Energy harvesting from multiple sources for Battery charging

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Abstract

This Project is an attempt for improving the communication in rural areas by developing an off-grid portable cellphone backup charger which uses various forms of renewable energy.

The various forms of energy used in this project are solar, wind and heat due to their availability and cleanliness. With the advancements in power, now it is able to harvest energy from sources which are impossible to harvest using traditional energy conversion methods. In this project, a proposed converter for the cell-phone charger was designed, constructed, and then tested. Results show the functionality of the proposed converter to charge Cell-phones. Further improvement of design will also be described.

1. Introduction:

Cell-phones and laptops are becoming an integral part of our social life. For everything from playing games to cooking food, sending sms messages to attending business conferences, watching movies to doing banking, we depend on our cell phones. Cell-phones and laptops are to becoming a must moving from being a luxury. According to “The Guardian” there are 4.1 billion users of cell phones in the world, which is 60% of the world’s population, proving cell phones are becoming the most important personal communication device [1]. Just like how the cell phone is becoming an important need, it is equally important to be able to power up cell phones. According to the International Energy Agency, in 2011, 1.4 billion people around the world did not have access to electricity [2]. There is a huge portion of world population who cannot use a cell phone due to the lack of electricity. Also during natural disasters, like tsunamis or earthquakes, power outages will happen for days. During these power outages, communication is very essential, but the main communication device, cell phones, will be useless due to the lack of power.

This senior project is developing a cell phone charger that uses multiple renewable sources of energy to provide uninterrupted power for cell phones. With further investigation, the most convenient sources that could be used in this project are solar, wind and thermal sources. During the day time, the cell phone charger could use solar energy from the sun. During night time, the cell phone charger could use the heat from fire, or even excess radiating heat from cooking stoves or heaters. The wind source can be used when the consumer is travelling such as by boat. By integrating three different sources, this cell phone charger will be able to provide power to a cell phone in three different diverse conditions

2. Design Requirements

A. Project Goals:

The project goal is to design a portable cell phone power backup/charging unit that uses three renewable sources of energy, and can be used in rural areas or disaster affected areas without electricity from the grid.

Charger Specifications:

Below is a list of project specifications.

- Should be able charge cell phone without using electricity from the grid
- should be portable
- Should use renewable, readily available energy
- Should be safe to use
- Weather proof
- Affordable in third world countries

Solution Statement

As a requirement, in the project, three renewable sources of energy is included - solar, wind and heat as power sources. The main advantage of having these three as sources is that it is readily available, free of cost and little maintenance. After considering various options and components of design, the design shown in figure 2.1 is selected to implement.

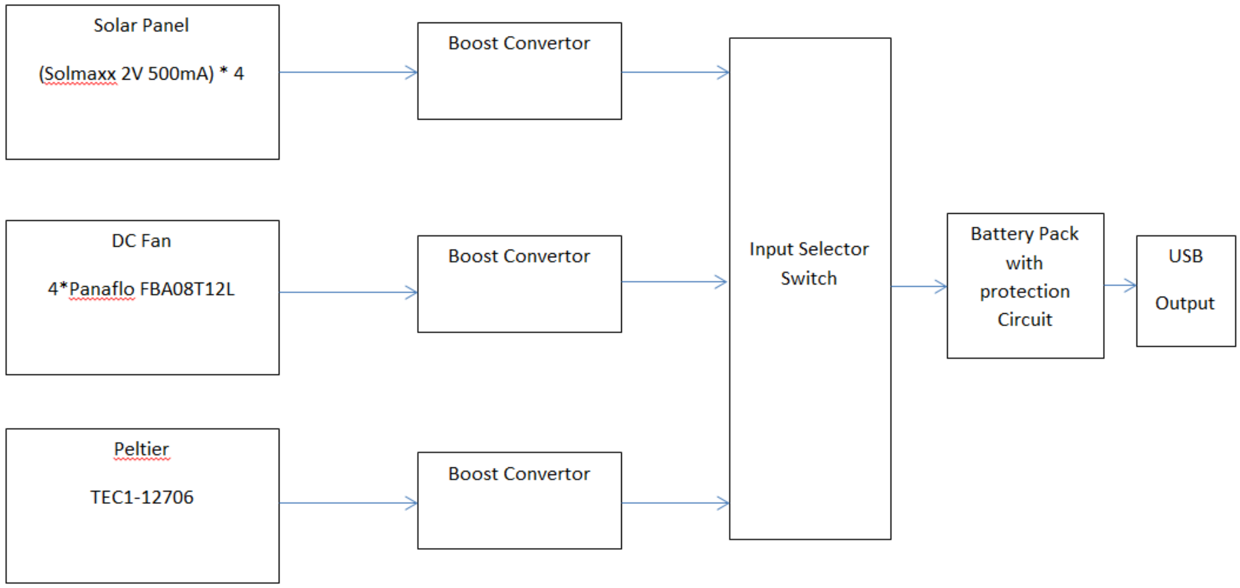

Figure 2-1 Block Diagram of design

Input

As per the requirement to use three renewable sources, the sources selected were solar, thermal and wind, since they are most readily available. For converting solar power to electrical power, solar panels were used. For converting wind power to electrical power, DC brushless generators are used. For the conversion of heat to electrical energy, peltier cells are used in this project.

Since there are three sources are present in the project, three DC-DC converters are needed to implement this project. For solar input source, a less expensive DC-DC converter is used because of solar panels relatively stable and high current supply. For wind and thermal inputs more expensive DC-DC converter like Ultralow Voltage Step-Up Converter and Power Manager (LT3108)

For Petlier cells, to keep a constant temperature difference a sealed oil (which stores

heat energy even though the source of energy is removed) container on one side keep it hot and heat sink on other side to make it cool. It is achieved due to the property of oil to restrain the heat provided to it.

Output

Due to the variable availability of solar, low power supply wind and heat power, it is convenient to store the energy into a battery pack and then charge the cell phones from that battery pack. Having a battery pack will also provide an extra layer of back up during emergencies.

B.Project Timeline:

The following table displays various goals that should be achieved during each week of the winter and spring quarters of 2012.

Table 2-1 Schedule of the project

<table>
<tr><td>13-Jan</td><td rowspan="2">Read thesis and articles</td><td></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>20-Jan</td><td rowspan="2">Do the simulations for initial design</td></tr>
<tr><td>27-Jan</td><td rowspan="2"></td><td rowspan="2">Order Parts</td><td rowspan="4">Make the stucture of report</td></tr>
<tr><td>3-Feb</td><td rowspan="3"></td></tr>
<tr><td>10-Feb</td><td rowspan="11">Read articles and Consult</td><td rowspan="2">Built the Hardware</td></tr>
<tr><td>17-Feb</td></tr>
<tr><td>24-Feb</td><td rowspan="4">Trouble-shooting</td><td rowspan="2">Test and troubleshoot</td><td rowspan="2"></td></tr>
<tr><td>2-Mar</td></tr>
<tr><td>9-Mar</td><td rowspan="2">Demo</td><td rowspan="2">End of Quarter report</td></tr>
<tr><td>16-Mar</td></tr>
<tr><td>23-Mar</td><td rowspan="5">Improve Design</td><td rowspan="6">Improve the design</td><td rowspan="2"></td></tr>
<tr><td>30-Mar</td></tr>
<tr><td>6-Apr</td><td rowspan="3">First Draft</td></tr>
<tr><td>13-Apr</td></tr>
<tr><td>20-Apr</td></tr>
<tr><td>27-Apr</td><td colspan="2" rowspan="5"></td><td rowspan="2">Second Draft</td></tr>
<tr><td>4-May</td><td rowspan="4"></td></tr>
<tr><td>11-May</td><td rowspan="3">Final Draft</td></tr>
<tr><td>18-May</td></tr>
<tr><td>25-May</td></tr>
<tr><td>1-Jun</td><td></td><td></td><td></td><td></td></tr>
</table>

3. Design

A. Input

As per the requirement input sources of this project has to be renewable, available in rural areas and cheap. So three renewable energy sources: Solar for day time, Thermal for night time, and wind during traveling time is used in this project

Solar Cells

The main considerations given in picking solar cells in this project is durability, strength, output power and customer safety. Considering those as requirements and price, Solmaxx 2V solar panels are selected.

Figure 3-1 Solmaxx 2V solar panel

The advantages of this solar panel module is that it is weather proof, strong, tempered glass protected(If it breaks, it will shatter without leaving sharp edges so safe for the customers) and thermal electric insulated coating on rear side. The electrical properties of the solar panel is shown in table 1

Table 3-1 Properties of solar panel

Material used	High density crystalline solar cells
Voltage(OC)	2 V
Current(Isc)	400mA
Power	.8W

To attain voltages more than minimum input voltage of DC-DC converter (.9V) even during shades, two solar panels were connected in series as shown in figure 3-2. To reduce the charging time, the current has to be increased. So in order to increase the total current two units of two solar panels (connected in series) connected in parallel as shown in figure 3-2.

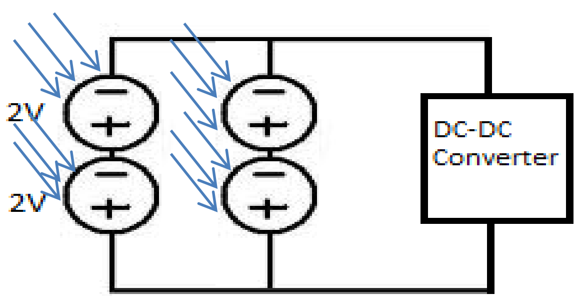

Figure 3-2 Solar panel Connections

DC generator

To utilize the wind energy, a DC generator has to be used. The most common DC generator convenient is the computer fan because of its availability, price and light weight. For this project PANFLO FA08T is been utilized.

Figure 3-2 DC brushless fan

Two fans are connected in series which is then connected in parallel with the two other fans connected in series. This setup will allow to increase the voltage and current by two times than the rated voltage of single fan. The output of DC generator is then connected to the DC-DC converter and it is connected to a battery pack.

Peltier Cell

Another source of energy used in this senior project is the excess heat emitted to the surrounding from cooking and thermal emitting devices. To utilize this heat, a Peltier cell is used. Most common application of peltier cells is for cooling purposes such as wine cooler. If you apply a temperature difference across the plates of a peltier cell, it produces Seebeck voltage due to seebeck effect.

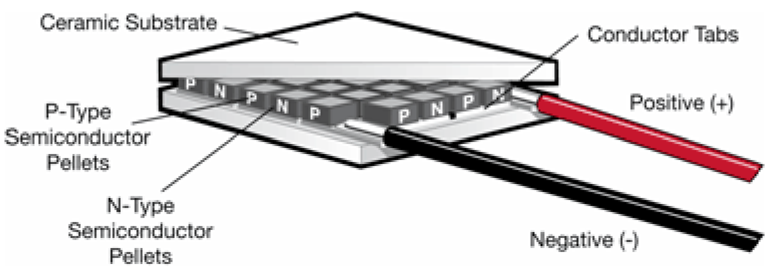

Figure 3-3 Basic structure of Peltier cells

Table 3-2 Perfomance Specifications of TEC1-12706

Performance Specifications

Hot Side Temperature (° C)	25° C	50° C
Qmax (Watts)	50	57
Delta Tmax (° C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

To create a constant heat source the hot side of TEG is attached to oil filled Altoids container, in which oil absorbs and retain the heat for longer time. The colder side of the Peltier is connected to a heat sink to dessipate heat to the surrounding so that way the colder side will

remain cold and a temperature difference will be maintained. In this senior project the Peltier cell used is TEC1-12706. The performance specifications for cooling of the TEC1-12706 is shown in table 3-2

B. Converters

DC-DC converter (for Solar and wind Module)

The DC- DC converter used in this project is a simple Boost converter available in the market. The picture of one used in this senior project is displayed below. The main advantages of this boost converter are its compact size and prize. The specifications of the boost converter are shown in the table 3-3. The output voltage of solar panel set-up displayed in figure 3-2 is 4.75 to 4 V which falls under the input range of this converter, which also has required current rating. The 5V output is the required voltage to charge the battery pack, which makes this converter preferable than others available now. The compact size of this is another reason to select this prefer to LT3652 from linear technology.

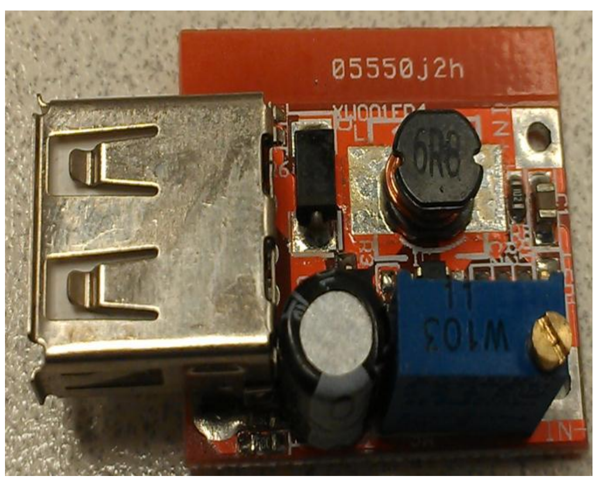

Figure 3-4 Boost Converter

Dimensions	33mm*18.8mm*11mm
Input Voltage	0.9V-6V
Output	3.3V-9V adjustable
Output Current	1A
Conversion efficiency	Upto 94%
Output Ripple	50mV
Load regulation	±1%
Voltage regulaton	±.5%

Table 3-3 Specification of boost converter

DC-DC Converter (Peltier Module)

For wind and Peltier input sources, due to very small output power, more complex DC-DC converter has to be used. In this project, the DC-DC converter used for peltier module is *Ultralow Voltage Step-Up Converter and Power Manager* (LTC3108)[5]. The main advantage of LTC3108 is its ability to operate in ultra-low voltages. Figure 3-5 shows the schematic of the DC-DC converter

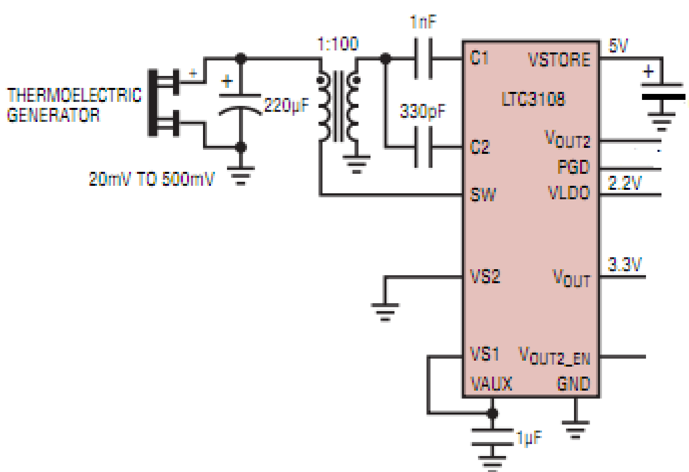

Figure 3-5 Ultralow Voltage Step-Up Converter and Power Manager (LTC3108)

Table 3-4 lists the specifications of the LTC3108 DC-DC converter. Due to its ultra-low input voltage range, LTC 3108 is one of the best DC-DC converters available in the market for a Peltier cell. The wide range of input voltage (20mV to 400mV) makes this suitable for a unstable low voltage input like Peltier

Table 3-4 Operating parameters of LTC3108

Input Voltage Range	50mV-400mV (Typical no load start-up = 20mV)
VLDO	2.2V
VOUT	Jumper Selectable from 2.35 to 5.0V
VOUT2	Switched Output, VOUT2=VOUT
VSTORE	5.25V

C. Output

3 way switch

All the outputs from the DC-DC converter go to a source selector shown in figure 3-6. Source selector allows you to manually select which source to use in order to charge the battery pack/Cellphone.

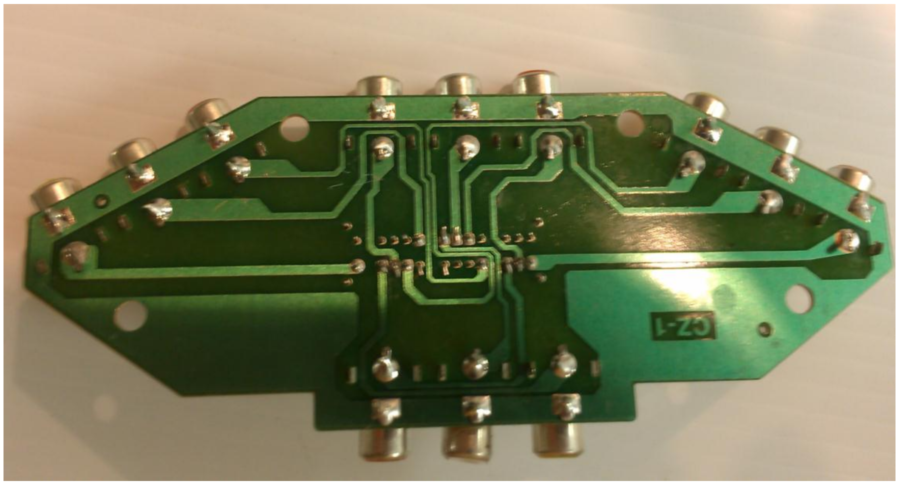

Figure 3-6 Circuit diagram of the source selector

Battery pack

The battery back used in this senior project is a standard Li-Poly (2800mAh) battery. The main advantage of using 2800mAH battery is during the day time unit can charge for a longer time and store more energy in the battery and during the times when power is not available, the store energy can be used to charge up to two cellphones due to its high storage capability

4. Test results

For testing the equipment, each module of the charger is tested separately and analyzed.

Solar Module

The average of various charging test runs of solar mode is displayed in table 4-1

Table 4-1 Solar panel Output

Panel Output		
	Vout	4.5-4V
	Iout	.9A-.775A
Boost converter Output		
	Vout	5.05V
	Iout	.7A-.6A
Time to charge Backup Battery		
	Time	3.75-4.5hr
Time to charge Cellphone		
	Time	1.5 - 2.5 hr

The runs varied from bright sunny day to cloudy day. The output voltage of solar panels were varying from 4.5 – 4 V depending on the amount of sunlight it receives. According to the test results the equipment can be operated at various weather conditions and also able to charge

the backup battery in around 4 to 5 hours. From the energy acquired in 4 to 5 hours, it is able to charge up to two cell-phones.

Wind Module

Wind module is tested by holding it outside of a moving vehicle. Around 65 mph the module is producing a voltage around 3.5V and current around 110 mA. This current is not sufficient enough to charge a cellphone directly, but can be used for energy harvesting for back-up system.

Peltier Module

The energy acquired from peltier module was really varying because of the difficulty in maintaining a constant temperature difference. For a temperature difference of 25 degree Celsius, the Seebeck voltage starts around 3V and reduces to rapidly diminishes due to rapid heating of heat sinks. With a more advanced cooling system, peltier technology is definitely a path for green energy

Final assembly

The one of the main challenge faced in this project is to design a final product which incorporates all these input modules, converters, and storage and still light and portable. To reduce the size, during primary design to have a multilevel hinged solar panel system was planned. Due to the difficulties in drilling hinge holes in tempered glass of solar panels, it has to change into a static solar panel structure. The picture of final product is shown in figure 4-1. The top part have solar panels and the input selector switch. Under the solar panel all the circuit components and battery pack were securely stored. Below it, the four fans for wind module is securely fixed using wooden brackets

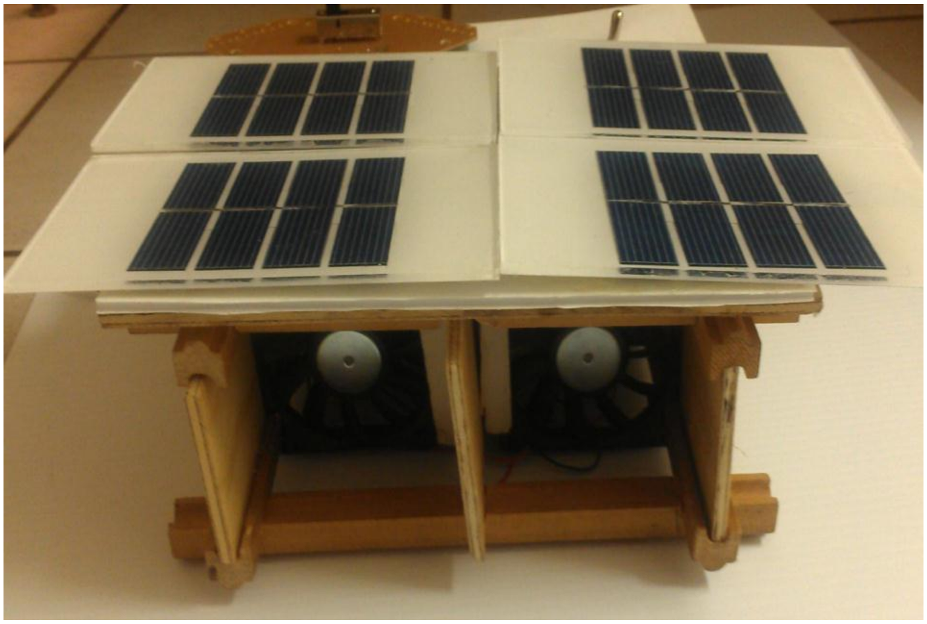

Figure 4-1 Final Product

The final product is 18cm(width) X 18 cm (depth) x 12 cm height excluding the solar panel extension. It weighs 744 grams. If it is commercially manufactured, by making tempered glass solar panels, using custom designed plastic fabrications, the size of the product can be reduced significantly.

The solar panel module of this product works perfectly fine and the design could be used to commercially produce the product. The Peltier module needs a design improvement to have a better heat sink. Another improvement that could be suggested is to use different type of a DC fan which can output more current, that way it will reduce the charging time

5. Conclusion

Working on this project helped me to go through the various steps of a project, such as brainstorming, designing, planning and executing. It has also taught me a lesson that various things might go differently from the original plan due to various reasons, and as an engineer you should expect it all the time. I was also able to use the concepts of power electronics I learned in class in this project.

The resulting design of the module can be built and marketed in less than 50 dollars in rural areas. It is a good working charger powerful enough to harvest the sun power and store energy required to charge up to 2 cellphones. This product would be a good starting step in developing the communication systems in rural areas.

Even though wind and peltier module need further improvement as explained in the previous chapter, with the developments in the field of science and technology, we are not that far to have an improved DC generator powerful enough to charge a cellphone, or to have a cooling system fast enough to reduce the temperature of the cold side of peltier. Overall, this project meets the goal of providing a cell-phone charger for rural areas though the use of renewable energy.

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Appendix A

List of Parts

Table A-1 List of parts

Solar Panels*4	19.8
3 Way AV RCA Switch	3.75
Thermoelectric Peltier Cooler*2	20.76
DC-DC Convertor*2	4
LT3108 module	Free Sample
Battery Pack	13.78
Screws	3
DC-Fan	Free
Total	65.09