D-Lab

Final Project Report

Solar Cell Phone Charger

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Abstract

Following a research trip to Sabana Grande, Nicaragua during which we looked into a variety of different problems faced by the local population, we worked towards designing a solar-powered cell phone charger that can be built indigenously. This was found to be of primary importance because of the large number of cell phone owners in Sabana Grande with no access to grid electricity, meaning that they are forced to pay C$ 5-10 per charge for their cell phone, which adds up to a significant investment over time.

To address this concern, our team worked with a cooperative in Sabana Grande who already make and install large solar panels in the town. We designed a small charger panel and the associated circuitry to eliminate the need to cut the solar cells, getting the appropriate voltage and power output through a DC-DC step-up converter. We designed a final prototype that should be able to charge any of the commonly used local phones in 10-12 hours of direct sunlight.

Problem Statement

Community Background

The area where the project will be implemented is located in the district of Sabana Grande in the Northern part of Nicaragua. The closest city is Ocotal, accessible via a 15-20 minute bus ride made relatively frequently by a number of Sabana Grande inhabitants. The region is home to the 'Solar Center' which is a building complex where the locals make PV Panels for use in the community. 20 women and two men from the area make up a cooperative called the Solar Women of Totogalpa, a group dedicated to the research and implementation of sustainable energy systems. Together with a Managua-based group called GrupoFenix, whose mission includes helping such communities, the Solar Women have created a center in which their research can be continued.

One such research project includes the implementation of homemade solar panels built by the two male technicians in the cooperative. Made from industrial reject PV cells that they can buy for an affordable price, these panels have brought electrical power to many homes in the surrounding area that would otherwise be without access to electricity.

The current method for making these solar panels involves cutting solar cells into even quarters which they then connect in series. Since each quarter outputs the same voltage as the original cell, they do this to step up the overall voltage output. They then encapsulate this assembly in silicone and cover it with a glass casing within an aluminum frame.

The PV cells and Silicone Encapsulation are shipped in from the States by their American contacts. Each of the solar cells they ship in measures 8X15 cm and has a voltage output of 0.5V and a max current output of 2 A. They split the cells into four parts and then connect them in series to step up the voltage output from the complete assembly to 6 volts.

Currently they have already manufactured one panel for recharging cell phones. These panels are made using 3 original cells that are split into 4 smaller cells each (Making 12 small cells in total) which are wired in series for a voltage output of 6 V. The voltage is dropped over a resistor to the required voltage to recharge the battery.

Unfortunately, when the cells are cut, many of them break and hence are cost ineffective. They do not have access to laser cutting technology and mechanically cutting the cells leads to a large amount of wastage. The cells must also be cut larger than the theoretical area because of the efficiency lost at the cut edges.

To solve this problem, we have developed a circuitry attachment that can be attached to a panel consisting of three 'original cells,' which together will output 1.5V. The attachment will step up the voltage to the required amount (5V) while regulating the current during the charging process. It will hence eliminate the need for them to cut cells and hence save money.

Design Specifications

These were the considerations we took into account while designing our project:

1) The finished product should cost less than $20 in order to compete with the $20 China-made model available in Managua

2) The entire system should be built indigenously built in order to provide jobs and a self-sustaining production system

3) The product should be easy to visualize and should minimize design complexity, but should be durable and able to resist damage when handled on a daily basis

4) It should be aesthetically appealing and easy to use so that the public can use it without assistance

5) The product should be able to charge a cell phone in a similar time frame to the current method, meaning within 6 hours for a complete charge cycle.

6) The product should be versatile and charge the different cell phone brands available in the community

Final Design

Overview of Design

Fig. 1: Final Prototype

The prototype uses a simple hinged system which serves two purposes:

1) To angle the panel towards the sun so as to maintain a perpendicular planar angle. The panel is held in position by a notched wedge system
2) To protect the circuitry and phone from any light rain that may begin before the user has a chance to bring the system indoors.

Its compact design makes it portable, while its easy-to-use plug makes it simple for anyone to use. Three solar cells (shown below left) produce a voltage difference of 1.5V.

This is fed into the internal circuitry which is covered by the metal panel next to the hinge (shown below right) where it is stepped up to an even 5V using a differential amplifier in conjunction with the required circuitry (See Fig 5). This is the required voltage input to charge any of the cell phones we encountered in Sabana Grande.

Fig. 2: Top Panel, 3 Solar Cells

Fig. 3: Inside, Circuitry under metal panel

Indigenously Designed

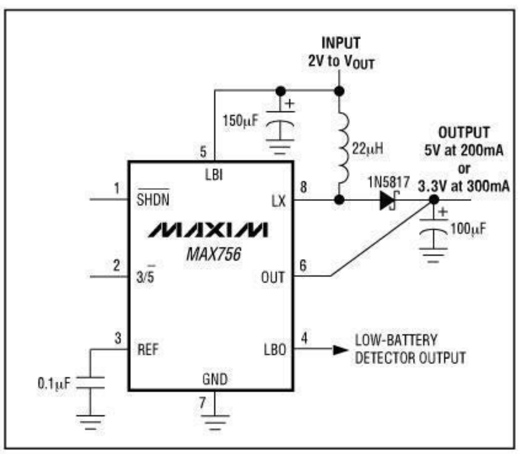
The system is designed so that it can be assembled completely from scratch with the resources available to our community partners. Some components (namely the solar cells and some circuitry components) need to be imported into the community by their American contacts but, since this occurs anyway, we do not think it will be a problem.

Fig. 4: Images of Solar Panels currently in production

Simplicity

We designed our system and internal circuitry so that it could be easily reproduced given design schematics. The actual building process does not involve complex machining or electronics. The external design is intuitive and easy to understand while the internal circuitry is easy to assemble given a circuit diagram.

The circuit itself, shown below, can easily be built by the local engineer. The circuit diagram at its left is a very simple one, with all parts except the step-up chip itself available locally.



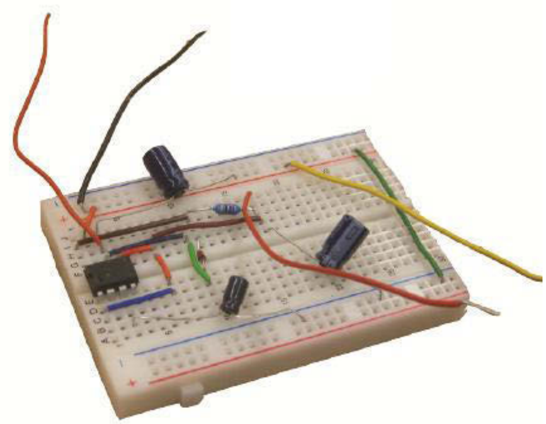


Fig. 5: Circuit Diagram and Final Circuit using this Setup

Aesthetics, Durability, and Usability

The design is compact and robust. It is not overly ornate but looks clean and efficient, such that the public will enjoy using it. It is a very clean and simple product which will not require people to change the way they approach charging their cell phones since we have included the same ports that are sold with grid adapters. If any problems occur, it is easy to take apart for the engineer to troubleshoot. That being said, the design itself is hardy and will not come apart easily

Rather than using moving parts to adjust the angle, we developed a simple wedge system. Both visually attractive and more robust than more typical angle adjusting systems, this ability lets the panel maintain a steady angle to the sun, with minimal effort required for adjustment.

Fig. 6: Notch and Wedge Adjustment System

In talking to our community partners and studying surveys on mobile phone usage, we came to the conclusion that there are two main models of cell phones people use in Sabana Grande. Our design allows for both compatible ports to be attached to our charging port so as to charge both types of phones.

Economic Viability

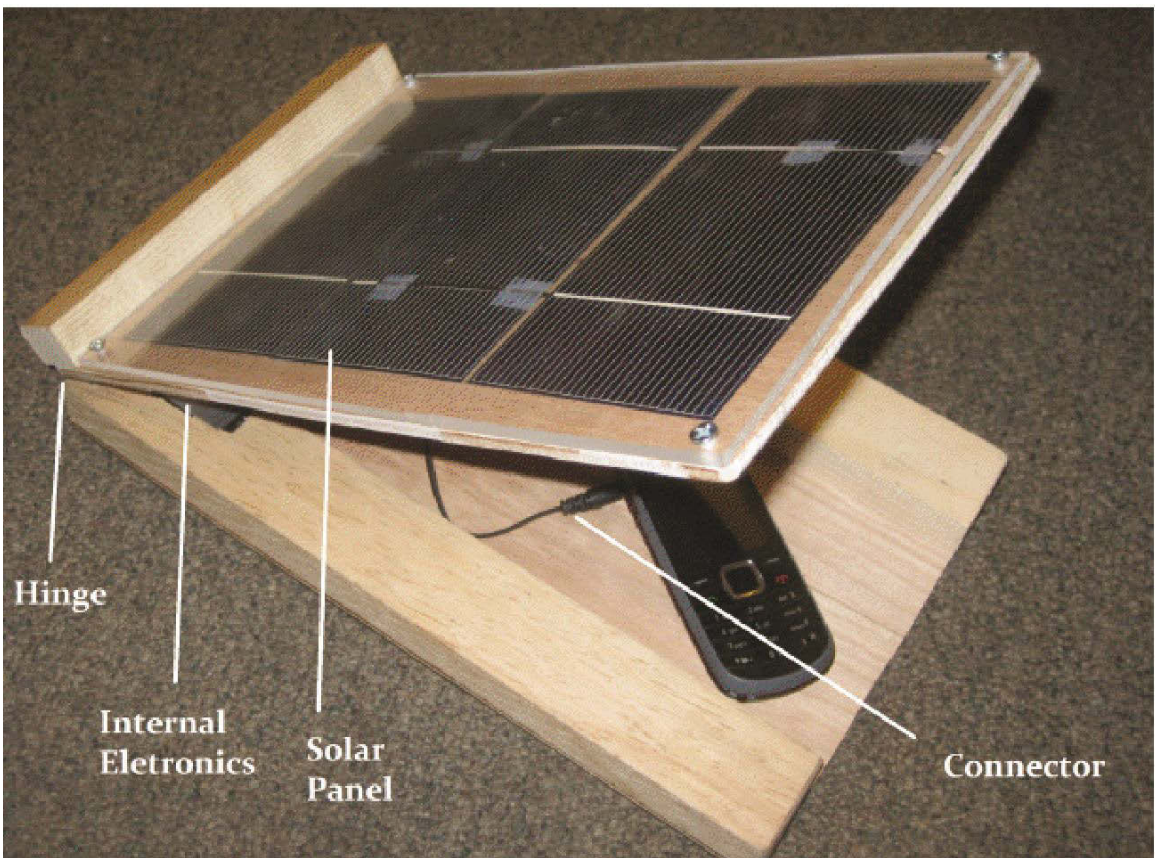
	Quantity	Part	Cost (per part)
Labor	8 hrs		50 cents/hour
Electrical parts			
	3	Solar cells	$1 per cell
	25 cm	Wire	10 cent
	2	100 microfarad capacitor	10 cents
	1	0.1 microfarad capacitor	1 cent
	1	22 micro henrys Inductor	30 cents
	1	Step up DC to DC converter chip	$5.5
Mechanical parts			
	2 (20*30cm)	Wood	$1
	2	Hinges	50 cents
	1 (20*30cm)	Glass	~$1
	6	Screws	10 cents
	100 cm	Angle Aluminum	~$2
		Silicone	~$2

Fig. 7: Cost Breakdown

Cost of Labor: $4
Cost of Solar Cells: $3
Cost of Circuit: $6.10
Cost of Mechanical Parts: $8.60

This translates to our product selling for $21.70 when built locally, which is a little above our design specification. However, we think we can cut down on this price using the 'Green Hours' system which eliminates labor costs by allowing members of the cooperative to earn their own chargers by working for the cooperative for a certain number of hours. We could also potentially cut down on the costs for mechanical parts by using scrap material and makeshift hinges although this might adversely affect the aesthetic appeal.

Meeting the Specifications



Our final design (see above) incorporates our design specifications to the greatest extent possible. Its cost has been maintained at just over the $20 specified (see below) through the use of low-cost and locally available materials. For instance, protoboards are not easily available in Sabana Grande, but breadboards are, so our final design has incorporated a breadboard, made more permanent with the addition of hot glue and tape to keep the pieces in place.

The local engineer is more than capable of assembling this system, there might even be a possible way to create a handmade DC-DC step up circuit which would circumvent the microchip and decrease costs by an estimated $5.

The simple hinged design lets the user set the angle of the panel perpendicular to the sun, adjusting it as necessary throughout the day, while using durable materials with as few moving parts as possible. Rather than hinged levers to set the angle, we developed a wedge system to simplify the system and lower costs. While the panel can still be adjusted to any angle, our system eliminates pieces that may break with use.

Because of its simple design and no naked circuitry, the system can be used by the public without fear of breaking or damaging it. They only need to plug in the phone, adjust the angle, and point it towards the sun. If troubleshooting is required, the engineer at the Solar Center should be able to easily access the internal circuitry to hone in on the problem.

The main shortcoming of the current design is that it takes roughly 10 hours to charge a cell phone. While this does not meet our initial 6-hour specification, we are hopeful that when exposed to tropical sunlight, the time to complete a charge cycle might drop to approximately 8 hours.

Because of the ease with which a port can be attached to the output leads, the possibility to attach multiple connectors to a single device remains, giving our product versatility in terms of charging different cell phone brands.

Testing and Results

Once the solar cell phone charger prototype was completed, it was necessary to test its real life performance. Our main goal at the beginning of this project was to have a cell phone charger that could charge a fully discharged cell phone in less than 6 hours. To test if our model could fulfill this task, we measured the power coming out of our circuit and into the cell phone and compared it to the energy capacity of the battery we were charging.

Charging Time

The energy capacity of the cell phone batteries is 800 mAh. If we test the amperage output of our charger, we could figure out around how long it would take for the cell phone battery to charge completely.

Experimental set up:

It was necessary to understand the amount of power going in to our circuit from the solar cells, and the amount of power coming out of the circuit and into the cell phone. To find both of these values, our device was set up as seen in figure 8 below.

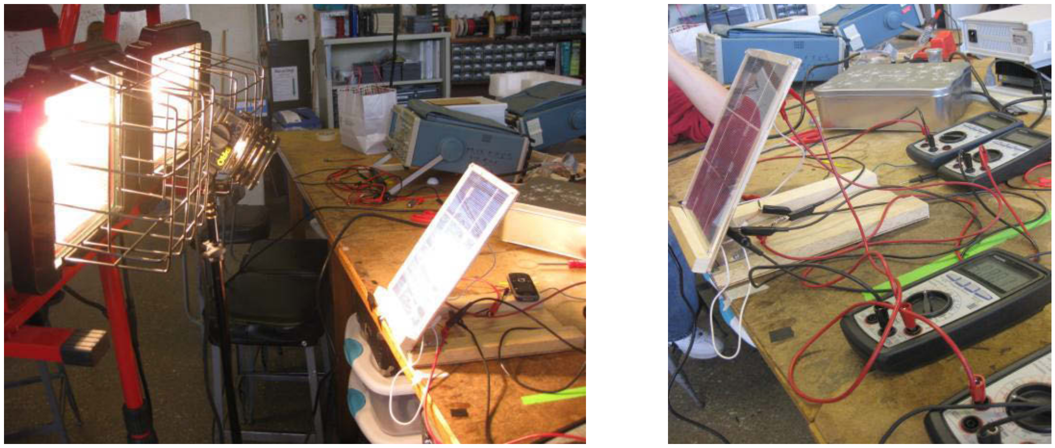


Fig. 8: Experimentation Images

We attached two digital multimeters that measured the current and voltage output in real time from the leads coming out of the solar cells so that we could calculate the power input when the device was working. Moreover, we also attached two multimeters that measured the current and voltage output from our internal circuit, which allowed us to calculate the power output.

Using this data, we could contrast the values and make an estimate of the efficiency of our circuit and of the time needed to charge the battery. Once the apparatus was set up, we used varying amounts of light to shine on the solar panel. We then measured the different input and output power values. We did this for 8 different amounts of light, including 2 different lamps, and sunlight.

Results:

The graph below plots the power data in Watts for the input power, or power that was measured out of the solar cells, and output power, or powered that was measured out of the circuit. The slope shows the efficiency of the circuit, and how much power is lost in the circuit.

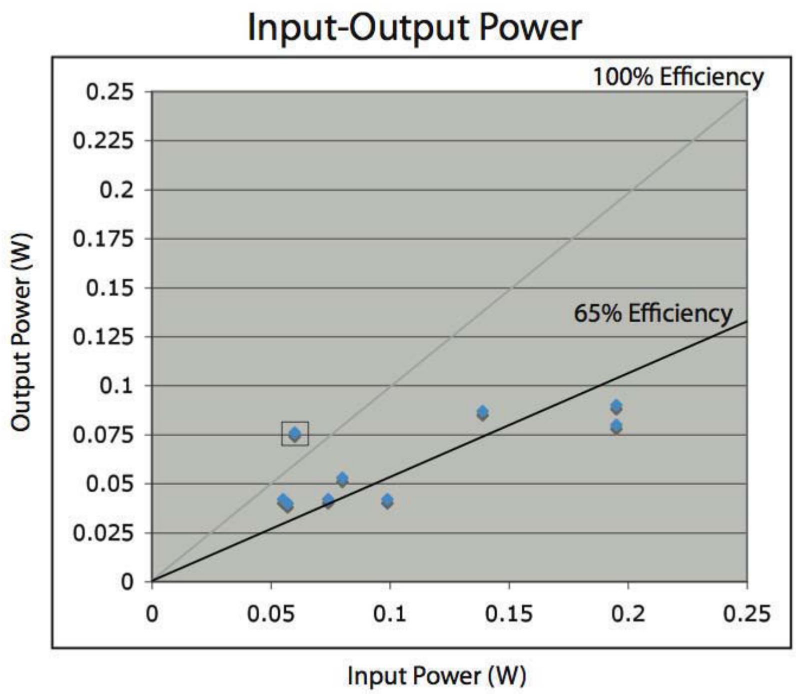


Fig. 9: Input-Output Data Graph. Figure above shows the input and output data for the solar cell phone charger. Note the linear fit on the input over output data.

From data that was collected while in Nicaragua, we were to estimate how much power the circuit would output if it was in Nicaragua. This data is shown in the graph below.

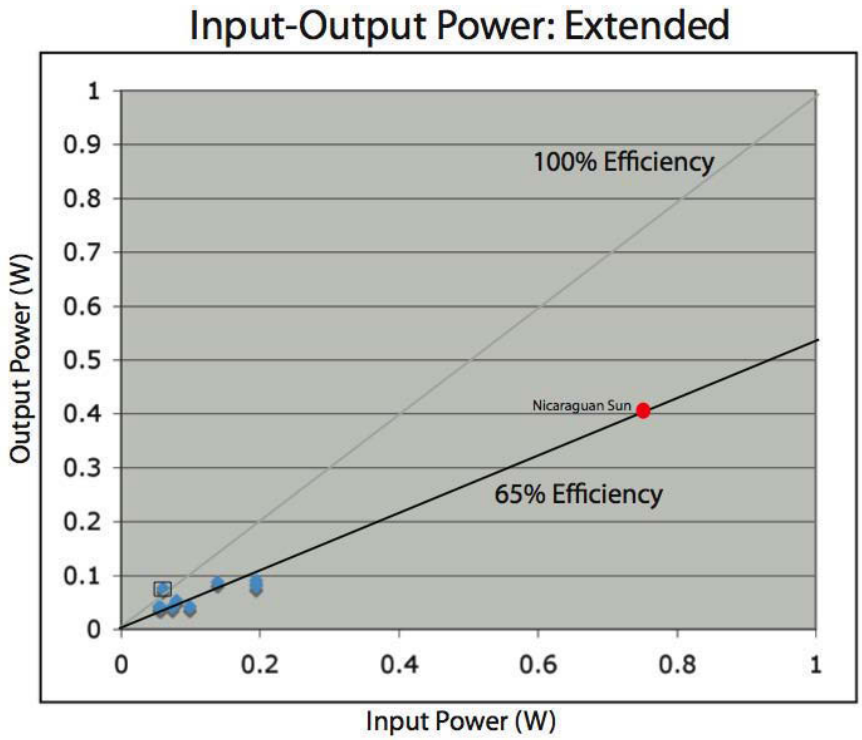


Fig. 10: Input-Output Data Graph Extended. Figure showing the projected efficiency calculated using data of solar panel output from Nicaragua

Conclusions of testing

The experimental data lead us to conclude that the output Amperage of the circuit, if used in Nicaraguan sun, could be about 80 to 100 milliamps. From this data, we estimate that if a cell phone battery were fully discharged, it would take about 10-12 hours for it to fully charge (the battery has an energy capacity of 800mAh). Realistically, most cell phone batteries are charged from half charge, reducing the time needed to charge.

Conclusion

We consider the project to be a successful attempt at supplementing their energy requirements while maintaining economic viability. Our initial goal was only to develop the economically viable circuitry required to step up the 1.5V to 5V. On developing the circuitry, we decided to prototype the entire system and did so successfully.

There are a number of ways to further optimize this system. We intend on sharing our research with our community partner and working with them to continue development on the system. The project has a lot of potential to be implemented in the community and we are eager to see it in action.

Based on our conversations with the community, they seem to have received the design very well. Mauricio and Lindsey of the Solar cooperative have agreed to work with us during the month of June to try and develop a version of our charger that can be built using only locally available parts (as opposed to importing the microchip).

As of now, we plan on sending them detailed schematics of our product along with the components required to build their version of our prototype. We could then work with them on further optimizing the model to suit their specific needs.

We highly recommend that another D-lab group take up this project and work on further optimizing it and reducing costs, possibly developing alternative ways to step up the voltage without the use of expensive components like the differential amplifier.