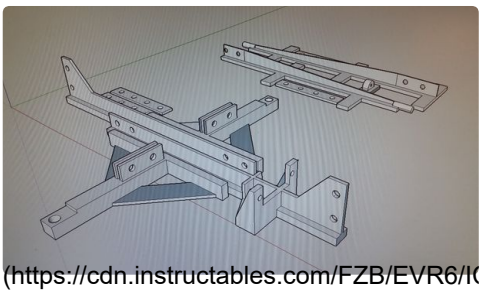

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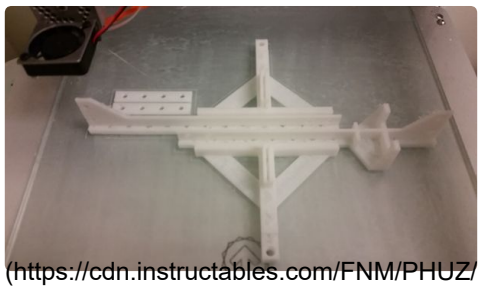

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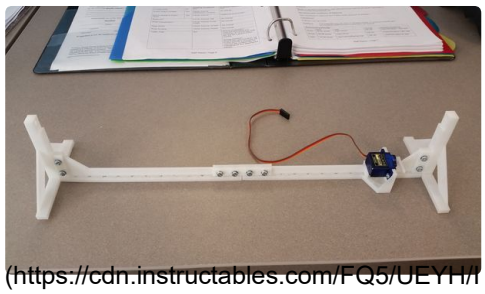

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Show All 8 Items

The rotating structure:

- Strong enough to sustain the 5 mini solar panels

- Equipped with a light sensor

- Moved by the servomotor through a stick

- Created in 2 pieces to facilitate transport

The supporting structure:

- Sustain the rotating structure

- Equipped with a servomotor

- Height determined by the module size

- Created in 4 pieces to facilitate transport

Printing the pieces: either with online service or with your own 3D printer

1/ Link to the Sketchup file

2/ Converting to STL (plugin)

3/ Creating the Gcode file with a slicer

4/ Priiiint!

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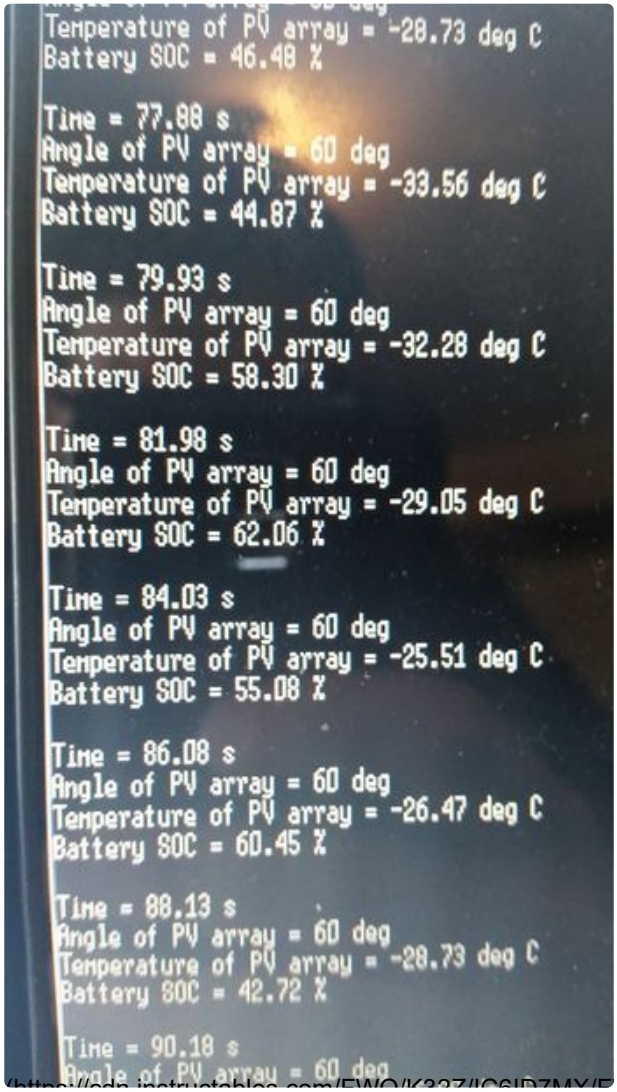
Step 8: Monitoring With Bluetooth



Measurement on Aug 1st 4.45pm in San Francisco

Voltage at	Battery disconnected, w/o load (no Arduino, servo, BT...)	Charging the battery, w/o load (no Arduino, servo, BT...)	Charging the battery w/ load (Arduino, servo, BT...)
Battery	NA	3,96	?
Boost (Arduino) output	?	?	?
Charger input	4,67	4,17 (w diode) and 5,03 wo diode?	?
Charger output	4,32	3,96	?

Note: not using a voltage regulator

In order to check the performance of the mini solar tracker, we want to measure and log the instantaneous amount of power produced by the solar array (expressed in Wh) and we want also to know the state of charge of the battery pack, and eventually we want to make sure that the battery is not depleted, to avoid a hard stop and to damage the Arduino.

To achieve this objective, we are going to measure 3 voltages from the Analog Input Pin of the Arduino:

1/ Voltage from the photovoltaic modules, mounted in parallel.

The purpose here is to

2/ Voltage from the current sensor

The purpose here is to

3/ Voltage from the battery

The code:

```
//Datalogging over bluetooth every X seconds

unsigned long currentMillis = millis();

unsigned long currentTime = millis() / 1000.0;

if(currentMillis - previousMillis > interval)

{

previousMillis = currentMillis;

Serial.print("Time = "); Serial.print(millis()/1000.0); Serial.print(" s | ");

Serial.print("Array angle = "); Serial.print(angle_corr); Serial.println(" deg");

Serial.print("Battery SOC = "); Serial.print( (int) battery_capa); Serial.print("% | ");

Serial.print("V batt = "); Serial.print(voltage_batt); Serial.println(" V");

Serial.print("V pv = "); Serial.print(voltage_pv); Serial.print(" V | ");

Serial.print("P pv (estimate) = "); Serial.print(power_pv); Serial.println(" W");

Serial.print("Vcc = "); Serial.print(ref_voltage); Serial.println(" V");

Serial.println();

}
```

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Step 9: Power Management

```
// Power Management

if (prog_speed == 200)

{

delay(prog_speed); //short delay for faster response to light

}

else if (currentTime > 10) // slower response if no major light change

{

Serial.print("Sleep for 8 sec...");

delay(50);

LowPower.powerDown(SLEEP_8S, ADC_OFF, BOD_OFF); // sleep for 1, 2, 4 or 8 sec

Serial.println(" Waking up!"); Serial.println("");

prog_speed == 200 ; // back to a faster response

}
```

Future improvements:

Light sensors dectect night time and put the entire system to sleep for a couple of hours.

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Step 10: Acknowledgment and Sources

Sources:

1. Bluetooth

1.1 Cheap 2-Way Bluetooth Connection Between Arduino and PC (by techbitar)

https://www.instructables.com/id/Cheap-2-Way-Blueto... (https://www.instructables.com/id/Cheap-2-Way-Bluetooth-Connection-Between-Arduino-a/step4/Set-up-your-PC-for-serial-Bluetooth-communication/)

1.2 Arduino AND Bluetooth HC-05 Connecting easily (by Mohannad Rawashdeh)

https://www.instructables.com/id/Arduino-AND-Blueto... (https://www.instructables.com/id/Arduino-AND-Bluetooth-HC-05-Connecting-easily/)

2. Solar panels

2.1 Blocking and By-Pass Diodes in Solar Panels: http://www.solar-facts.com/panels/panel-diodes.php (http://www.solar-facts.com/panels/panel-diodes.php)

2.2 SOLAR POWERED ARDUINO WEATHER STATION(by deba168) - Step 3: Sizing the solar panel

https://www.instructables.com/id/SOLAR-POWERED-ARDU... (https://www.instructables.com/id/SOLAR-POWERED-ARDUINO-WEATHER-STATION/?ALLSTEPS)

2.3 Solar Cells I-V Characteristics: http://www.alternative-energy-tutorials.com/energy... (http://www.alternative-energy-tutorials.com/energy-articles/solar-cell-i-v-characteristic.html)

2.4 Introduction to Solar Energy: http://www.esru.strath.ac.uk/Courseware/Solar_ener... (http://www.esru.strath.ac.uk/Courseware/Solar_energy/)

3. Battery

3.1 SOLAR POWERED ARDUINO WEATHER STATION(by deba168) - Step 2: Sizing the battery

https://www.instructables.com/id/SOLAR-POWERED-ARDU... (https://www.instructables.com/id/SOLAR-POWERED-ARDU...)

3.2 SOLAR POWERED ARDUINO WEATHER STATION(by deba168) - Step 6: Lithium-Ion battery charger

https://www.instructables.com/id/SOLAR-POWERED-ARDU... (https://www.instructables.com/id/SOLAR-POWERED-ARDU...)

3.3 Battery Chargers and Charging Methods: http://www.mpoweruk.com/chargers.htm (http://www.mpoweruk.com/chargers.htm)

3.4 Battery Performance Characteristics: http://www.mpoweruk.com/performance.htm (http://www.mpoweruk.com/performance.htm)

3.5 Test of Li-Ion Battery LG 18650 D1 3000mAh: http://lygte-info.dk/review/batteries2012/LG%20186... (http://lygte-info.dk/review/batteries2012/LG%2018650%20D1%203000mAh%20%28Pink%29%20UK.html)

4. Monitoring

4.1 ARDUINO ENERGY METER (by deba168)
https://www.instructables.com/id/ARDUINO-ENERGY-ME... (https://www.instructables.com/id/ARDUINO-ENERGY-MET...)

4.2 Measuring an Arduino's power source voltage using Analog In:

http://electronics.stackexchange.com/questions/647... (http://electronics.stackexchange.com/questions/64764/measuring-an-arduinos-power-source-voltage-using-analog-in)

4.3 Calculating battery percentage using an Arduino:

http://electronics.stackexchange.com/questions/110... (http://electronics.stackexchange.com/questions/110104/calculating-battery-percentage-using-an-arduino)

4.4 Secret Arduino Voltmeter – Measure Battery Voltage:

http://provideyourown.com/2012/secret-arduino-volt... (http://provideyourown.com/2012/secret-arduino-voltmeter-measure-battery-voltage/)

4.5 SecretVoltmeter - Accessing the secret voltmeter on the Arduino 168 or 328

https://code.google.com/p/tinkerit/wiki/SecretVolt... (https://code.google.com/p/tinkerit/wiki/SecretVoltmeter)

4.6 John Errington's Experiments with an Arduino. Precise voltage measurement with the Arduino board.

http://www.skillbank.co.uk/arduino/measure.htm
(http://www.skillbank.co.uk/arduino/measure.htm)

4.7 Making accurate ADC readings on the Arduino

http://hacking.majenko.co.uk/making-accurate-adc-r...
(http://hacking.majenko.co.uk/making-accurate-adc-readings-on-arduino)

5. Power Management

5.1 SOLAR POWERED ARDUINO WEATHER STATION(by deba168) - Step 11: POWER OPTIMIZATION BY USING SLEEP MODE

https://www.instructables.com/id/SOLAR-POWERED-ARDU...
(https://www.instructables.com/id/SOLAR-POWERED-ARDU...)

5.2 Lightweight Low Power Arduino Library:
http://www.rocketscream.com/blog/2011/07/04/light...
(http://www.rocketscream.com/blog/2011/07/04/lightw...)

5.3 Arduino Uno R3: Directly supply regulated 5V to 5V pin
http://electronics.stackexchange.com/questions/655...
(http://electronics.stackexchange.com/questions/655...)

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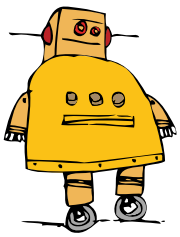

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