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THE ZEPHYR CHARGE

A WIND-POWERED USB CHARGER

by

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Acknowledgements

We would like to acknowledge and thank Dr. Taufik, for coming up with the idea for this project and allowing us to build upon his original thought under another advisor.

Also, we would like to thank Dr. Nafisi for taking this project on as an advisor.

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Abstract

The Zephyr Charge project is to design and build a cell phone charger using a small wind turbine generator that can be useful to the fishermen community, namely fishermen of third world countries. The generator will output to USB for ease of charging capability. The size of the whole system should be light enough to move around, and the turbine itself will be mountable onto an edge of a wall. The goal of this project is to design and build a compact and easy to use cell phone charger, which is also efficient.

In order to be a practical product, the cell phone charger must be affordable to the average consumer. Also, the viability of the product relies on the converter being efficient. To meet these requirements, effort will be afforded to using inexpensive components, while also sticking to those which have a higher efficiency.

1. Introduction

Today, cell phones contain so much needed information. When the battery dies the phone is useless. This can be especially frustrating when the user sails out at sea for a living, spending countless hours, days, even weeks away from electricity. The current wind-powered cell phone chargers are not durable enough to survive the weather out at sea, where winds will usually gust over 20 mph. This is the biggest weakness of those currently out in the market, therefore this is where this product will improve. The Zephyr Charge is a wind turbine-powered cell phone charger that utilizes USB to connect the phone to power. The wind turbine has a horizontal-axis that converts kinetic energy from the wind into electrical power, and has a survival wind speed of 40 mph. The survival wind speed of 40 mph will more than meet the expectations of our primary consumers which again are fisherman of third world countries that may not have the largest of boats. The purpose of this project is to create an affordable, easy, and reliable way for fishermen out at sea to charge their phones, while attempting to maximize both efficiency and affordability.

2. Specifications and Requirements

Marketing Requirements	**Engineering Requirements**	**Justification**
Compact Design	Actual size dimensions (12”x2”x2” not including turbine blades)	Large enough to be durable, small enough to remain out of the way.
2 types of outputs for variety of phones	The USB should have 2 outputs of both 5 V, 1 A and 5 V 2.1 A ports	Two outputs cover a large variety of standard phones used by the population
Cost Effective	Cost to develop 1 unit should not exceed $25 per 1000 units made. Selling price will not exceed $50.	The use of a stronger wind turbine creates most of the cost for the product but the ability to buy in bulk significantly reduces the cost to produce one unit. The selling price will be double the amount we plan to produce one unit.
Flexibility in wind required to produce charge	40 mph winds, as well as softer winds of 5-10 mph, should produce a 10 W output	While there are strong winds at sea, sometimes there isn’t much wind to use.
Efficient	Efficiency at full load must be greater than 70%	Higher efficiency leads to quicker charge times
Device’s battery capacity to fully charge a phone	The internal battery capacity must be around 12,500mA.h in size.	For convenience, a full charge of the Zephyr Charge should charge 4 or 5 phones.

Table 1: Zephyr Charge Requirements

Table 1 above lists the requirements for the Zephyr Charge from the market research that was done. Every requirement should be obtainable in the time allotted for this project. An additional requirement that may be included is weather-proof design, so rain and storm do not damage the finished product. This will be noted as a recommendation, instead of a true requirement.

Maximum Output wattage	10.5 W
Output Voltage	5 V
Output Voltage Ripple	< 5 %
Line regulation at Full Load	< 5 %
Load Regulation at nominal input	< 5 %
Efficiency at Full Load	> 75%

Table 2: Zephyr Charge Specifications

Table 2 above shows technical specifications that will be required for this charger. The testing of this product will be to ensure that each of these specifications are met. The overall goal of our device is to provide a device that is capable of outputting a maximum output of 10.5 W in addition providing an output voltage of 5V which will allow the device to charge phones, tablets and more.

3. Functional Decomposition (Level 0 and Level 1)

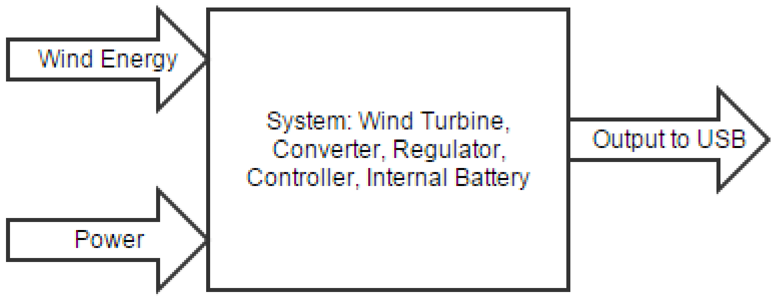

Figure 1: Level 0 Block Diagram

Input/output	Type	Description
Input	Wind Energy	The wind that hits the wind turbine
Input	Power	The electrical energy required by the converter and controller inside the system
Output	Output USB	A phone charger capable to charging the user's phone

Table 3: Zephyr Charge In/Out Descriptions for Level 0

The level 1 Block Diagram shown in **Figure 1** shows the overall input and output for the Zephyr Charge. **Table 3** lists descriptions for the few inputs/output of the device. The input for the portable wind-powered charger is the wind energy that is supplied to the wind turbine. The second input of the wind-powered charger is power which will be supply the needed power for the converters and controller within the system. The output for the level 0 block diagram is the USB port which will supply a 5V/ 1A or 5V/ 2.1 A that can supply power to a phone or another electronic device.

Figure 2 below shows a level 1 diagram of our whole system, and how each component falls into place. Wind energy will power the turbine of the generator, which will provide a voltage at its terminals. This voltage will be put through a converter (Buck-Boost), which will charge a battery. From the battery, a voltage regulator (Buck converter) will step the voltage down to the required USB levels at the output. **Table 4** shows the in/out signals and descriptions between each stage.

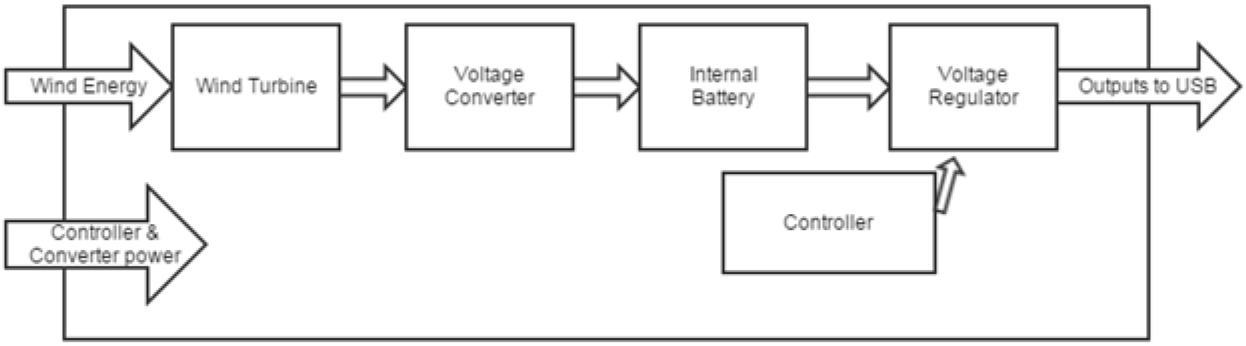

Figure 2: Level 1 Block Diagram

Input/output	Type	Description
Input	Wind Energy	The wind that hits the wind turbine
Input	Power	The electrical energy required by the converter and controller inside the system
Output	Output USB	A phone charger capable to charging the user’s phone
Input to Converter	Power	AC from Turbine flows into the converter to be converted to DC
Input to Regulator	Power	The rectified DC value is sent into the regulator to step down the voltage to 5 V
Input to battery	Power	Battery will hold the charge
Output of Controller	Signal	Controls the frequency of the switch utilized.

Table 4: Zephyr Charge In/Out Descriptions for Level 1

4. Design/ Building

Buck/Boost Converter:

For our design we looked at a couple different integrated circuits available on the market and compared their datasheet values and costs. We looked at the LTC3789 and the LTC3780. Both are variants of a similar 4-switch synchronous buck-boost controller [2]. The decision was based on several areas, including input voltage range, output current, output voltage, and its efficiency.

Factors:

- Input Voltage Range: The input voltage range needs to handle the voltage range that the generator outputs. As the amount of voltage range that the controller can handle increases, the overall efficiency increases since the voltage coming from the motor can and will vary. By selecting a chip with a larger input voltage range we increase the total energy from the generator.

- Output Current: Our design needs to be able to source up to 5A of current to charge a battery effectively. Therefore we need a controller that can handle that load.

- Output Voltage: We are charging a 14.8V Lithium Ion battery, which is made of four 3.7V cells connected in series [1]. The optimal voltage for charging was found in datasheets to be 16.8V [7]. Therefore, whichever controller we choose, it should be able to handle this voltage.

- Efficiency: The efficiency of our DC-DC converter is important because we wanted to maximize it as much as possible. By minimizing the dissipation across our device, we can utilize as much energy as possible. A higher efficiency will generate more energy whenever the device is active.

In the end, after considering both options and after gathering all the data for each controller, the two seemed pretty close. So a judgement call was made and we decided to go with the LTC3789.

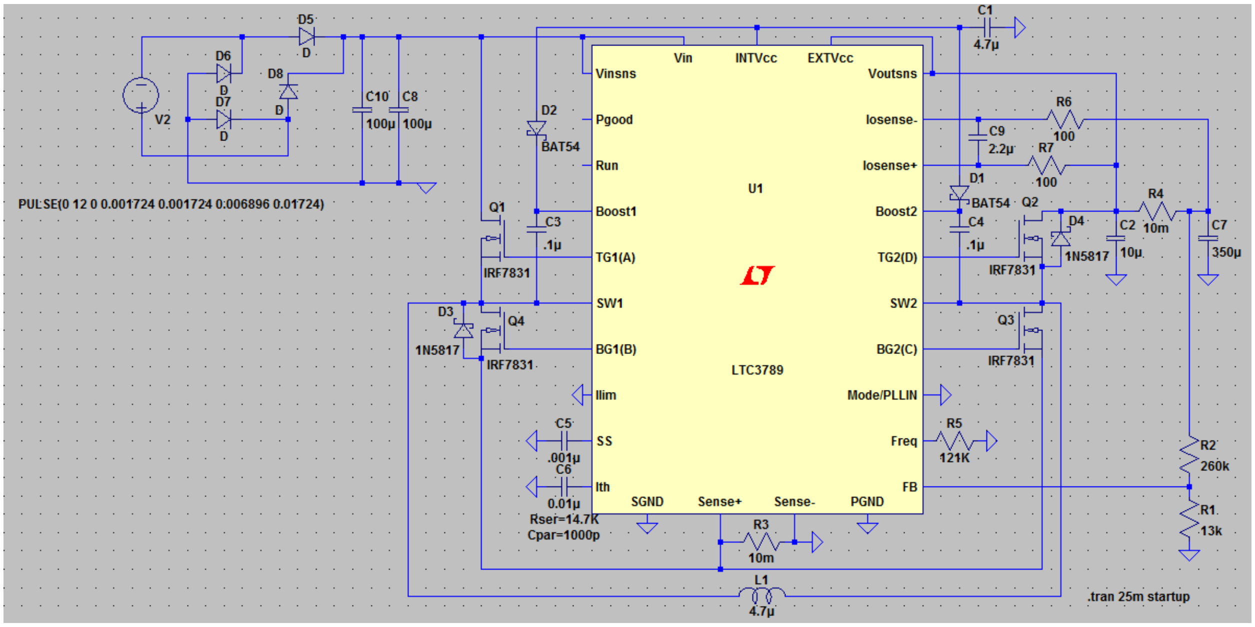

Figure 3: General Schematic for the LTC3789 [2]

The buck/ boost converter was a crucial component to the building of the portable wind-powered phone charger. The LTC3789 chip is a high efficiency, 4-switch Buck/ Boost Controller which allowed us to input 4V to 38V and output 16.8V, which is what our output was set to [2]. As seen in **Figure 3,** a general schematic was created using LTSpice of the Buck-Boost converter. In the top left corner of the figure is a full wave rectifier that leads into the input of the converter. Since a generator power source could not be found, this was simulated using an ideal power source, utilizing a PWM controller. This signal was set to act as a chopped DC input, which is basically a trapezoidal waveform. Its magnitude could be adjusted to go from 0 to 24 V, which was the max our motor could output [5]. For multiple test cases, the input was altered to various voltages to see how the converter would react. According to the datasheet, the converter should be able to operate between 4 and 35V [2].

In the test case seen below in **Figure 4,** an input voltage of 11V was used. The input is actually the voltage seen at the end of the input capacitors, so this explains the decaying waveform. With this signal going into the converter, the output was held at approximately 16.8V, as was designed. The output voltage was set to be 16.8 V in order to charge the 14.8V battery properly [1]. To set this voltage, we chose the resistors in the resistor divider such that:

$$Vout = 0.8V\left(1+\frac{R2}{R1}\right) = 14V$$

Equation 4-1

For this, we chose R1 to be 13k and R2 to be 261k. Other values were chosen which match or were similar to the values provided in the datasheet for the LTC3789 [2].

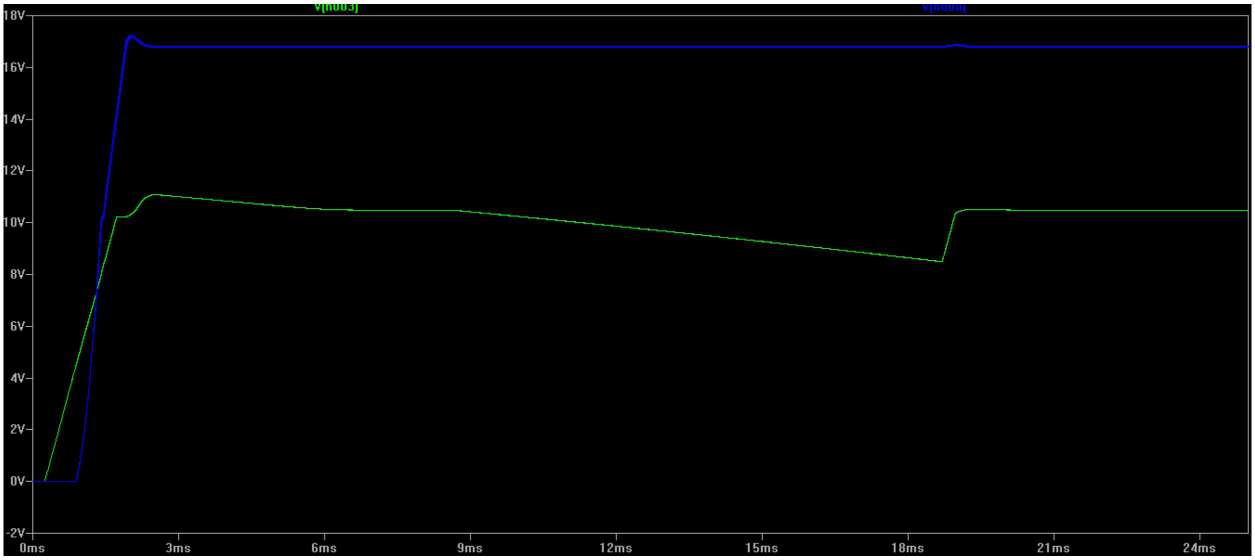

Figure 4: Simulation waveforms for Buck/Boost Converter. Green=Input, Blue=Output

Once we had determined the values of the resistors that would be needed to output a voltage of 16.8V, we simulated the circuit and probed the output to show that the output would result in 16.8V as shown in **Figure 4.** For this plot, the green curve is the input signal into the buck/boost. That is, this signal is after the rectifier and the input capacitance. The blue curve is the output signal, which goes into the battery. Ideally, this would be as close to DC as possible, since the battery is a DC source. Even with the dip in the input, which drops to around 8.5 V, the output is kept at 16.8V. The converter has a minimum input voltage of 4V; therefore, the output will continue to be 16.8V as long as the input is greater than 4V [2].

Design 1

Initially, for prototyping purposes, a breadboard was to be used for constructing the Buck/Boost converter. Using a breadboard would allow for easy replacement of parts, and allow for tweaking of the overall design. However, after consulting with a few colleagues and Professor Taufik, it was decided that a breadboard would not work. Our switching frequency is in the hundreds of kilohertz, and with the inherent nature of a breadboard, between nearly every component there would be capacitance seeping into our system. In addition, the connections among a row were limited and so the length of some leads would have to stretch a distance, and this distance would also increase capacitance between the endpoints of the leads, plus add unnecessary inductance and resistance to the system as well. Unfortunately, a picture of our initial breadboard test was not captured.

Design 2

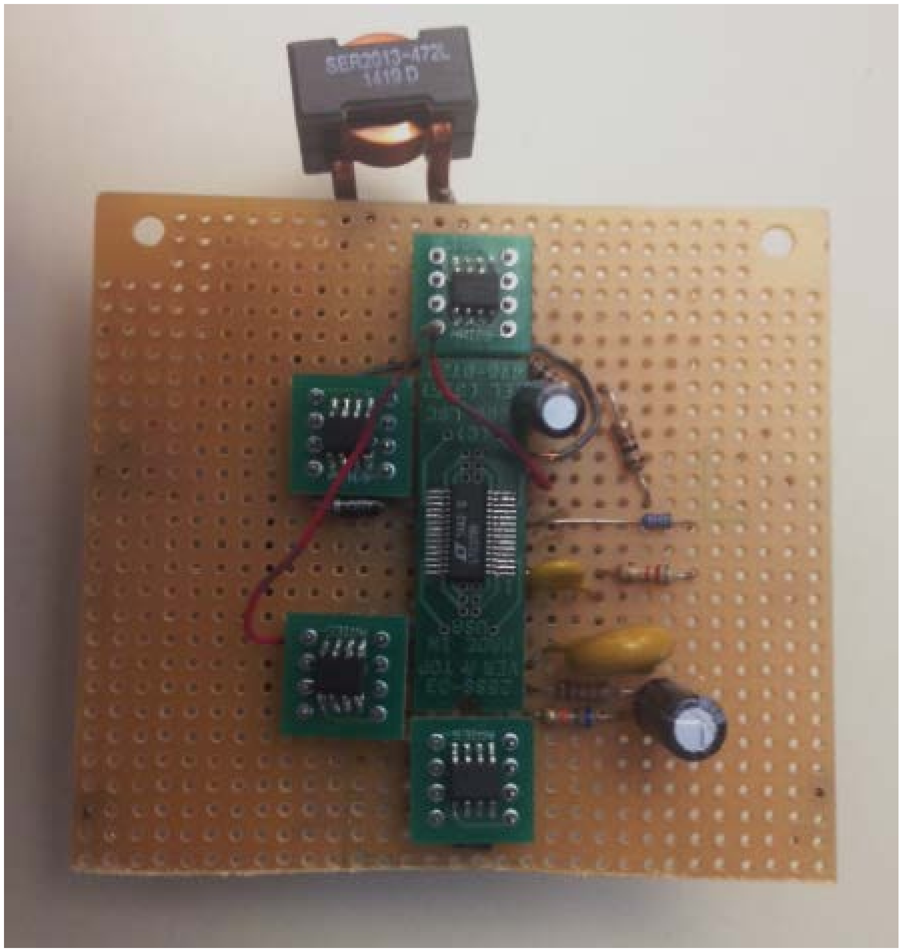

Figure 5: Design 2 for Buck/Boost Converter

After the first design attempt was unsuccessful, we changed our approach and decided that we would solder the components to a perforated board for prototyping. **Figure 5** is the resulting circuit that was constructed. The switches, along with the IC were surface mount parts, so we used SMT-Throughhole adapters. Once the proto-board had been laid out and all of the components had all been soldered we began to test the buck/boost converter to see if it would output a voltage of 16.8V. Our first test run did not work as we had expected. No voltage was seen on the output, no matter what voltage was set at the input. We decided to re-solder some leads that appeared to be bridging, which may have led to some connections being incorrect.

The second test using the perf-board resulted in an output voltage of around 2.5V, no matter what the input voltage. From this we concluded that there must be some connections on the board, either a shorted lead, or a slightly bridged connection which is disrupting the proper functioning of the system.

Design 3

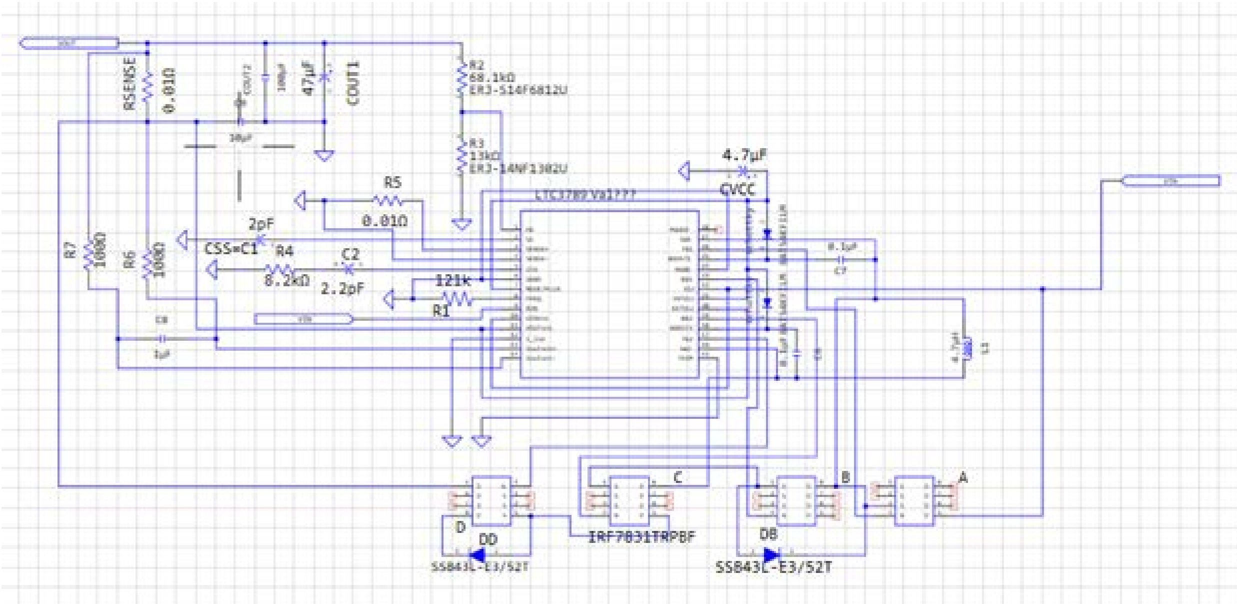

Figure 6: Schematic of Buck/Boost Converter

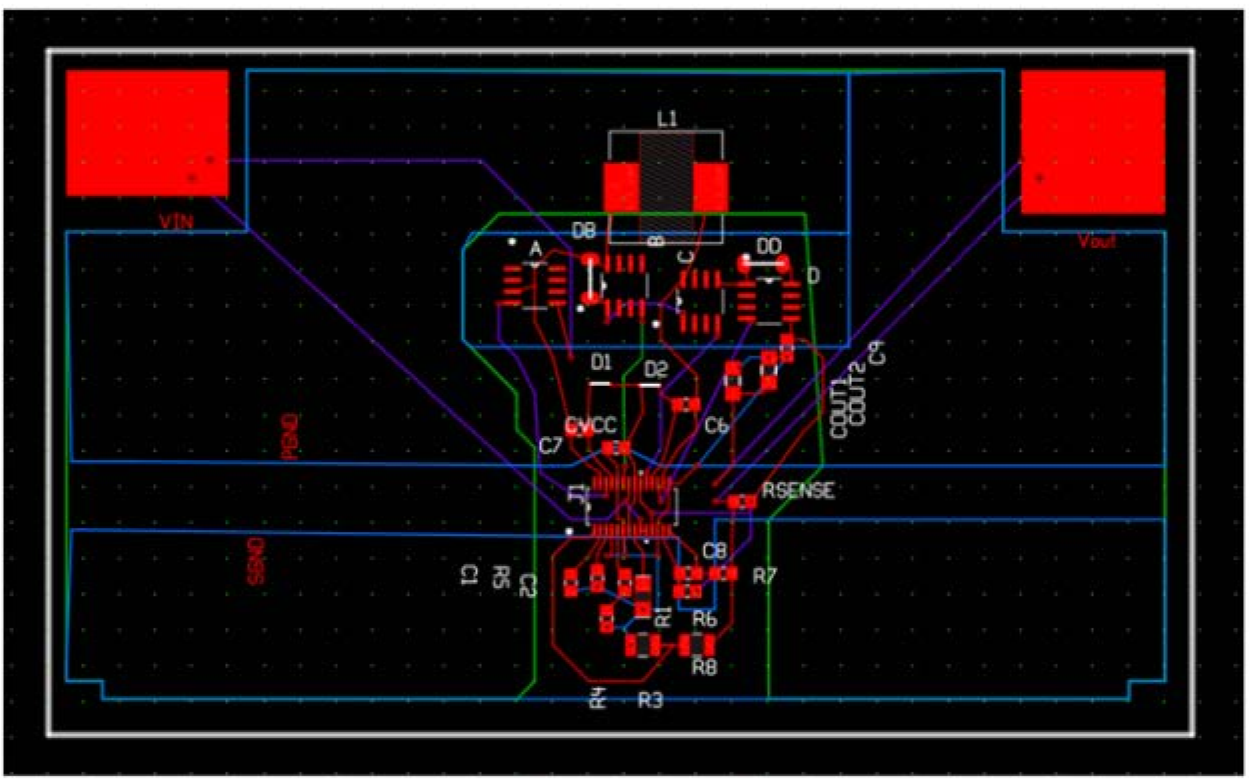

Figure 7: PCB Layout for the Buck/Boost Converter

After consulting with Dr. Taufik about how this converter should be presented, it was decided that a PCB layout should be designed. After researching several layout programs, PCBWeb was chosen because of its integration with DigiKey, which is the popular components warehouse from which we would be purchasing our parts.

Using PCBWeb, the schematic was created, as seen in **Figure 6.** In order to protect the more sensitive control components from the high voltage switching power components, each were separated on either side of the circuit, with a separate ground for each. Their grounds would be connected on the chip itself in order to provide an accurate reference node. Each individual component chosen matches up with the exact part that was to be purchased. At the end of the build, a Bill of Materials was produced by the program and ordered from DigiKey.

The most challenging part of the design was the PCB, seen in **Figure 7.** Using the PCB Layout Checklist from the datasheet of the LTC3789 [2], the optimized component placement was implemented.

PCB Layout Checklist [2]:

- PCB should have a dedicated ground layer
- Switch A, switch B, and D1 are in one compact area, along with switch C, switch D, and D2, and Cout in another compact area
- Flood unused areas on layers with copper to assist with heat sinking
- Segregate signal and power grounds, as well as signal and power components
- Connect the ITH pin compensation network closely to the IC, between ITH and the signal ground pins. The capacitor helps to filter the effects of PCB noise and output voltage ripple voltage from the compensation loop.
- Connect CVCC closely to the IC, between the INTVCC pin and the power ground pins. This capacitor carries the MOSFET drivers' current peaks
- The filter capacitor between SENSE+ and SENSE– should be as close as possible to the IC. An example is shown in **Figure 8**

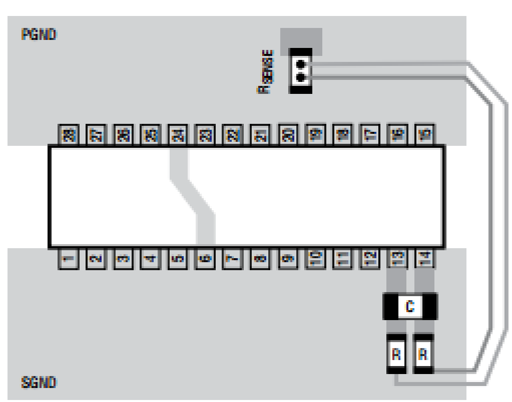

Figure 8: Suggested layout of Sense Lines [2]

Buck Converter

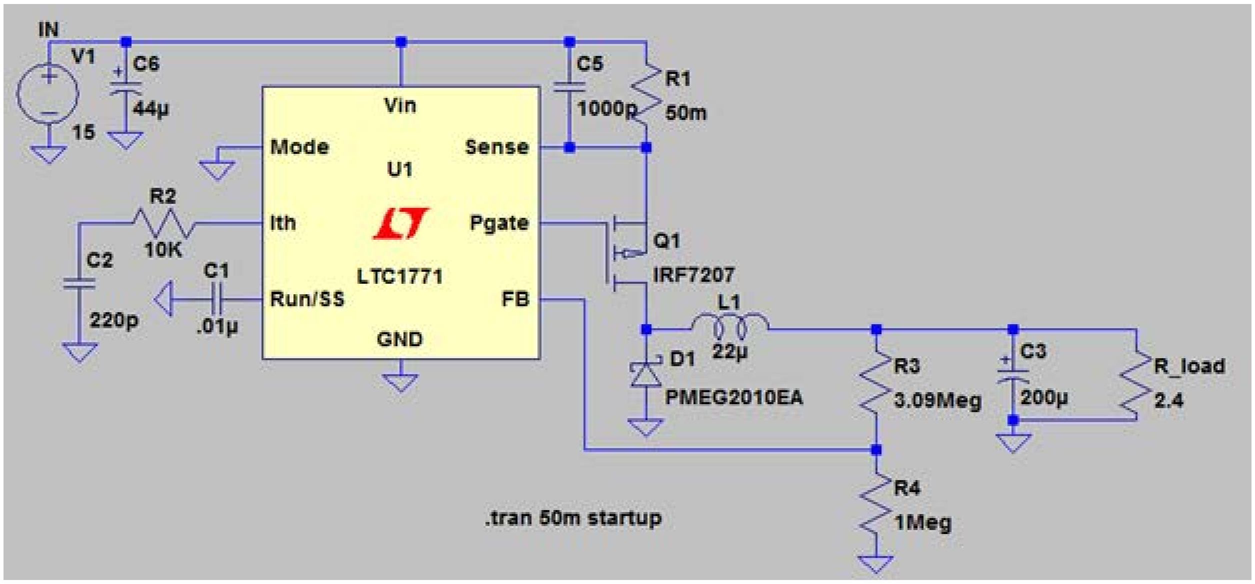

Figure 9: General Schematic for the LTC1771[3]

The LTC1771 chip is a high efficiency step-down DC/DC controller. The buck converter's purpose in the system is as the output stage from the battery to the USB. As seen in **Figure 9,** a general schematic was created using LTSpice of the Buck converter, which will be the output of the whole system. The basic design was borrowed from the datasheet of the LTC1771 [3]. In the top left corner of the figure is an ideal voltage source which represents the 14.8V battery. The voltage used was 15V as a close approximation of where the battery could be around full charge.

In a test case seen below in **Figure 10,** an input voltage of around 11V was used. The input is actually the voltage seen at the end of the input capacitors, so this explains the decaying waveform. With this signal going into the converter, the output was held at approximately 5V as was designed.

The output voltage was set to be 5 V. This voltage was chosen because cell phones and tablets require 5 V. To set this voltage, we chose the resistors in the resistor divider such that:

$$V_{OUT} = 1.23\left(1 + \frac{R2}{R1}\right)$$

Equation 4-2

For this, we chose R1 to be 1 Meg and R2 to be 3.09 Meg. These values were chosen to be so large in order to block any current to the feedback. Other values for the IC were chosen which match or were similar to the values provided in the datasheet for the LTC1771 [3].

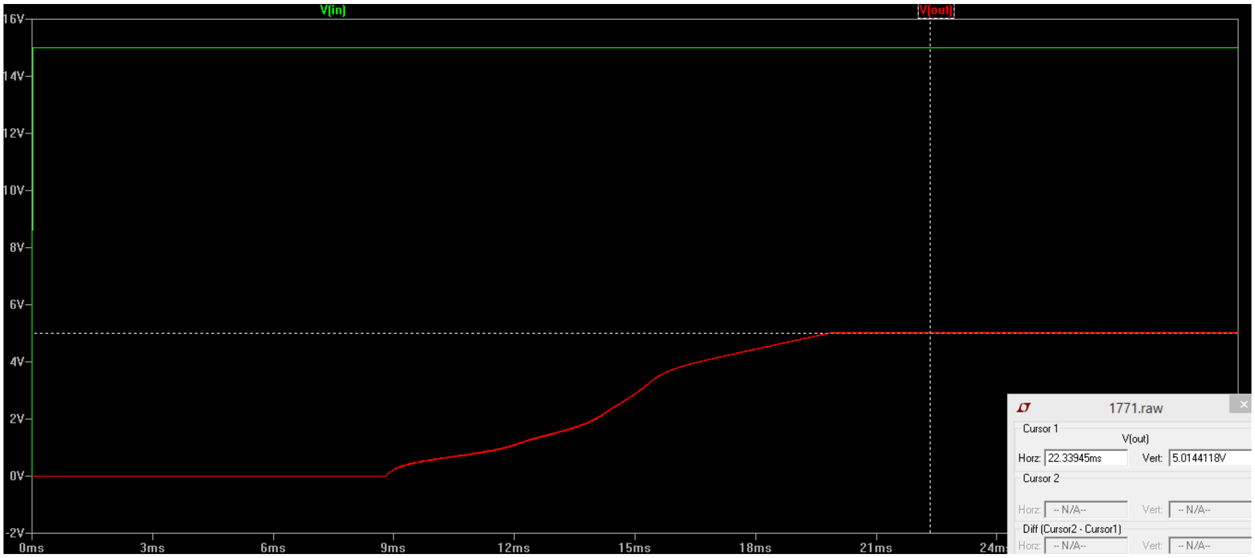

Figure 10: Simulation Waveforms, Buck Converter (Input = Green, Out = Red)

We simulated the circuit and probed the output to show that the output would result in 16.8V as shown in **Figure 10**. The input is the green curve, held at the 15V. The output is the red curve which should be at 5V and stay there as long as the converter is receiving its minimum input voltage of 2.8V

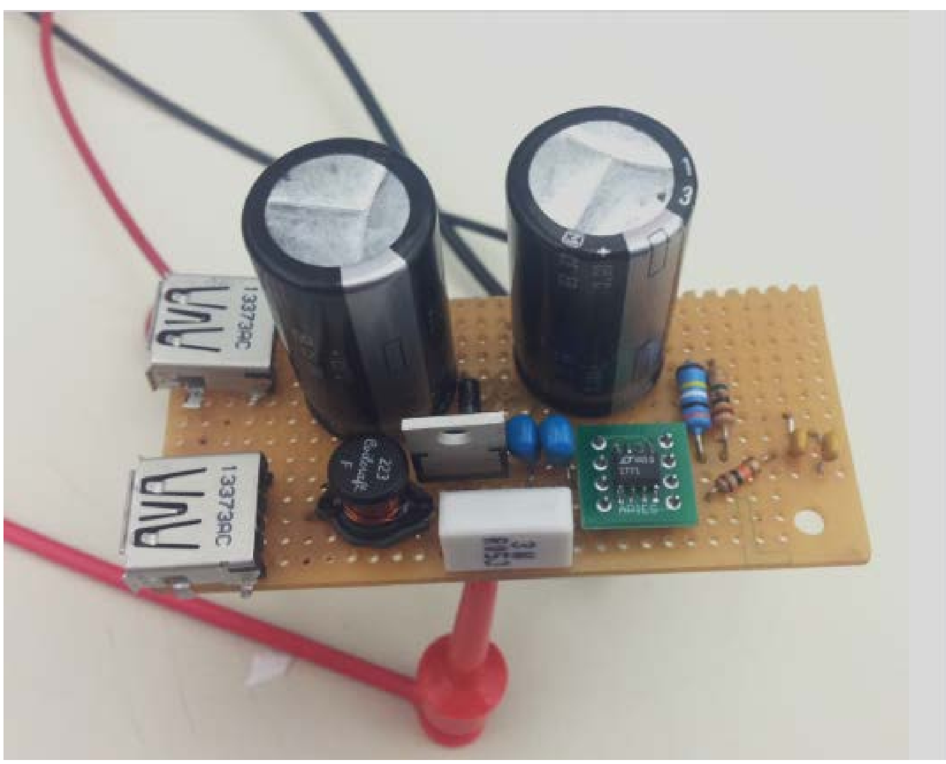

Figure 11: Buck Converter

Figure 11 above shows the final design for the Buck Converter. There are two USBs at the output; both can handle 1A of load current. Laying out the components for this wasn't too difficult overall. The only issue was fitting the giant output capacitors. However, this issue was minor and room was found.

The components on the right side are the control circuitry, setting output voltage and soft-start mode**.** The chip is the LTC1771 Buck converter, placed on a surface mount to through-hole adapter. The blue capacitors are the input capacitors in parallel. The large white block is the sense resistor, which monitors switch current. Then there are the inductor, the PMOS, and the diode (between the output capacitors) which are the power components, assisting in the "buck" action.

Motor/Propeller

The motor and propeller are necessary to the project because they will be supplying the power throughout the circuit and output 5V/1A or 5V/2.1A to the connected device. The motor had many requirements that would need to be met, as shown in **Table 5** below, to power the board.

Table 5: Motor Requirements [5]

Requirements (Motor)	Anaheim Automation BLY17S-24V-4000
Motor Type (Brushless DC)	Brushless DC Motor
RPM (1500 RPM - 4000 RPM)	4000 RPM
Rated Voltage (12V - 38V)	24 V
Rated Power (Motor > 30W)	53 W
Cost (Motor < $30)	$23.94
Rated Torque (Motor > 10 oz-in)	18 oz-in

The motor that we selected was manufactured by Anaheim Automation and is the BLY-172S-4000, as seen in **Figure 12** below [5]. The first requirement that would be required by the motor was that it would be a Brushless DC motor. The main reasons being that a brushless DC motor would be much more efficient than a brush DC motor and that they have much better tradeoff for speed and torque [4]. RPM of the motor was a factor that must be considered when selecting the motor. The reason is due to the fact that a much higher speed will ultimately lower the torque and output less. Having too low of a speed for the motor will result in a higher torque which would increase the output but would cause the starting torque required to start outputting a voltage to be much higher.

As a result we selected a motor with 4000 RPM which was somewhat on the higher end of the requirements [5]. This was so that it would be possible to meet the other requirements especially the cost. The 4000 RPM motor will require a large amount of torque in order to produce a higher output and with our source being wind it may be difficult to generate a higher rated voltage.

Figure 12: Anaheim Automation BLY-172S-4000

In correlation to the RPM, the rated voltage that would be required is between 4V to 38V. The buck/boost requires a minimum voltage of 4V and maximum voltage of 38V in order to function properly [2]. The motor we ended up selecting was rated for 24V which will ultimately be enough to power the buck/boost converter even if it never reaches the rated voltage due to the higher RPM that the motor has [5]. With our source of power being provided from the wind turbine, it all depends on the wind speed but with the higher RPM motor and 24 rated voltage would allow for a lower minimum wind speed to provide power to the Buck/Boost converter. The fourth requirement was the rated power that the motor would provide. Having a higher rated power would allow the circuit to increase the amount of current that would be able to flow within the circuit. The selected motor has a rated power of 53W, which should be capable of providing the circuit with enough current [5].

Being a project that is intended for fisherman of third world countries, the Zephyr Charge would require to have a relatively low cost and that would include the cost of the motor. Ultimately, the BLY172S motor that we selected had the lowest cost while also being capable of meeting all of our other requirements. While in search of the motor that we would select, we came across many motors that had a lower RPM and higher rated power which would have been better but ultimately were at a price point that were too expensive with most costing well over a couple hundred dollars. The BLY172S fortunately enough was able to be purchased for about $24 which was well below the $30 limit that we thought would be very difficult to find. The last requirement that was taken into account for the motor that would be selected was the rated torque. The rated torque is important for the motor and must function correctly while within the limits of the speed of the motor. The motor’s 18 oz-in was within range to work within what we expected of our motor [5].

Propeller

The propeller is another essential part of the Zephyr Charge. The propeller will serve as the mechanism that rotates the rotor of the motor thus allowing the motor to act as a generator and provide power throughout the rest of the circuit. The propeller had very few requirements that it had to meet. The most important requirement when selecting the propeller, was the diameter. The diameter of the propeller is important because its diameter and area determine the amount of power that it will be able to generate. The equation to calculate the power can be found below. The reason why this is important is because the circuit will require a minimum amount of power needed to run the circuit correctly. The second requirement when searching for the propeller is the material that is made from. The composition of the motor is important because the integrity of the propeller must remain the same even under very extreme wind speeds (up to 40 MPH). The third requirement when selecting the propeller was the weight. This requirement can conflict with the second requirement because a more durable propeller may result in a heavier propeller which may require a higher wind speed to start the rotation of the propeller. In the end, the propeller that was selected produced by Master Airscrew and was a 3-Blade 15”x7” propeller [6].

$$\text{Power}=12*\rho*A(\text{propeller})*v3(\text{wind speed})$$
$$\rho=\text{Air Density}=1.225\ \text{kg/m3}$$
$$A=\pi(r2)\ (r=7.5''=0.1905\text{m})$$

Equation 4-3

Figure 13: Propeller Chosen for the Zephyr Charge [6]

Table 6: Power generated by Propeller

Power	Power(50% Eff.)	0.5(ρ) (kg/m^3)	A (m/s)^2	v^3 (m/s)^3	MPH	m/s
0.00	0.00	0.6125	0.114	0.00	0	0.00
0.78	0.39	0.6125	0.114	11.17	5	2.24
6.24	3.12	0.6125	0.114	89.34	10	4.47
21.06	10.53	0.6125	0.114	301.52	15	6.71
49.91	24.95	0.6125	0.114	714.71	20	8.94
97.48	48.74	0.6125	0.114	1395.92	25	11.18
168.44	84.22	0.6125	0.114	2412.14	30	13.41
267.48	133.74	0.6125	0.114	3830.39	35	15.65
399.27	199.64	0.6125	0.114	5717.67	40	17.88

5. Demo / Test

Generator:

After designing / building everything, we began experimentally testing each stage, starting with the generator. **Figure 14** and the other figures below display the testing setup of the generator.

Figure 14: Testing setup for wind generator

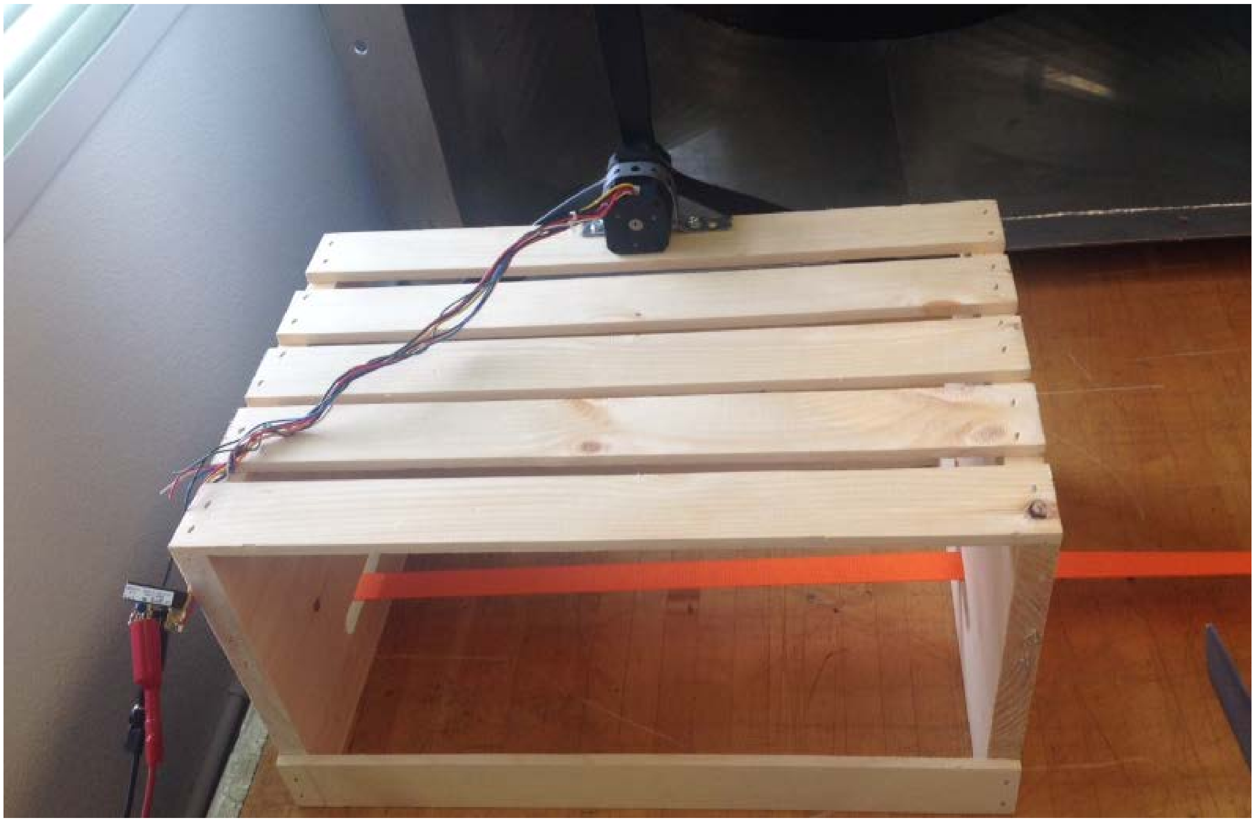

Figure 15: Rearview testing setup for wind generator

The generator was tested using a wind tunnel provided by Dr. Dolan. For extra support against the strong winds, it was screwed in with supports onto a wooden crate, which was then tied down with car straps onto the table. The wind tunnel was controlled using a digital interface, where magnitude of the wind speed was incremented using the control pad. The disadvantage of the wind tunnel is the wind speed displayed on the display was not accurate, so a handheld anemometer was used to measure the exact wind speeds. In addition, due to the physics of the tunnel, a uniform wind couldn't be produced, meaning that the center of the tunnel had a smaller wind velocity then toward the edges. To compensate for this, the generator was set up toward the left side of the tunnel as to apply the most uniform wind as possible to the propeller.

Figure 16: Front view testing setup for the generator

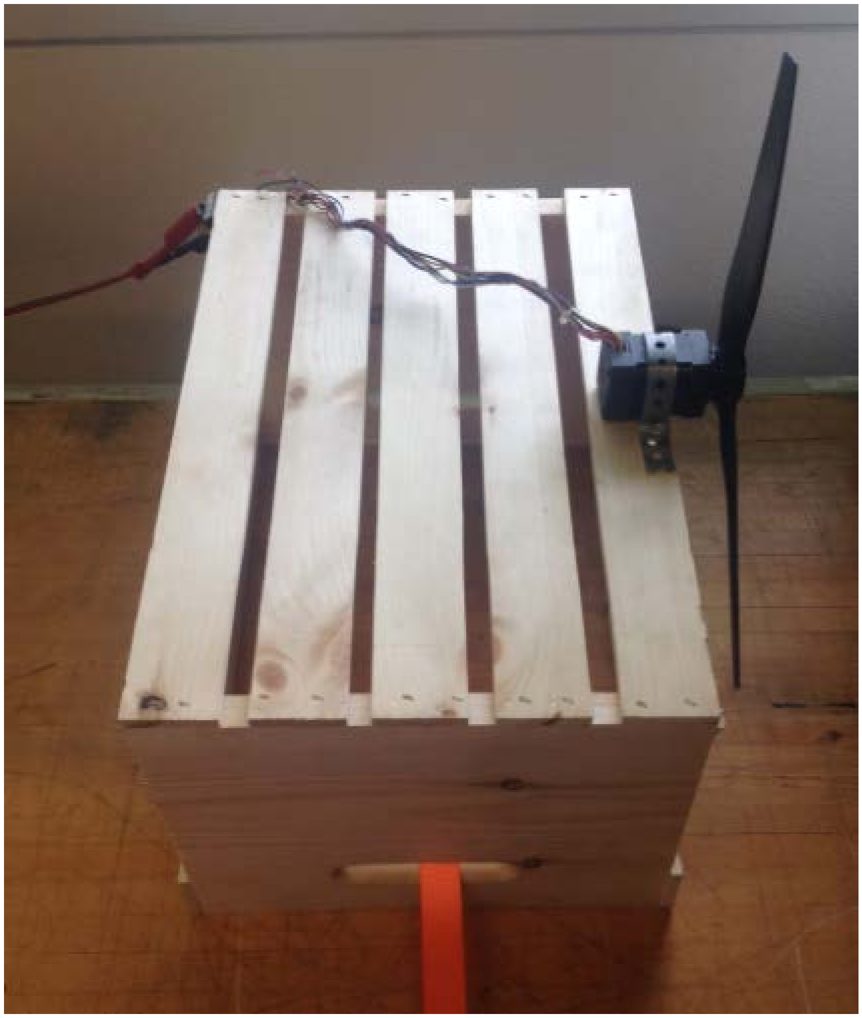

Figure 17: Side Profile testing setup for the wind generator

For this, we began testing with open circuit conditions. This was done with no load on the output of the generator, just measuring the voltage using a voltmeter. Wind speeds were applied and the voltage generated was recorded and can be seen in **Table 7.**

Table 7: Open Circuit Voltage vs Wind Speed

Wind Speed (MPH)	13	15	17	19	21	23	25	27	32
Voltage (V)	0.96	2.55	3.5	4.66	5.03	5.75	6.6	7.2	9.1

Buck Converter:

The buck converter was tested using an electronic load at the output, while connected to a power supply acting as the input. The load was increased in increments of 100mA and the output voltage at each load was recorded. From this, the load regulation could be found. This is an important characteristic since it shows how the output voltage changes when different loads are applied to it. These results can be seen in **Table 8** below.

Table 8: Output voltages for the Buck Converter

Load (A)	Voltage (V)
0	5.04
0.1	5.03
0.2	5.02
0.3	4.99
0.4	4.97
0.5	4.96
0.6	4.96
0.7	4.95
0.8	4.95
0.9	4.95
1	4.94
1.2	4.94
1.4	4.93
1.6	4.93
1.8	4.92
2	4.92
2.1	4.91

Using these results, the load regulation was found using the equation below. The Load Regulation is **2.4%,** which is under our 5% requirement we set in the beginning.

$$\text{Load Regulation (\%)} = 100\% \times (V_{No\text{-}load} - V_{Full\text{-}load}) / V_{nom\text{-}load}$$

Equation 5-1

Also, the line regulation is another characteristic of our converter that needs to be found. Knowing that line regulation is the amount the output voltage changes when the input voltage is varied. This is important to know because it informs the user about how much the input can change and still have a usable output. The equation used for the line regulation equation used can be seen below. **Table 9** shows how the output voltage changes with input voltage.

$$\text{Line Regulation (\%)} = \Delta Vout/\Delta Vin = 100\% \times (V_{out\text{-}high} - V_{out\text{-}low}) / \Delta Vin$$

Equation 5-2

Table 9: Output Voltage vs Input Voltage

Vin at Load:	**Vout**	
	1.00	**2.1A**
10	**5.02**	**5**
15	**4.94**	**4.92**
16.8	**4.93**	**4.91**

Using these results, the Line Regulation was calculated to be **1.3%.** This calculated value falls under our 3% requirement.

6. Future Research/Work:

Unfortunately for our group, time became an issue and we were unable to fully complete this project. With the Buck-Boost not working, the project as a whole could not be completed. So for future references, it is advised that the Buck-Boost be initially implemented on a PCB, both to limit noise / interference from long leads and to provide a PCB-style heat sink as a copper layer of the board. Also, completing this converter earlier in the year would allow for more time to be spent on testing, fine tuning, and packaging the whole project,

An additional thought on this project is when charging a battery from completely dead, the voltage on the output of the Buck-Boost shouldn’t be near the nominal level of the battery. If the output of the converter is 15V and the battery is at 0 V, the torque applied to the generator will be much greater than it can handle due to the high change in voltage. A solution to this would be including a potentiometer for the top of the resistor divider in the converter. This would allow a manual control over the charging voltage. However, this would have to include the user also monitoring the battery voltage levels. Ideally, the adjustable resistance would be controlled by a feedback system that monitors the battery levels.

7. Conclusion:

Over the course of this project, we planned out, simulated, and then attempted to build a wind-powered USB charger. Time was spent researching the market of wind-powered generators, including the market and customer needs, the competition already established, and determining how our team could get into this particular industry. For the first few months, time was spent in spice running simulations of each converter in order to determine the proper values required for the project. The bulk of the time was spent on the Buck-Boost converter, which was considered the central component to this whole project. It was also the most complicated piece of the project so it took the longest time in spice to simulate, taking about 15 minutes to simulate a full cycle.

The Buck-Boost converter was considered the important component of the project because it was the middle man between the generator and the battery/buck converter output. It was the joiner between the input and output stages, that handled the variety of input voltages that the generator could supply, yet hold the voltage the output stage requires. Unfortunately, after 3 attempts of implementation, on breadboard, on a prototyping board, and finally on a PCB, the Buck-Boost could not be made to work. So the project changed its focus on demonstrating the ability of the generator, as well as showcasing how the buck converter worked as the output.

The generator was built and was demonstrated as producing the required voltages. While the wind speed to produce the required voltage was a lot higher than originally planned, it would still be able to power the Buck-Boost. Also, the buck converter was showcased as properly working. The battery voltage of 15V was applied to the Buck's input, which produced the 5 V at the output required by most USB chargers. Even when a load was drawn from the converter, the voltage remained within acceptable conditions.

Overall, the knowledge and understanding gained in this senior project benefitted both members greatly. This project gave us great experience at dealing with power electronics, both in simulation and in practice. Building the generator and testing it were pleasant experiences as well, especially when utilizing the wind tunnel. This project also made us research more than we ever had in our college classes, which was a great experience for us for our future careers. Given the opportunity, we would recommend future senior students interested in electronics and sustainability to take on this concept as a senior project, and hopefully generate better results.

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Appendix

Marketing

Research:

The market leader for this product seems to be Kinesis Industries with their product: the K3 Wind and Solar Phone Charger. It took quite some time to find products that would be comparable to the product that our group hopes to complete by the school year's end. As listed in **Table 10**, the K3 Wind and Solar Phone Charger seem to be a popular item that is sold in many retail marketplaces such as Sears and Amazon.

Table 10: Competitor Product List

Company	Product	Cost	Note
Kinesis Industries	K3 Wind and Solar Phone Charger	$16.99-$65.97	Market leader
Hymini	Hymini Basic Package	$49.99+	Product Discontinued
Trinity	The Portable Wind Turbine Power Station	N/A	Still in development

The market for Wind Powered Phone Chargers is very limited and there are very few competitors that offer a phone charger that is powered only with a wind turbine and wall charger. While researching for current products it was difficult to find products that were being sold in the retail market. For example, the Trinity charger is a Kickstarter product which has had the popularity to fund the product but it is not set to go into production until 2015. The Hymini was a popular product that was used mainly for bike riders but has since been discontinued from the market. It can still be found for sale on second hand sites like eBay but no longer available from the manufacturer's site. The only real competition at this point in time will be Kinesis Industries which has produced the K3 Wind and Solar Phone Charger. While the product also includes a solar panel to also charge the device, it is the most comparable product that is currently in the market to the Zephyr Charge.

The weakness in the market is where the Zephyr Charge plans to excel in; a lasting wind turbine durable enough to survive winds above 20 mph. Therefore the area of the market that is not well served is definitely areas and locations that have high wind speed especially for fishermen out at sea. The Zephyr Charge can make it possible for fishermen to charge their cell phones at wind speeds up to 40 mph, which is 20 mph more than any of the other competitors such as the Trinity charger which can handle a max speed of 17 mph. At a max speed of 40 mph, the Zephyr Charge could also serve customers that ride bicycles or are in locations such as the cities in the Midwest, which have an annual average wind speed of up to 24 mph.

The key area of strength that our product will bring to the market is the durability and size of the wind turbine that we plan on including in the project. As mentioned earlier, the competition includes a wind turbine that is capable of utilizing wind speeds of up to 20 mph. The Zephyr Charge will be capable of wind speeds up to 40 mph which will be much more manageable for consumers at sea.The reason that the Zephyr Charge will meet the consumers need with a max survival wind speed of 40 mph is due to our intended consumers which are fisherman of third world countries. Since our intended consumer is fisherman of third world countries we expect them to have boats that are equipped with very small motors (<25 hp). From an experiment conducted by boattest.com to test a 25 hp motor, the findings revealed the boat's max speed in one experiment was listed as 28.1 mph while the second experiment listed the boat's max speed as being 31.6 mph. We anticipate that the average third world fisherman will have a motor much smaller than 25 hp and based on the results from the experiments, the maximum survival wind speed of 40 mph will be more than sufficient.

Marketing/ Customer Needs

- The device must be compact (12"x2"x2" not including turbine blades)
- The device must be cheap and affordable (Manufacturing cost <$25)
- The device must be capable of wind speeds up to 40 mph
- The device must have output of 5V/ 1A and 5V/ 2.1A
- The device must be able to provide 4-6 charges of phones based on a full charge
- The device must be durable against high wind speeds (30-40 mph)
- The device should also be able to draw power from a wall outlet

ABET Analysis

Project Title: Zephyr Charge
Students: James Carson and John Lopez
Advisor: Dr. Nafisi

1. Summary of Functional Requirements

The functional requirement of the Zephyr Charger is to produce an output of 5V/ 1A or 5V/ 2.1A to charge a cell phone. The device must also be portable and light-weight in order to fit on a small boat for our intended consumer which is fishermen. The battery that we include in the product must be able to provide up to 4-6 full charges for the cell phone so we believe that we must get a battery that has an electric charge of 12500 mA*Hrs. The product must also utilize materials and costs that are relatively cheap but efficient to meet our efficiency of 75% while keeping the cost of the product below $60. The last important requirement is that the wind turbine must be the primary source of power and so must be able to charge a phone.

2. Primary Constraints

The primary constraint of the Zephyr Charge is the cost to produce the product. It is our goal to produce a product that will cost the consumer less than $60 while also trying to make a profit. The next obstacle and possible constraint of the Zephyr Charge can be the wind that powers the product. Since the product depends on the wind speed and more wind speed equals more power it would be our hope that the product receives the amount of power needed to charge the device. But the wind speed is a natural phenomenon and can vary in different locations.

3. Economic

The Zephyr Charge is meant to be a low-cost product to help fishermen have a means of charging their phone in case of emergency. Thus the materials used to produce the product are meant to also be low cost. The only possible economic problems may come from manufacturing which can create problems of pollution which can then create a problem that must be solved. The other possible problem of pollution can come from harmful disposal of the product especially the battery which can cause a problem that must be solved with money.

4. If Manufactured on a Commercial Basis

If the Zephyr Charge is manufactured on a commercial basis it could help reduce the cost of the product tremendously in order help sell our product to our intended market. The largest cost of the product will be the wind turbine / motor. If manufactured on a commercial basis and with the help of a distributor that will decrease the cost of materials would also help us profit more.

5. Environmental

The Zephyr Charge as a product itself will have a positive effect on the environment as long as the consumers utilize the product correctly. The Zephyr Charge is a Wind-Powered Cell Phone Charger meaning that the source of power is coming from a renewable and sustainable resource in this case the wind. The use of wind to power the cell phone utilizes no resources that can be depleted. The one environmental downside is the manufacturing of the product depending on the materials that are used. The reason for this being is the possible ill-effects of materials biodegrading over a long period of time. It can be a minimal effect as long as we can utilize products that can biodegrade easily in the environment and are not toxic.

6. Manufacturability

The manufacturing of this product will definitely need to be produced on a large scale basis in order to meet the $60 cost. We have found a wind turbine with motor that will eat away at most of our cost and so we must try to build a relationship with the distributor to lower that cost. Another key aspect to manufacturability is getting funded by a sponsor. With enough capital we can purchase more products thus possibly reducing the cost of the product or at least funding the cost of the project.

7. Sustainability

The Zephyr Charge is a sustainable product that has relative minimal maintenance needed. The device is run on wind power which is a naturally occurring phenomenon and so the consumer does not need to input any source of energy to charge the mobile device. The device can be rated at a voltage of 5V and 1/ 2.1 A and so as long as the device is kept in a secure place and is provided with some care, the device should run efficiently and effectively. The other source of sustainability that could be affected is if the product uses battery which is to be determined. If one is used then the battery can pose some sustainability issues especially with the disposal of the product and the manufacturing of the product.

8. Ethical

The Zephyr Charge overall is meant to have a positive effect on not only the consumers but also with the environment by implementing a renewable and sustainable resource: wind. But with any product no matter the expected positive effects comes some negative and possible ethical issues. The IEEE Code of Ethics has 10 ethical statements in order to agree “in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct”.

Of the 10 IEEE Code of Ethics, two stick out the most as ethical problems that could possibly affect the manufacturing and use of our project. These two are listed below:

I. “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment” (IEEE Code of Ethics #1)

II. “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others” (IEEE Code of Ethics # 7)

The first IEEE code that is listed above is important to our project because the manufacturing and materials that we use can impact the public and/or environment and so it is our duty to try to limit any unsafe and harmful practices and materials. If any ill effect comes of the product then it will be our duty to inform the public and look for solutions to decrease that ill effect. The second IEEE code is important to our project especially in the infancy. We must ask and accept any criticism for our work for example our teachers and advisors in order to create the best possible product that is possible.

9. Health and Safety

The Zephyr Charge is meant to be a sustainable and renewable energy source for cell phones and so the device should have no health and safety issues. Its overall goal is to try to help the user in case a phone may be needed to call for help. The device may have some safety issues if not properly maintained such as electrical shock. The main issue of concern for health and safety can be seen in the manufacturing of the product depending on the materials used to produce the Zephyr charge and also from the battery that is used which may contain harmful toxins. The disposal of the battery can be another health and safety issue to take into account.

10. Social and Political

The largest social and political impact of the device comes from the manufacturing of the Zephyr Charge. The reason is due to the location and production of the materials and packaging of the product. The purpose of the Zephyr Charge is mainly to allow fisherman in third world countries to have access to a cheap and reliable means of charging of their phone while out at sea. This goal of producing a low cost product could create a social problem of utilizing manufacturing and materials outside of the U.S. The use of products outside the U.S. may help produce cost effective products for our main intended consumers but may also negatively affect possible employees and companies within the U.S.

11. Development

The development of the Zephyr Charge will mostly deal with the manufacturing of the product. The only coding that will be used for the project is LTSpice and PSpice in order to simulate the expected outputs and values. Another key aspect to the project will be determining the correct values for certain circuitry such as capacitor or resistance values.