

Sunflower Power:

A solar tracking system implemented to a solar charging circuit, proving charge to a 5-volt USB charger!

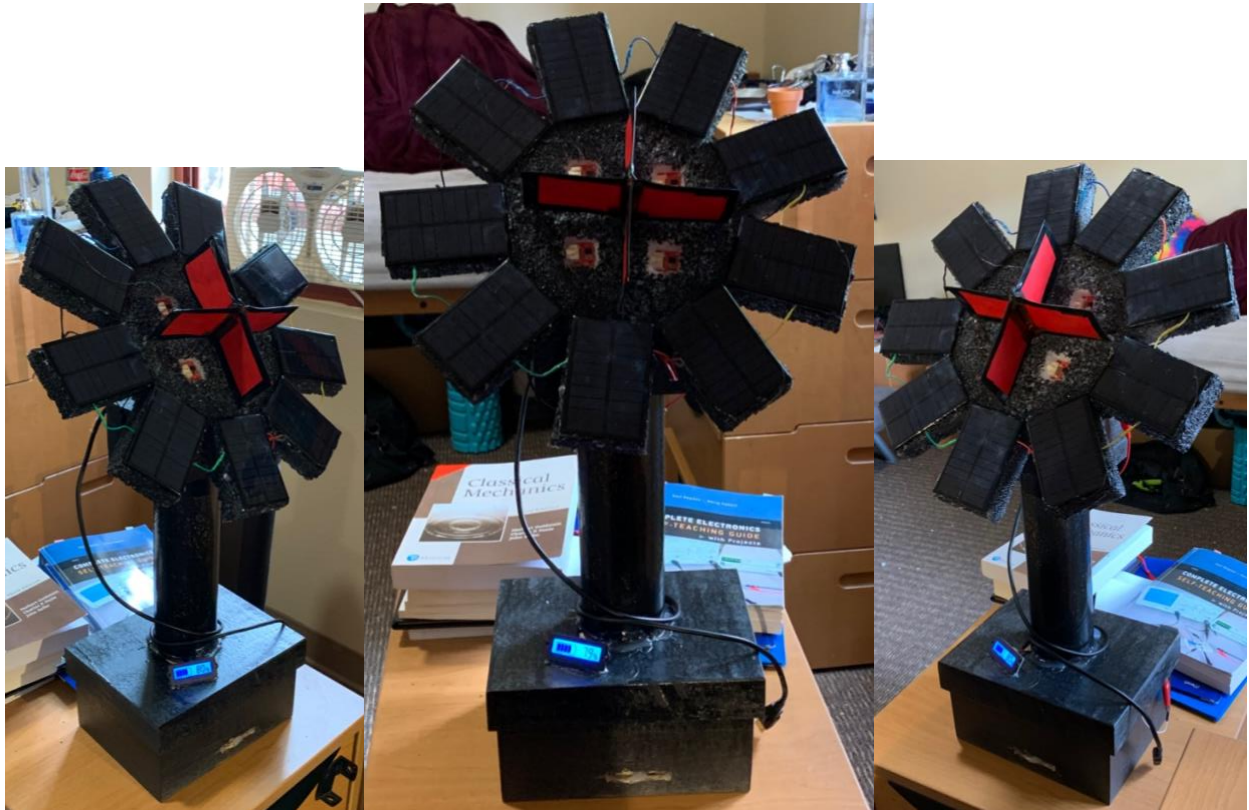
California State University Channel Islands

Phys-310 Sec-01

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Abstract

This project's objective is to explore the use of clean and renewable energy converted to electrical energy for everyday uses and technology. In the current times where, one holds abundant pieces of technology simply in their pockets, it seems that the idea of creating renewable solar energy to a USB charger can have immense effects on the day-to-day persons electricity bill!

How much power does your smartphone play on the electricity one uses? According to Forbes¹, the answer is 1kiloWatt-hour. This means your phone takes about 12 cents to charge, and in one-year accounts for a quarter of the electricity one uses in the year. Also, an iPad takes more power than an iPhone due to its larger screen. Some may say I do not own an iPad, or other high-end products, but how much of the technology in your possession is USB charged. Such devices have become like pencils scattered around the house. To the calculators, power banks, smartphones, earbuds and headphones, smartwatches, rechargeable chargers, controllers, etc.! The list appears endless when it comes to rechargeable technology using USB charging. If an iPhone takes up a quarter, then it can be easily stated a significant portion of our electricity use is provided to such devices.

So, what if we were to create a device that implements clean and renewable energy? This solar tracking project aims to be a respectable device that can be placed by the window and collect such energy and charge said devices. By collecting solar power through the solar tracker, in connection to a solar charging circuit proving an appropriate trickle charge to our rechargeable 12v-7Ah lead acid battery, that will then supply our 5v boosters (USB) we aim to accomplish such a goal.

¹ Helman, Christopher. "How Much Electricity Do Your Gadgets Really Use?" *Forbes*, Forbes Magazine, 17 Feb. 2015, www.forbes.com/sites/christopherhelman/2013/09/07/how-much-energy-does-your-iphone-and-other-devices-use-and-what-to-do-about-it/?sh=5b4e3a562f70.

Methods

Sunflower

The first task we approached was implementing what we deemed our solar tracking "Sunflower". As per usual we look to mother nature to progress us and inspire us in the field of engineering and scientific study. A sunflower blooms and faces its pedals in the direction of the sun, optimizing its ability to absorb the maximum sunlight. With the use of Arduino, light sensors (an implementation of photoresistors), a pan tilt and our solar panels we constructed our solar tracking sunflower.

In order to provide a significant amount of voltage and

current to our color charging circuit through our sunflower, we implanted the use of a solar panel circuit both in series and in parallel. With 9 solar panels we placed 3 panels in series and then placed the 3 sets of series in parallel. The provided data from our solar panels inform us

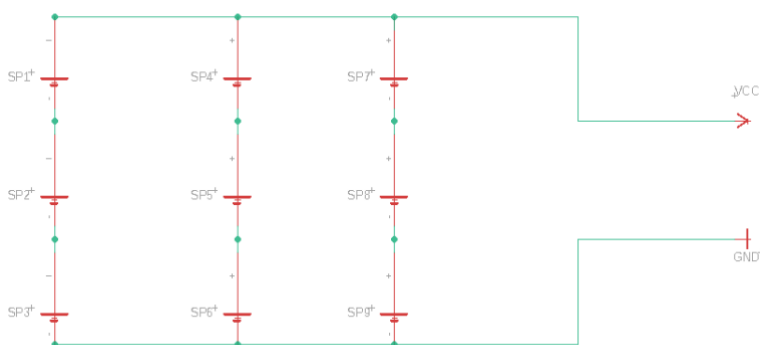


Figure 1. Solar Panel Schematic

that each panel provides +5volts and 150milli-Amps. Using the provided equations for circuits in series:

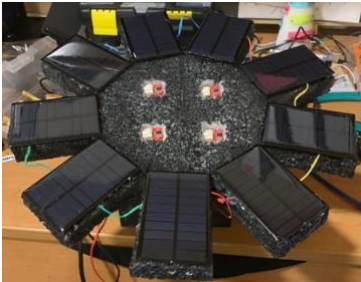
$$V_{\text{series}} = V_1 + V_2 + V_3 = 5\text{v} + 5\text{v} + 5\text{v} = 15\text{v}$$

$$I_{\text{series}} = I_1 = I_2 = I_3 = 150\text{mA} = 150\text{mA} = 150\text{mA}$$

We have 3 sets of series solar panels, each series having 15 volts and 150mA of current running through. Now using the equations for parallel circuits derived using ohms law, $V = I/R$, we achieve:

$$V_{\text{parallel}} = V_{\text{series1}} = V_{\text{series2}} = V_{\text{series3}} = \underline{V_{\text{total}} = 15\text{v}}$$

$$I_{\text{parallel}} = I_{\text{series1}} + I_{\text{series2}} + I_{\text{series3}} = 150\text{mA} + 150\text{mA} + 150\text{mA} = \underline{I_{\text{total}} = 450\text{mA}}$$



As a result, we expect to achieve a supply of approximately 15 volts and 450 mA of current from our sunflower. Now that we have obtained the data that supports the

Figure 3. 3 Solar Panels in Series

information needed to assemble our solar charging circuit and lead acid battery, we will move forward to our solar tracker via Arduino.

The solar tracking project was inspired and provided from an Arduino project

known as "Arduino Sunflower: An Electronic Sun-Dancer"².

For our solar tracker, we implemented

Figure 6. Solar Tracker



Figure 5. Sunflower Assembled

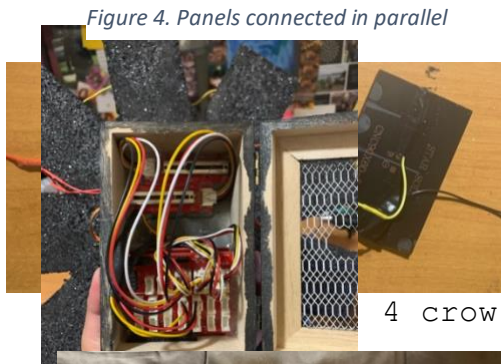


Figure 4. Panels connected in parallel



Figure 8. Solar Tracker Schematic

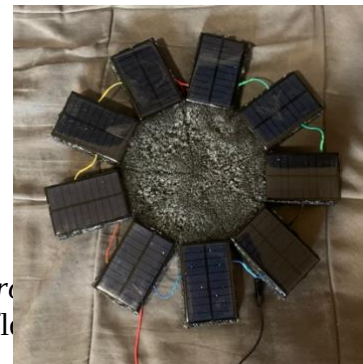


2 "

bc8f34.

4 crow taillight sensors, each sensor is

Sun-Dancer." Arduino Pro
JRYATEJA/arduino-sunflo



cer-

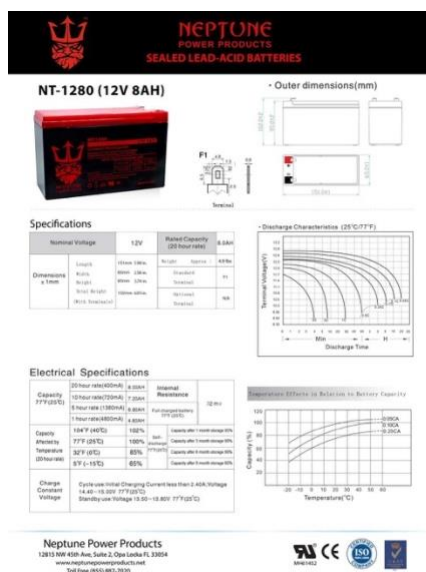
connected to the Arduino shield. The shield is placed upon the Arduino ATmega 328, the Arduino with the programmed "Solar Tracker" code, as provided in the appendix. The light sensors implement a photoresistor making it possible to detect if greater amounts of light are taking place in direction based on placement of the light sensors. The Arduino will intake this data from the light sensors and will output data to our pan tilt to adjust itself to the point of which greater light is shined. Therefore, implementing a solar tracker. In addition, we placed two linear potentiometers in order to be able to increase or decrease the pan and Arduino's response capabilities. The potentiometer placed in A4 controlled the delay of the reaction time, as shown in our solar tracker code. The potentiometer placed in A5 serves in controlling the reaction speed.

Solar Charging Circuit

Now that we have created a supply we can point our attention to our solar charging circuit. In order to implement our charging circuit, we must understand our lead acid battery further in order to understand the proper and safe way to charge it. The lead acid battery that we obtained is a 12V 7Ah battery capable of being charged with a current of 350mA allowing it to obtain a full charge within 20 hours.

There are now four key factors we learned from PowerSonic³, that play a role into charging our lead acid battery:

4



1. Overcharging A Lead Acid Battery
2. Undercharging
3. Battery Cycle Charging
4. Battery Standby Charging

Overcharging is a result of too high a charge voltage excessive current will flow into the battery, after reaching full charge, causing decomposition of water in the electrolyte and premature aging. At high rates of overcharge a battery will progressively heat up. As it gets hotter, it will accept more current, heating up even further. This is called

³ <https://www.power-sonic.com/wp-content/uploads/2020/12/How-to-charge-Lead-Acid-batteries.pdf>

⁴ https://www.amazon.com/gp/product/B07BB6GVGY/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

thermal runaway and it can destroy a battery in as little as a few hours.

Undercharge is if too low a charge voltage is applied, the current flow will essentially stop before the battery is fully charged. This allows some of the lead sulfate to remain on the electrodes, which will eventually reduce battery capacity. Batteries which are stored in a discharged state, or left on the shelf for too long, may initially appear to be "open circuited" or will accept far less current than normal. This is caused by a phenomenon called "sulfation". When this occurs, leave the charger connected to the battery. Usually, the battery will start to accept increasing amounts of current until a normal current level is reached. If there is no response, even to charge voltages above recommended levels, the battery may have been in a discharged state for too long to recover, and in which case a replacement SLA battery will be needed.

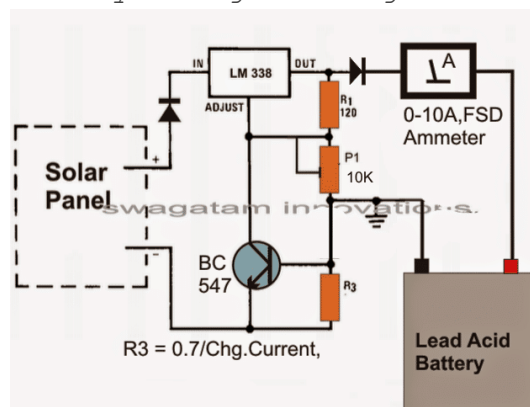
In the case of cycle charging, cyclic (or cycling) applications generally require recharging be done in a relatively short time. The initial charge current, however, must not exceed $0.30 \times C$ amps. Just as battery voltage drops during discharge, it slowly rises during charge. Full charge is determined by voltage and inflowing current. When, at a charge voltage of 2.45 ± 0.05 volts/cell, the current accepted by the battery drops to less than $0.01 \times C$ amps (1% of rated capacity), the battery is fully charged, and the charger should be disconnected or switched to a float voltage of 2.25 to 2.30 volts/cell. The voltage should not be allowed to rise above 2.45 ± 0.05 volts/cell.

Lastly, I area of application for our circuit is battery standby charging. Standby applications generally do not require that the battery be charged as fast or as frequently as in cycle operation. However, the battery must be kept constantly charged to replace the energy that is expended due to internal loss and deterioration of the battery itself. Although these losses are very low in Power Sonic lead acid batteries, they must be replaced at the rate the battery self-discharges; at the same time the battery must not be given more than these losses, or it will be overcharged. To accomplish this, a constant voltage method of charging called standby, or float charging is used. The recommended constant float voltage is 2.25 - 2.30 volts per cell. Maintaining this float voltage will allow the battery to define its own current level and remain fully charged without having to disconnect the charger from the battery. The trickle current for a fully charged battery floating at the recommended charge voltage will typically hover around the $0.001C$ rate (7mA

for a 7AH battery, for example.) The float charger is basically a constant voltage power supply. As with cycle chargers, care must be taken not to exceed the initial charge current of $0.30 \times C$ amperes.

In this current circumstance, we will depend on the understanding and information provided about standby charging. We don't have a system in place for protecting out battery from over charge and undercharge, and in order to implement a cycle charge we will need to implement a system for detecting when charge needs to be applied or be disconnected. Therefore, the best application for our system is a trickle charge. Making it possible for us to leave our sunflower unmonitored and safely charging without worrying of damaging or producing an unsafe circuit overtime.

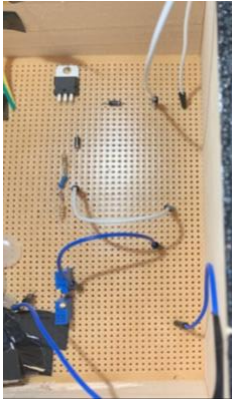
Know that we have our trickle current at 0.07mA for our lead acid battery, we can implement our solar charging circuit. In a provided article "9 Simple Solar Battery Charger Circuits"⁵, we were able to find a circuit that best suited the circumstance. As the article establishes, Solar energy may be used directly for powering an electrical equipment or simply stored in an appropriate storage device for later use. Normally there's only one efficient way of storing electrical power, and it's by using rechargeable batteries. Rechargeable batteries are



probably the best and the most efficient way of collecting or storing electrical energy for later usage. The energy from a solar cell or a solar panel can also be effectively stored so that it can be used as per one's own preference, normally after the sun has set or when it's dark and when the stored power becomes much needed for operating the lights.

Though it might look quite simply, charging a battery from a solar panel is never easy, because of two reasons. The voltage from a solar panel can vary hugely, depending upon the incident sun rays, and the current also varies for the same reasons we had just established.

⁵ <https://www.homemade-circuits.com/how-to-make-solar-battery-charger/>



Thanks to the modern highly versatile chips like the [LM 338](#) and [LM 317](#), which can handle the above situations very effectively, making the charging process of all rechargeable batteries through a solar panel very safe and desirable. In our case we will be using a LM317. We will also place 10k ohm potentiometers for P1 and R3. As such, we will be able to vary current and will also be used to serve as a 3-point intersection with the use of a potentiometers 3 leads. However, the special piece about this circuit is that it attributes a control feature. Meaning if the current tends to increase

at the input, which might normally take place when the sun ray intensity increases proportionately, the voltage of the charger drops proportionately, pulling down the current back to the specified rating. As we can see in the diagram, the collector/emitter of the transistor (BC547) is connected across the ADJ (LM317 Adjust Pin) and the ground, it becomes responsible for initiating the current control actions. As the input

current rises, the battery starts drawing more current, this build up a voltage across R3 which is translated into a corresponding base drive for the transistor. The transistor conducts and corrects the voltage via the LM317, so that the current rate gets adjusted as per the safe requirements of the battery. Lastly, we have solar panel system that provides supply meant to charge our battery, however we also have a battery meant to be supplied but is also capable of providing a supply. Therefore, we will be including two diodes in our circuit. One diode placed between the LM317's in pin and the Solar panel and one between the LM317's out and the lead acid battery. To protect against any reverse current supply that may damage our circuit or panels, and in fact even our lead acid battery. To top it off, rather than place an ammeter we will be placing a battery meter, so that we can account for if the battery increases and decreases in charge, monitoring our progress.

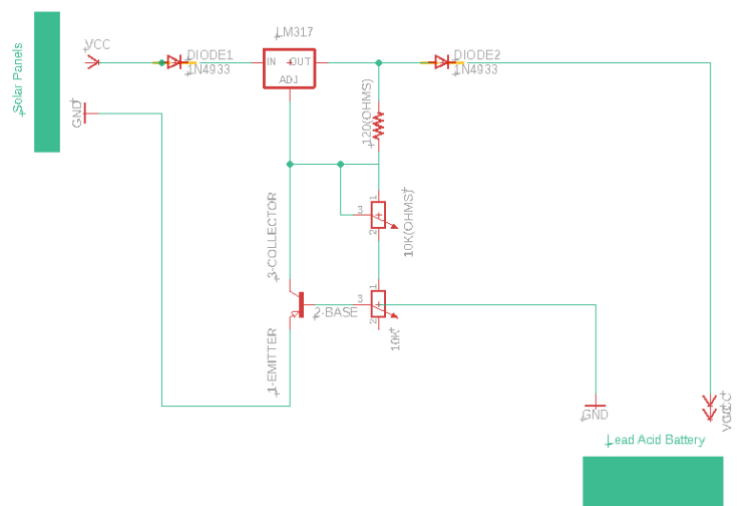


Figure 9. Solar Charging Circuit Schematic

As seen in the seen by the picture, we placed two 10-ohm resistors in series with a 100-ohm resistor to create the 120-ohms of resistance needed for our circuit. The white connections being our positive voltage and our blue wires are ground. The long ones being the connections to our solar panels, and the short being our connections to charge our lead acid battery.

USB Charging

Figure 10. Solar Charging Circuit

Know that we have a safe charge and supply to our lead acid batter we can know place our focus on obtaining supply to charge via USB so that we can power the Arduino and other USB devices simultaneously and safely.

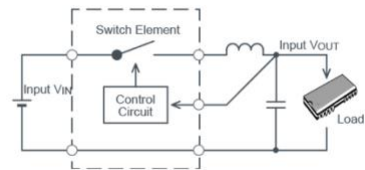
However, to do so we must lower the 12V output of the battery to 5v so not to fry the Arduino or any of our precious USB charged technology.



Figure 11. DC DC Converter

To do so we have looked at two options. The initial thought was to apply a voltage divider and a few resistors in series to down our voltage to 5v before reaching our USB.

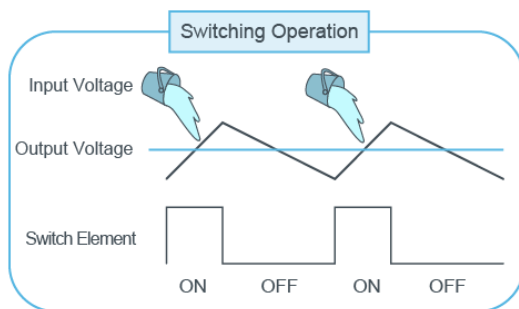
However, though this may prove successful, it would be highly inefficient. Causing loss of charge to our battery far greater



than we would hope when the USB

charging would not even been in use. The latter however is to implement the use of a DC/DC converter. With the use of this 5v switching regulator we could achieve efficiency of up to 91%, saving us from a tremendous amount of loss charge if we had implemented resistors instead. In a data sheet provided by Recom

Power⁶, we learn that this component is a switching regulator module that has been designed to offer advantages such as: high efficiency, wide input range, and accurate voltage regulation. We also learn how the DC/DC switching work with the aid of Rohm⁷. A switching regulator is a voltage regulator that uses a switching element to transform the incoming



power supply into a pulsed voltage, which is then smoothed using

⁶ <https://recom-power.com/pdf/Innoline/R-78E-1.0.pdf>

⁷ <https://www.rohm.com/electronics-basics/dc-dc-converters/linear-vs-switching-regulators>

capacitors, inductors, and other elements. Power is supplied from the input to the output by turning ON a switch (MOSFET) until the desired voltage is reached. Once the output voltage reaches the predetermined value the switch element is turned OFF and no input power is consumed. Repeating this operation at high speeds makes it possible to supply voltage efficiently and with less heat generation. This can be witnessed by the provided diagrams.

Once we connect the battery (Vin and ground) to the component we can connect Vout and ground to our USB hub/mobile charger in order to supply the 5v volts passing from the DC DC converter.



Figure 13. USB hub & DC/DC Converter

In the provided circuit, the yellow cable attached alongside the wall of the wooden box will connect from the lead acid battery to Vin of our switch regulator. The green wire also alongside the wall of the wooden box that will connect ground from the lead acid battery to the switch regulator. Now from the converter we have the white wire Vout from the converter to the USB hub and the green is the ground.

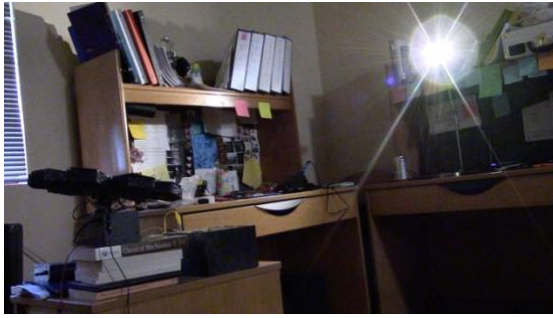
Both are connected in parallel to the USB provide an equivalent 5v to both hubs. We know have our circuit as seen in the picture where we have everything such as: our charging acid battery, switch



Figure 12. Completely integrated circuit

sunflower, the solar circuit, the lead the USB hub with the regulator, and battery charge display.

Results:



Here is a video of the resulting solar tracker, as you can see with a power supply to the sunflower, the solar tracker will place itself in an optimum position to the light. Resulting in a sunflower that optimizes its solar energy intake that allows it to reach voltage outputs exceeding our theory. The sunflower system

in place was capable of supplying 17-18 volts and nearly 500mA of current.

When the sunflower is attached to our solar charging circuit, we achieve a minimum current supply 0.03 mA when our sunflower is left in the room with close to no light supply. Then approximately 0.015 mA when the sunflower achieves peaks voltage output at 17v-18v.



Lastly, when we integrate our DC DC switch regulator our USB ports supply approximately 5.086 volts, capable of power our Arduino, and an iPhone as well as other USB capable charged devices.

Here I had taken the completely built sunflower project and had tested it out at the shore by Malibu Rock. It was cloudy which gave the sunflower opportunity to have to fix its position due to the moving clouds and change in positions to absorb optimum sunlight. In the provided video, the Sunflower did need some slight recalibration due to cloudy sky and the conditions being applied. So, as you can see, I did increase the delay time slightly and slow down the pan tilt's reaction time, since it is quite capable and did not want it to rip itself apart. The video was also placed in 4x speed in order to depict the movement and progression of the sunflower over a span of approximately a half hour. As predicted, the sunflower does not move much or require continuous movement during the day, aiding to the sunflowers's low amount of supply needed to function properly.



As seen in the provided photos above we found that within the time span that had occurred the battery had increased 2 percent in charge. The time

that elapsed between these occurrences has been approximately 3-4 hours. Which is as expected since we have implemented a trickle charge and since our 12v 7Ah battery requires 350mA in order to charge our battery from a completely empty state to a full charge within 20 hours. This means to receive 1% of charge at 350mA will require 12 minutes in order to occur. Now if we take into account that at peak supply to our battery, we are delivering approximately 15mA, receiving 2% of charge within 3-4 hours is as expected of our sunflower.

Finally, in this short video provided, we can depict our objective. Which was to use solar power to charge our lead acid battery that will safely deliver to our Arduino and be capable of safely a USB charged device. In this case, you will see me doing so with my iPhone.



Discussion:

As seen, we have proven quite successful in our goal to create self-powering "sunflower" capable of automating itself to receive the optimum sunlight and adjust for any circumstances that require it to adjust or account for settings that require minimum adjustment or drastic adjustment in its position. With our sunflower we were able to power not only itself but other devices simultaneously, all with the use efficiency, self-sustainment, all with the use of green-clean-renewable energy. With this project I was able to gain greater insight into the understanding of electronics and components, such as: solar panels, lead acid batteries, DC/DC Converters (Switch regulators), light sensors, Arduino Shields, etc. With that being said there is most definite room for greater improvement with time and research. Our charging circuit using a trickle current for safe measure of the lead acid battery. So, what if we were to further integrate the use of Arduino and control. We

have a way of measuring the batteries level of charge. So, if we were able make use of this and create a circuit and a program that will optimize this with the use of trickle and cyclic charging. The Arduino could detect low batter levels and allow 350mA of current, but as the charge approaches 100%, the Arduino can help aide in diminishing the current to a trickle charge. Or even consider either inputting a manual switch that will do this. However, we would prefer manual and self-managing, so we can even consider a transistor switch to help aide in disconnecting the charge or connecting the full 350mA of charging current to it. Though it can be cost in energy use, we will not only replace the greater supply needed, but optimize the use of the lead acid battery, and solar charging. These are just a few ways in how we can further improve and optimize our "Sunflower", and all of which are within reach and possibility. It is highly enjoyable to research and implement new ways into projects and possibilities that have significant effect on issues at hand currently. Such the damage we are encoring to our environment and the use of harmful pollutants.

Appendix:

Solar Tracker

```
#include <Servo.h> // include Servo library

Servo horizontal; // horizontal servo
int servoh = 90; // stand horizontal servo

Servo vertical; // vertical servo
int servov = 90; // stand vertical servo

// LDR pin connections
// name = analogpin;
int ldrrd = 0;
int ldrld = 1;
int ldrlt = 2;
int ldr rt = 3;

void setup()
{
    Serial.begin(9600);
    // servo connections
    // name.attach(pin);
    horizontal.attach(9);
    vertical.attach(10);
}

void loop()
{
    int lt = analogRead(ldrlt); // top left
    int rt = analogRead(ldr rt); // top right
    int ld = analogRead(ldrld); // down left
    int rd = analogRead(ldrrd); // down right

    int dtime = analogRead(4)/20;
    // read potentiometers
    int tol = analogRead(5)/4;

    int avt = (lt + rt) / 2; // average value top
    int avd = (ld + rd) / 2; // average value down
    int avl = (lt + ld) / 2; // average value left
    int avr = (rt + rd) / 2; // average value right
```

```

int dvert = avt - avd; // check
the diffirence of up and down
int dhoriz = avl - avr; // check
the diffirence og left and rigt
if (-1*tol > dvert || dvert >
tol) // check if the diffirence
is in the tolerance else change
vertical angle
{
if (avt > avd)
{
servov = ++servov;
if (servov > 180)
{
servov = 180;
}
}
else if (avt < avd)
{
servov= --servov;
if (servov < 0)
{
servov = 0;
}
}
vertical.write(servov);
}
if (-1*tol > dhoriz || dhoriz >
tol) // check if the diffirence
is in the tolerance else change
horizontal angle
{
if (avl > avr)
{
servoh = --servoh;
if (servoh < 0)
{
servoh = 0;
}
}
else if (avl < avr)
{
servoh = ++servoh;
if (servoh > 180)
{
servoh = 180;
}
}
else if (avl == avr)
{
// nothing

```

```

}
horizontal.write(servoh);
}
delay(dtime);
}

```