

Electricity Harvesting Laundry Bat

By

Henry Haesung Ahn & Steve Hyounmin Wang

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TA: Zitao Liao

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Abstract

For this project, we explored power generation and power delivery to help people in the 3rd developing nations to have free electricity. This project is largely composed of 3 sections of mechanic, magnetic and electronic. Each of them has distinct characteristics. In this paper, we will address those components in the specific order of mechanic, magnetic and electronic. The reason is unlike other projects, our project has specific mechanical restraints which limit functionality of magnetic and electronic parts. The goal of this project is crystal clear: harvesting and charging. To implement this project, we used fundamental knowledge we learned throughout the college from physics(phy211) and electromagnetic(ece329) to electronic(ece342 & 343). Combining all those knowledge, we had to find the optimal, not the maximal design to yield most desirable outcomes.

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I. Introduction

1. Statement of Purpose

Throughout 4 years of college, we always have wondered ‘how much knowledge we have learned in electrical engineering can we actually use’. We have went through at least four physics courses, three mathematics and so many electrical & computer engineering courses. It is good that we managed to went through them all. Yet, we believe as future engineer in the industry, we should not be complacent on knowledge itself. Therefore, we are very glad that this course of ece445 provides us the chance to go through what we have learned and applied those knowledge on solving real world challenge.

One of the challenge we chose to solve is the lack of electricity in developing nations. Among many factors which distinguish developed nations from developing nations, the crucial one is electricity. Look at the satellite picture taken at night. While all developed nations are covered with bright light, developing nations are covered with silent darkness. Therefore, the goal of our project is providing ‘electricity’ to people in developing nations.

To do so, we have focused on their everyday activities; how can we generate electricity from their routine everyday motion? And, we thought of laundry bat. People in developing nations could not afford to buy expensive laundry machine. Even still nowadays, people in 3rd developing countries go out on lake and swing their washing bat for laundry. Since hours and power of people doing laundry are formidable, we thought it would be good idea to convert those times and power into electricity. Therefore, our project is called, “Electricity Harvesting Laundry Bat”, and comprehensive knowledge of mechanic, magnetic and electronic are used.

2. Objectives

2.1 Goals

The purpose of this project is to develop ‘electricity harvesting laundry bat’ in order to provide electricity to people in 3rd developing nations.

2.2 Benefits

Whenever people go back to their house after 4 ~ 6 hours of arduous laundry, they can use the charged battery right away for the various purposes from cooking to just lighting up.

2.3 Functions

Every time people smash their laundry bats on clothe, vibration energy oscillates magnets attached on spring inside of the bat. This oscillation enables magnet to go inside and out of the center of copper wire. By Farady’s law, this motion harvests electricity. Then, electricity is converted DC

signal and stored in battery. After people come back to their home, they can separate battery from laundry bat and use it various purposes.

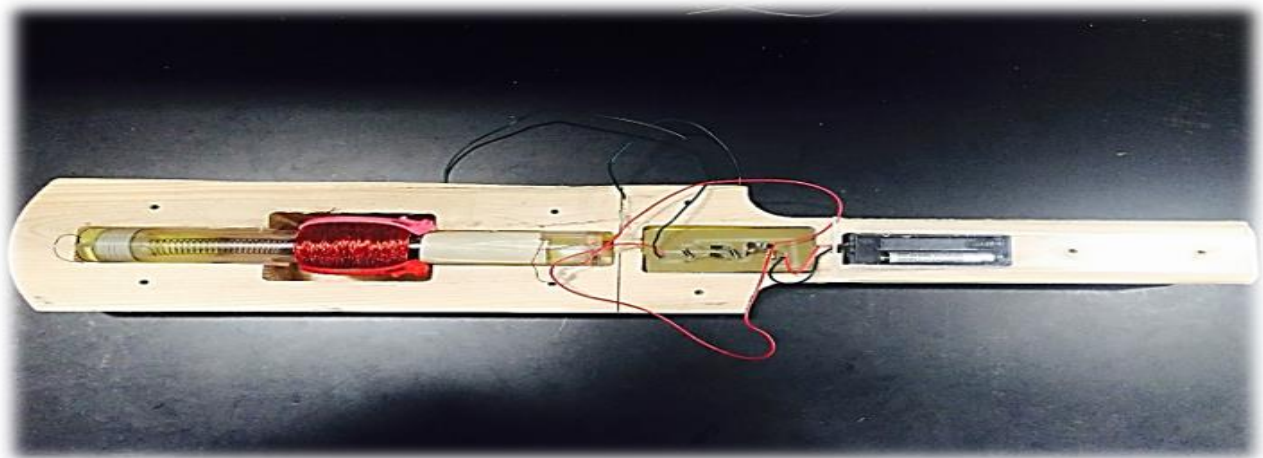
2.4 Feature

- Balanced design for the maximized stability
- Rechargeable battery for everyday usage
- Strong enough to prevent the electronic compounds to be secured from constantly created vibration energy
- Handy to use

II. Design

1. Overall

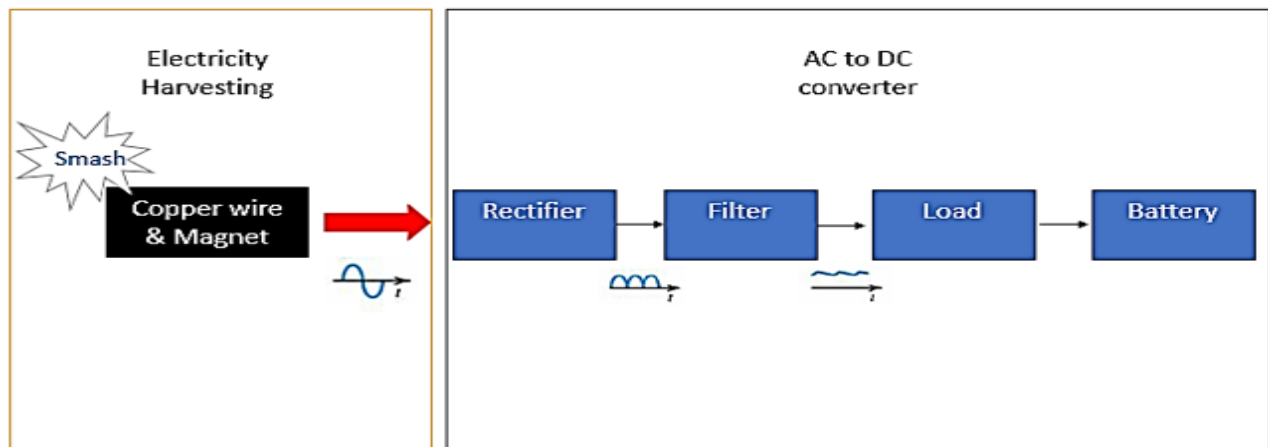
The following picture below is our overall design. As one can see, all components are placed inside of wooden bat. Left component is the magnetic generator. The middle component is called AC to DC converter. The last part is battery.



(Figure 1. Overall Design)

2. System Diagram

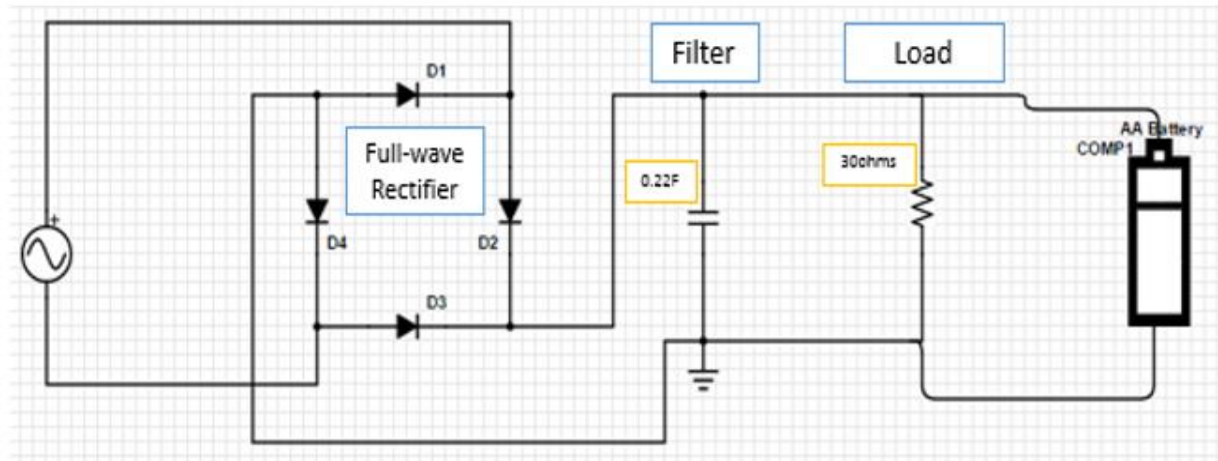
The following diagram below is our overall System diagram. As one can see, the system is largely divided into two groups of generation and conversion. EMF voltage created on the first group of the system is AC signal. This signal passes through the second part of AC to DC converter and charges the battery.



(Figure 2. Block Diagram)

3. System Schematic

The system schematic version of the above diagram can be described in following below. The detailed explanation of functionality of each parts will be discussed later.



(Figure 3. System Schematic)

4. Block Descriptions

4.1 Copper wire

Thin copper wire is used to construct solenoid shape cylinder with 500 numbers of wiring. This solenoid generates induced current when magnet is coming in and out of its center. The radius of copper solenoid is made in 1.15 cm.

4.2 Neodymium N42 Magnet

Very powerful magnet is used here. It is called 'Neodymium N42'. It is strongest rare earth type magnet whose magnetic field is usually 10 to 100 times stronger than normal one. Indeed, its magnetic field is 13,200 Gauss or 1.32T. Size is $\frac{3}{4}$ diameter and the weight is 0.0514kg. As this magnet goes in and out of copper solenoid, by Faraday and Lenz's law, current is induced. This current is the product of the electricity harvesting from kinetic force.

4.3 AC to DC converter

In order to store the AC signal from the first part into battery, it must be converted into DC signal. The goal of this part is to convert the induced AC signal to DC. This part is made of rectifier, filter and battery.

4.4 Full wave Rectifier

As magnet moves in and out of copper solenoid, induced current constantly changes its direction. Therefore, it is the job of rectifier to rectify bi-directional electric signal to uni-direction. 4 identical D1N4001 diodes were used.

4.5 Filter

Signal after rectifier shapes like upward bumpy hill. This is not good for charging the battery. Therefore, filter is placed after rectifier to smooth out the bumpy DC signal. 0.22 F of super capacitor was used.

4.6 Load

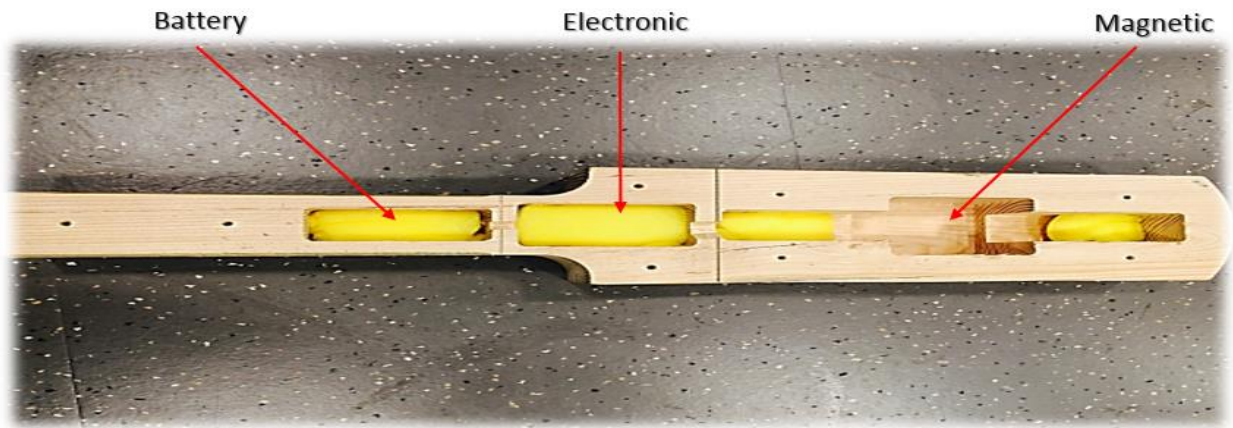
30 Ω of resistor was added in order to demonstrate our project meets to the specification of the battery. By doing so, we showed output voltage is 1.4 V, which is slightly greater than 1.2 V of battery specification. Also, 47 mA of current was formed of which the value is very close to 50 mA of the battery charging specification.

4.7 NiMH Battery

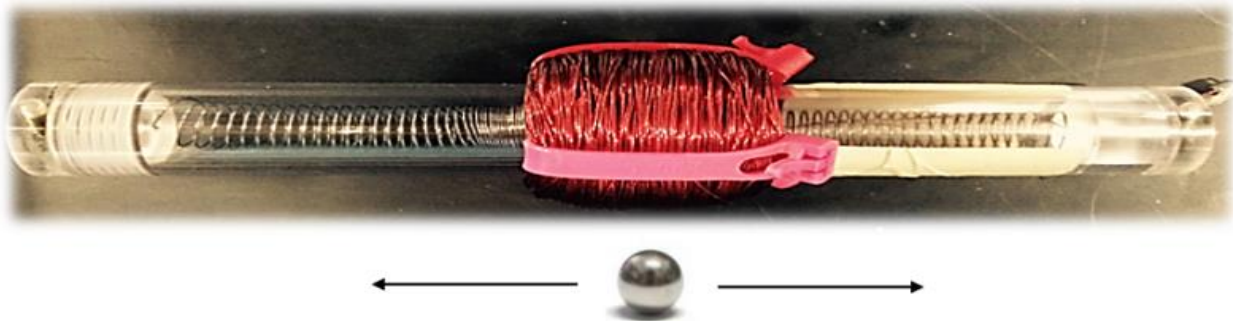
This is Nickel-metal hydride battery. Its operating voltage is 1.2 V, the ultimate voltage target of this project. In other words, whatever comes after filter should be little higher than 1.2 V in order to efficiently charge the battery. Also, the charging criteria for this battery is 50 mA for 14 hours.

III. Mechanic

As one can see from the picture below, all components are buried inside of the bat. Therefore, characteristics of the bat, such as weight and length definitely affect overall functionality of the project.



(Figure 4. Wooden Bat)



(Figure 5. Spring and Magnet Tube)

For this reason, unlike other projects, mechanical design comes as priority in ours. One good example which shows how mechanical design affects project functionality is usage of specific spring constant. Depending on spring constant, oscillation frequency is changed. And, since inverse of frequency is time period, this value directly influences electromotive value at the end.

Before jumping into mathematical elaboration, we want to go over why we decided to use spring rather than any other methods. One of many challenges we had during the project was maintaining constant frequency, because battery, the ultimate goal of our project, requires constantly inflowing current. If delivery of current varies from time to time, due to change of frequency, the battery will not be charged. Indeed, the mathematical interpretation below clearly shows the relationship between energy and frequency.

$$E = \int P(w, t)dt = \int V(w, t)I(w, t)dt \quad (3)-1$$

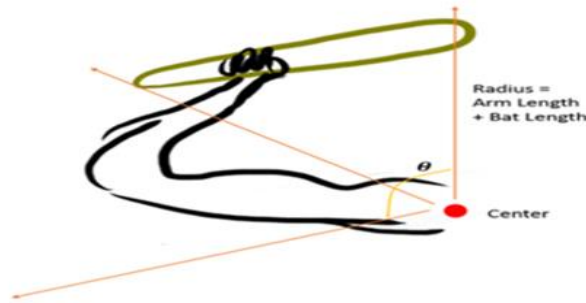
$I(t) = I^* \sin(wt + \phi)$: current is in constant frequency of w

Therefore, electricity being harvested from human motion of bat smashing must yield constant frequency. However, unfortunately, human motion is such as random it can never be maintained in constant frequency. To compensate, we decided to use the spring in order achieve the constant frequency. This harmonic oscillation equation indicates that even though human motion can be random, spring oscillation frequency is fixed by spring constant and mass of magnet.

$$F = \frac{1}{2\pi} \sqrt{\frac{K}{M}} \quad K = \text{Spring Constant, } M = \text{mass of magnet} \quad (3)-2$$

Based on the above justification, we can now jump into the actual mathematic calculation. Yet, there is one more mechanical restraint to think of. As people swing their bats, great amount of kinetic energy is formed. This kinetic energy may seem to be transferred into spring and magnet inside, causing high amplitude of spring oscillation. This idea may lead to the conclusion of increasing the mass of bat in order to intensify more kinetic energy to generate.

However, this is not true. Since both bat and magnet inside are traveling along with the same speed, we have to separate the force delivered to the magnet and force delivered to the bat.



(Figure 6. Physical Description of swinging bat)

$$\text{Kinetic Energy} = \frac{1}{2}mv^2 \quad (3)-3$$

$$\text{Velocity} = 2\pi R * \frac{120^\circ}{360^\circ} \quad (3)-4$$

This picture illustrates why we decided to use the angle of 120; pretending the actual laundry bat smashing motion, the average angle of bat traveling generally forms 120 degree. And, the radius in this scenario becomes the sum of length of arm and bat.

$$R = \text{Arm Length} + \text{Bat Length} = 0.80 \text{ m} + 0.5 \text{ m} = 1.3 \text{ m} \quad (3)-5$$

Here, the time it takes for the bat to land on the ground is 0.2s. And, the mass of neodymium N42 ¾ diameter ball shaped magnet weight is 0.0514kg. Of course, the center of mass is not at the red-dotted center, but rather it lies on the center point of total length of arm and bat. Rigorously, this yields less force applied. However, we also know that people are not swinging their bat while their arms being stretched. Arm will sometimes be bent and stretched so that the center of mass moves the exact location constantly. Therefore, we decided use the end point as the reference point. This

may not yield the exact value, but very close approximation value. Now, we are all equipped with all information for the calculation.

$$\text{Kinetic energy} = \frac{1}{2}mv^2 = \frac{1}{2} * 0.0514\text{kg} * \left(\frac{1.3\text{m} * 2\pi * \frac{1}{3}}{0.2\text{s}}\right)^2 = 4.76 \text{ J} \quad (3)-6$$

$$\text{Since Energy} = \int_{x_1}^{x_2} \text{Force } dx, \text{ Force(Newton)} = \frac{\text{Energy(Joule)}}{\text{distance}} \quad (3)-7$$

$$\text{Force by Kinetic energy} = \frac{4.76\text{J}}{1.3\text{m} * 2\pi * \frac{1}{3}} = 1.75 \text{ N}$$

$$\text{By Hooke's Law of } Kx = F = 1.75 \text{ N}, K = \frac{1.75\text{N}}{x} \quad (3)-8$$

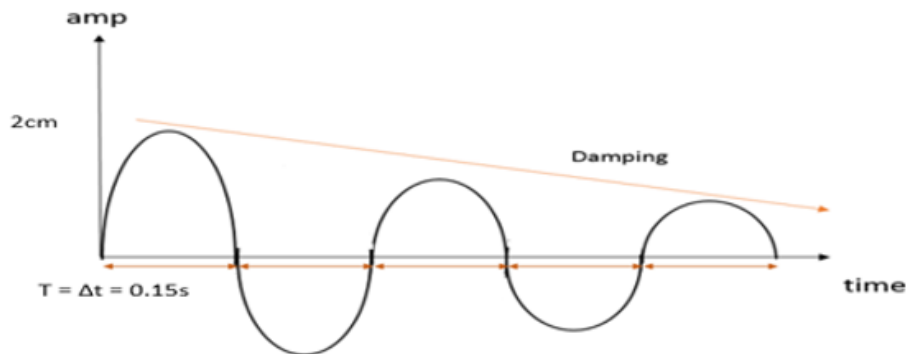
$$\text{Then, } K = \frac{1.75 \text{ N}}{20\text{mm}} = \mathbf{0.088 \frac{N}{mm}}$$

Here, we want the amplitude of magnet oscillation to be 2 cm. The reason we chose 2 cm to be the oscillation distance is because this distance is the optimal point where we can simultaneously achieve high emf voltage and durability of spring. If we use high spring constant, then, frequency may go up, but since oscillation distance decreases, emf voltage indeed drops. On the other hand, if we reduce spring constant, the magnet travels further distance, but because frequency is decreased, emf voltage is also dropped. Also, low spring constant leads to easy worn out of spring. Throughout the experiments, we saw how weak spring could be destroyed based on continual movement by force. Therefore, experimentally, we figured out 2 cm of magnet oscillation was the optimal.

Ultimately, the harmonic oscillation frequency can be found.

$$F = \frac{1}{2\pi} \sqrt{\frac{K}{M}} = \frac{1}{2\pi} \sqrt{\frac{0.088\text{N/mm}}{0.0514\text{kg}}} = \mathbf{6.58 \text{ Hz}} \quad (3)-9$$

This calculated frequency can be interpreted as the speed of spring oscillation through the center of the copper solenoid. This being said, the time the magnet to reach the end of copper solenoid and come back to the original position is period: $\frac{1}{\text{frequency}} = \mathbf{0.15 \text{ s}}$.



Therefore, it is clear that through harmonic oscillation, we achieved yielding constant frequency.

IV. Magnetic

At the previous section, we formed the system of yielding constant frequency and set up few mechanical restraint for the practical purposes. In this section, we are going to elaborate how mechanical energy is being transferred into electrical energy.

The idea of harvesting electrical energy from oscillating magnet is simple: Faraday's induction law. As we learned this material at ece329, Faraday's induction law indicates electromagnetic induction: falling magnet induces a current within the copper solenoid. By Lenz's Law, current creates a magnetic field that opposes the field of the falling magnet¹.

The above claim also tells the direction of magnet moving is vital in determining the direction of voltage flow. If magnet is falling into the center of copper solenoid, the magnetic force (pointing downward) near the solenoid is strengthened. To oppose this change, by Lenz's law, current is induced in counter clockwise direction so that magnetic force pointing upward is formed.

On the other hand, let assume the magnet reaches the end of copper wire and it is ready to go back to the original position. This movement is going up to the center of copper solenoid. Then, the magnetic field pointing upward will be strengthened. To oppose this change, by Lenz's law, the current is induced in clockwise direction so that magnetic force pointing downward is created.

Therefore, it is clear that oscillation of magnet through the copper solenoid is harvesting electricity in two different directions. One may wonder how to compensate this bidirectional movement of electricity. The answer is using rectifier and this matter will be discussed in the later section of electronic.

Since now we are fully aware of the nature of Faraday induction and Lenz's Law, we can now jump into the mathematical calculation to find out exactly how much electricity (voltage) is being harvested through the process.

According to Faraday's Law, $\text{Emf}(\text{electro motive force}) = N * \frac{d\phi}{dt}$. Of course, there is minus sign in front, but let us skip this since the voltage is in bidirectional.

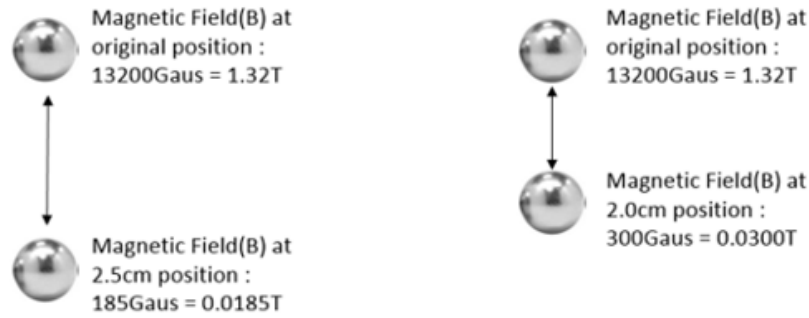
By the definition of magnetic flux, $\phi = \int B \, ds$. Since the integral indicates the integral of magnetic field B over closed loop, this can be interpreted as the magnetic field over the certain area. And that certain area is the area of our copper solenoid: $d\phi = dBA$

Here, we can not accurately estimate the 'instantaneous change' of magnetic flux over the given time. Yet, we can borrow the parameter calculated at the mechanical section: $\Delta t = 0.15\text{s}$.

Δt is the time it takes for the magnet to hit the end and come back to the original position. Then, if we are able to find out the difference in magnetic flux at the original position and the end, we can find $\Delta\text{magnetic flux}$ as the equation following below.

¹ ECE 329 Lecture Note, Lecture 14, page 1-4, Professor Erhan Kudeki

$$\frac{d\phi}{dt} = A \frac{\Delta B}{\Delta t} \quad (4)-1$$



(Figure 8. Magnetic Field Strength on different position)

According to the data we acquired from ‘K&J Magnetics, Inc’, magnetic field strength of N42 Neodymium(world’s strongest rare earth magnet) is 1.32T. And, this magnetic strength decreases rapidly away from the origin. Based on the information provided, for example, at 2.5 cm, magnetic field is dropped to 185 Gauss which is 0.0185T. Magnetic field strength at the targeted position 2.0cm is 300 Gauss or 0.0300T.

From this information, we can approximate the emf voltage.

$$\text{Emf}(2.5 \text{ cm}) = NA * \frac{\Delta B}{\Delta t} = 500 * 1.15 \text{ cm} * 1.15 \text{ cm} * 2\pi * \frac{1.3015 \text{ T}}{0.15 \text{ s}} = 3.6 \text{ V} \quad (4)-2$$

$$\text{Emf}(2.0 \text{ cm}) = 500 * 1.15 \text{ cm} * 1.15 \text{ cm} * 2\pi * \frac{1.29 \text{ T}}{0.15 \text{ s}} = 3.57 \text{ V} \quad (4)-3$$

Distance(cm)	Gauss(G)	EMF(v)
2.50	185	3.60
2.00	300	3.57
1.90	328	3.56
1.60	457	3.52
1.30	665	3.47
1.00	1022	3.37
0.70	1685	3.20

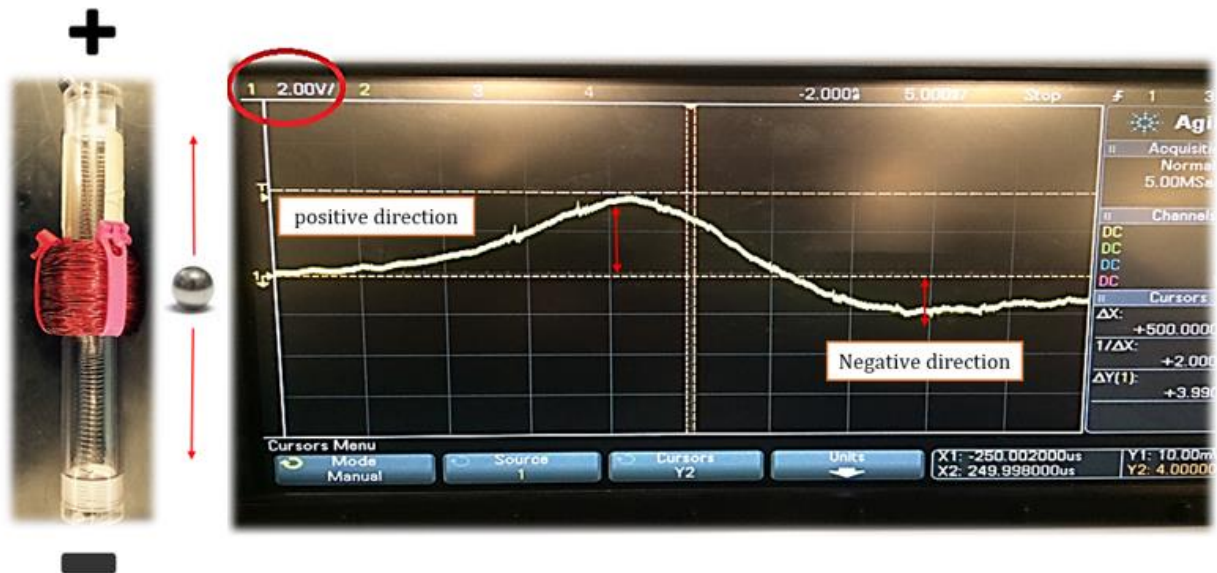
(Figure 9. Position, B Field and EMF)

2

From the above equation, we notice that the faster the magnet goes in and comes out, the greater the emf voltage is induced. Since Δt is the value determined in mechanical part, from this, we are reaffirmed how influential the mechanical design is on our project.

² K&J Magnetics, Inc. <https://www.kjmagnetics.com/calculator.asp>

Based on the table above, we conclude that EMF voltage at our optimal 2 cm is **3.5V**. And, this value drops significantly as less distance the magnet travels.



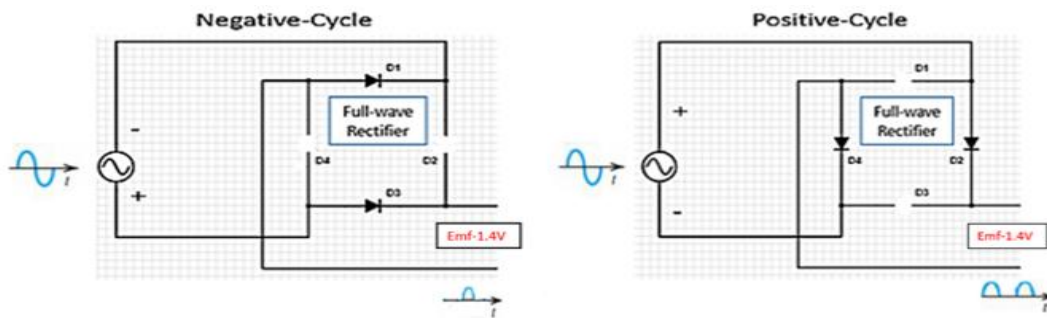
(Figure 10. Faraday's Law and Experimental Data)

However, even though neodymium magnet is strong, if it is stationary(no movement), there is no EMF to be induced, because by the definition, EMF is the instantaneous change of magnetic flux over time. If there is no change on flux, obviously there can not be any EMF.

V. Electronic

This is the final step of our project design. The function of this last section is crystal clear: convert emf voltage into constant DC signal in order to store it to rechargeable battery. The technical name of this process is called, “AC to DC converter”. It receives AC signal from the source and converts it to DC signal through three steps of rectifier, filter and regulator.

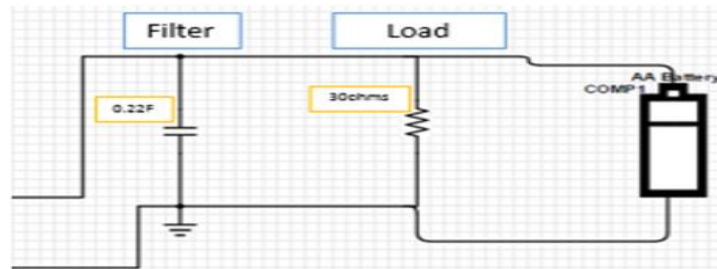
First of all, rectifier is generally divided into full bridge and half bridge. Since full bridge rectifier converts all bidirectional signal into uni-directional signal without waste, this will be used in our design. All diodes of D1 to D4 in this design use D1N4001.



(Figure 11. Positive and Negative Cycle of Rectifier)

3

Theoretically, the voltage output out of full wave rectifier is whatever the voltage comes in minus 1.4 V. The reason 1.4 V is taken off is the rectifier needs 1.4 V to turn on two diodes of which the operating voltage standard is 0.7 V. Since there are two for both negative and positive cycle pattern, 1.4 V is subtracted from 3.5 V of AC input. By this time, output voltage is rectified into uni-direction.

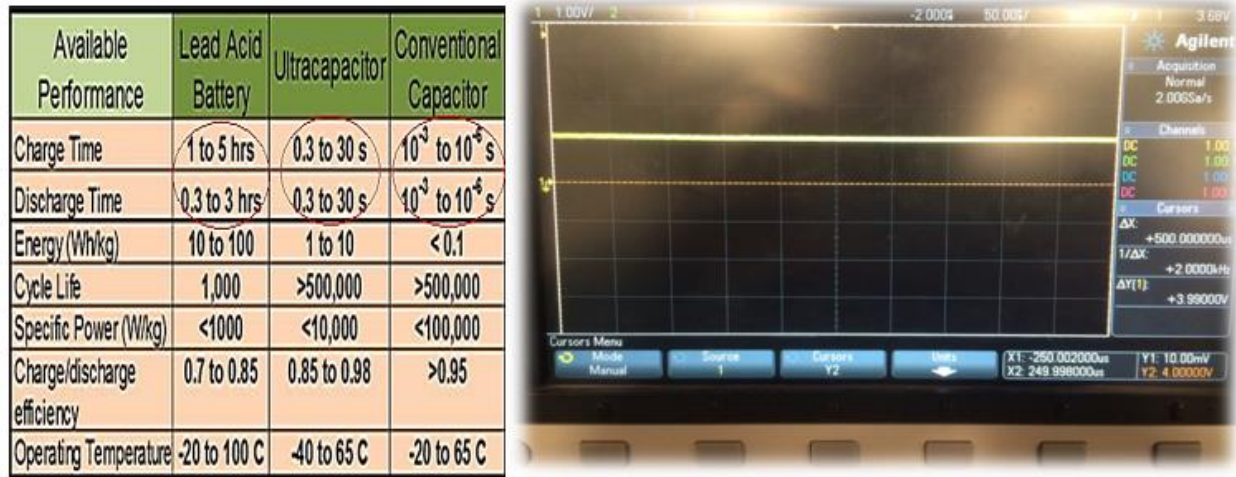


(Figure 12. Filter and Load Schematic)

The next part of the electronic part is the filter. The objective of filter is signal smoothening. Here, we did not use the ordinary capacitor whose values are normally $\sim$ micro, $\sim$ nano and $\sim$ pimco Farad. Instead, we used super-capacitor whose value is 0.22F. The sole reason we used super-capacitor instead of ordinary one is to increase discharging time of voltage across capacitor. Since ordinary capacitor demonstrated 2~3 seconds of discharging speed, we had to use alternative to increase discharging time of capacitor to enhance the amount of electricity delivered to the battery. By using super-capacitor, we were able to achieve 10 seconds of slower discharging speed. Furthermore, the voltage across super-capacitor was shown **1.4 volt**. Although only 1.4 v should

³ ECE343 Lab Report #2

have taken off from the emf voltage theoretically, we experienced additional 0.5 v loss due to various reasons, such as power loss and heat dissipation. Furthermore, it is not clearly shown on the picture below, but there exists voltage ripple. Since battery needs constant DC voltage, this ripple has to be get rid of. However, at least, by using both full-wave rectifier and filter, we generated DC-like voltage.



(Figure 13. the voltage across super-capacitor)

The last part is load. On the demonstration, we added 30 Ω of resistor across capacitor. The reason is we wanted to show our demonstration fits to the battery specification as below.



NiMH	Specification
Voltage	1.2 V
Ampere hour	700 mAh
Standard Charging Method	50mA for 14 hours

(Figure 14. NiMH Specification)

Since standard charging condition is 50 mA of current inflow, we added 30 Ω of resistor across 1.4 v of super-capacitor. This yields **47 mA**, which is very close to the battery specification. However, we do not really need the resistor. Furthermore, our design had a problem in terms of efficiency. Since each swing generates 10 seconds of DC voltage, in order to fulfill 14 hours, one must swing 5700 swings! Therefore, we had to come up with the better energy managing system. The alternative for this issue will be discussed on conclusion chapter at the end.

VI. Cost

<i>Members</i>	<i>Hourly Rate</i>	<i>Total Hours</i>	<i>Multiplier</i>	<i>Labor Cost</i>
<i>Henry H. Ahn</i>	\$30.00	250	*2.5	\$18,750.00
<i>Steve H. Wang</i>	\$30.00	250	*2.5	\$18,750.00
<i>Net sums</i>		500		\$37,500.00

<i>Item</i>	<i>Quantity</i>	<i>Cost</i>
<i>Neodymium N42 ¾ Magnet</i>	2	\$15.60
<i>Wooden bat</i>	1	\$3.00
<i>Copper wire 20 Gauge * 50'</i>	1	\$2.15
<i>Elastic spring</i>	2	\$2.00
<i>Thin Rubber sheet 42inch wide * 0.006 Inch Think</i>	1	\$6.15
<i>3M Scotch Brite Heavy Duty Scrub Sponge</i>	1	\$0.99
<i>wires</i>	5	\$0.50
<i>D1N4001 Diodes</i>	5	\$0.70
<i>30 Ω resistor</i>	3	\$0.15
<i>0.22F capacitor</i>	2	\$6.92
<i>BD135 Bipolar Transistor</i>	1	\$0.23
<i>3300uF Capacitor</i>	1	\$0.92
<i>D1N5226 zener diode</i>	1	\$0.12
<i>AA size 2200mAh NiMH battery</i>	1	\$16.00
<i>Total</i>	27	\$55.43

<i>Section</i>	<i>Total</i>
<i>Total Labor</i>	\$37,500.00
<i>Total Parts</i>	\$55.43
<i>Grand Total</i>	\$37,555.43

VII. Conclusion

1. Accomplishment

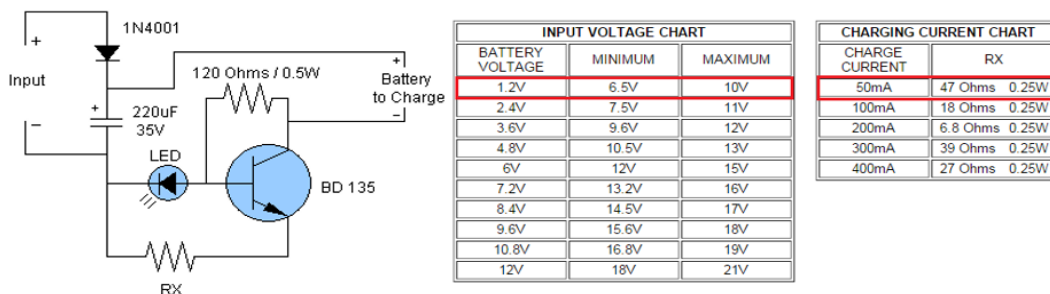
We can proudly say we made accomplishment. Our objectives are harvesting electricity and charging the battery. Of course, as we mentioned at the end of the electronic part, we had energy management issue. Yet, there is no doubt that we produced 3.5 emf input voltage and 1.4 v of DC output. Furthermore, we accomplished conversion of random human motion into constant frequency by using spring oscillation. If we had not used the spring, we would not have achieved any of our goals. We believe one of few reasons that industry is yet to use human motion(random motion) to generate electricity is failure of converting it to harmonic motion. Yet, again, we overcome this hardship by implementing our project on spring oscillation.

2. Uncertainties & Challenge

There are two main challenges that we had. First one is harvesting electricity based on random motion as we discussed above. The second challenge that we had was finding the optimal design between durability and functionality. For example, emf voltage depends on frequency of spring oscillation. To increase emf voltage, we can use spring of higher constant. Yet, this reduces the traveling distance, which eventually leads to the decrement of emf voltage. Also, we have another option of using weaker spring constant. This increases the oscillation travel distance, which leads to the higher emf voltage. However, weak spring constant leads to easy worn out of spring. Since durability matters just as functionality, throughout the project, we had to find the optimal, not the maximal point where both durability and functionality are guaranteed. In other words, there was no such thing as ‘free lunch’. At the end of this project, we realized that finding optimum state is better than finding maximum state.

3. Alternatives & Future Works

For the better management, we have to use NiMH battery charger. This circuit will be placed at the end of super-capacitor of the electronic part.

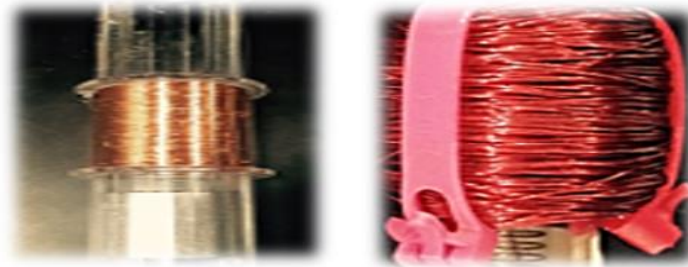


(Figure 16. NiMH battery charger and specification)

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⁴ Circuit Diagram <http://www.circuitdiagram.org/nicd-nimh-battery-charger-circuit.html>

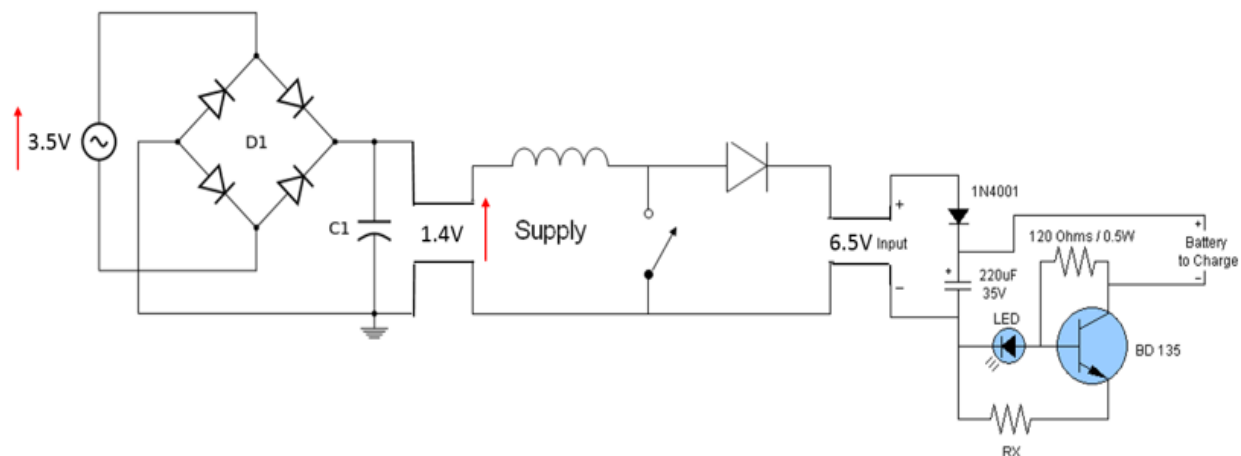
However, as clearly listed on the voltage specification table, in order to charge 1.2 v battery, the input voltage to the circuit should be 6.5 v. To achieve this criteria, we came up with two ideas. The first one is using thinner copper wire.



(Figure 16. Alternative copper wire)

The thinner copper wire takes less volume so that greater number of loops can be made given fixed volume in the laundry bat. Furthermore, this one has less resistivity compared to the thicker one. This will generate smaller resistive force toward the movement of magnet within the tube.

The second idea is adding boost converter between super-capacitor and NiMH battery charger. The idea of boost converter is amplifying the DC voltage input. With the intensified emf voltage from using thinner copper wire, boost converter will amplify the input voltage even higher to reach the 6.5 v of minimum voltage criteria to run the NiMH battery charger. Therefore, our ultimate electronic design becomes as following below.



(Figure 17. Final electronic design)

Of course, the boost converter design above is bare schematic so that modification is required. However, we believe this is the better management design for charging the battery.

4. Ethical Issues

We went through 7.8 IEEE Code⁵ of ethics and like to summarize few lists which were specially applicable to our situation.

(3) *To be honest and realistic in stating claims or estimates based on available data*

As we have went through complex and arduous calculations, we realized that since the range of numbers we are playing with is small, small manipulation on the number can yield huge difference on the output. Little change of magnetic field strength difference or delta t can dramatically increase the induced emf voltage. Since, whole purpose of our project is generating electricity, we promised to be honest and realistic on data and our calculation.

(5) *To improve the understanding of technology; its appropriate application, and potential consequences*

It is our job and duty as an engineer to understand the technology and apply it appropriately and always be mindful of the potential consequences. Even though the short term profit may seem beneficial, if we sense the potential danger in the future, we should reconsider the project and follow the right path.

(9) *To avoid injuring others, their property, reputation, or employment by false or malicious actions*

For whatever reasons, we understood that by any means of false and malicious actions(direct willingness of harness others), we should not injure others, their property and reputation.

5. Safety Statement

Since we are dealing with the power(voltage and current), we will go through our project with high caution. Specially, when we contact with circuit while it is generating the power, we will wear such as rubber globe which prevents electric shock. Furthermore, we expect our project involves bit of circuit wiring. This being said, we will be careful while wiring so that such cases of ‘shorting’ and ‘burning’ would not occur.

The other potential risk is at Neodymium N42 magnet. This magnet boasts the magnetic field strength 100 ~ 1000 times stronger than that if typical normal bar magnet. Its field strength is 13,200 gauss or 1.32 T. We actually watched the videos in youtube⁶ how strong this magnet is. For example, if it senses iron and coins, literally, it draws those products, flying roughly 15 cm in the air. We also saw this magnet attached on cross-driver. The user tries to force 4seconds to disconnect the attraction force of the magnet. Therefore, while using this magnet, we will make sure that we make our pockets empty and try to keep away from electronic machinery.

⁵ Code of Ethics, <http://www.ieee.org/about/corporate/governance/p7-8.html>

⁶ Power of Neodymium Magnet, <https://www.youtube.com/watch?v=aAV1RKeg5Sw>

VIII. Reference

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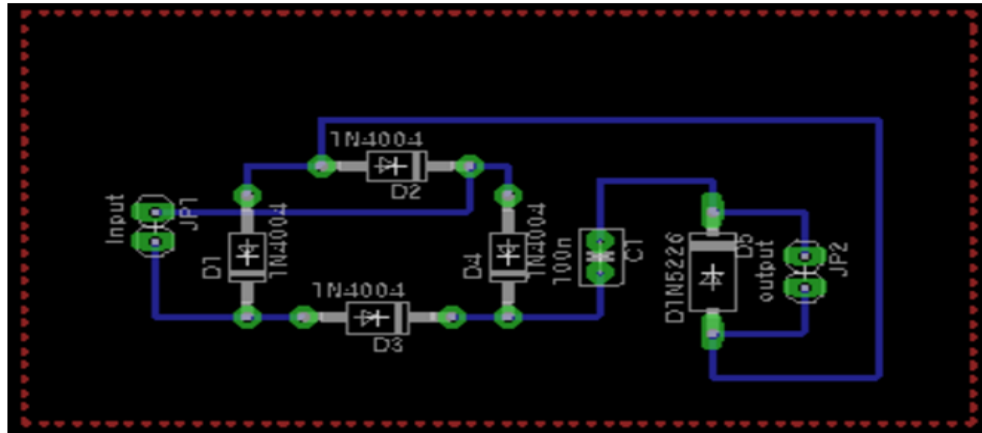
<https://www.youtube.com/watch?v=aAV1RKeg5Sw>

Appendix A Verification Table

	Requirements	Verifications	Verified
1	<i>Spring</i> - 0.088N/mm Constant	First of all, there is no spring in the market of which the constant is exactly 0.088N/mm. That value is calculated based theoretical assumption: $K = \frac{F}{x} \dots \dots \dots (3)-8$ Here, mass of magnet and gravitational force are fixed values. However, external force applied varies. Furthermore, we desired the maximum spring oscillation is 2.5cm. In other words, K is calculated based on theoretical assumption and this value of 0.088K/mm becomes only criteria, not a definite standard. Therefore, in the real modeling, we will purchase multiple numbers of springs with different spring constants, test them individually and choose the most desirable one. And, based on the best spring constant we choose, we will calculate frequency $: f = \frac{1}{2\pi} \sqrt{\frac{K}{M}} \dots \dots \dots (3)-2$	Yes
2	<i>Neodymium Magnet</i> -weight: 0.0514kg -Diameter: ¾ inch -Magnetic Field: 1.32T -induce emf voltage	Neodymium N42 Magnet oscillation through the center of copper solenoid is the core of our project. As it goes in and out of the solenoid, by Faraday's Law, emf voltage is induced, the source of our electricity. Based on K&J Magnetic website, the manufacturer and retailer of neodymium magnet, we are able to find out the magnetic field of the magnet on different location. The field strength from the distance of magnet is highly important because of the following equation: $\frac{d\phi}{dt} = A \frac{\Delta B}{\Delta t} \dots \dots \dots (4)-1$ In other words, the difference between magnetic field strength at two different position at the given delta t determines the amount of emf voltage. Theoretical emf voltage created is 3.5V. <u>Oscilloscope will be used to measure emf voltage</u>	Yes
3	<i>Full Wave Rectifier</i>	The primary reason we are using full wave rectifier is (i) need to convert AC signal into DC and (ii) rather	Yes

	- 4 equivalent diodes - D1N4001 - Rectify Signal	than ignoring half of the total signal as half wave does, full wave converts all bidirectional signals. The function of full wave rectifier can be divided into two groups of positive and negative cycle. Each cycle passes two D1N4001 diodes. And, each diode consumes 0.7V. This being said, the spitted out voltage after rectifier will be the input voltage minus 1.4V. Theoretically, we calculated the input voltage is 3.5V. Then, the voltage after rectifier will be 2.1V. Since, the real experiment may yield different amplitude of input voltage, in general, rectifier relation can be written as : <u>$V_{ouput} = V_{input} - 1.4$</u> Furthermore, depending on voltage input, the voltage across diode slightly varies. This means actual voltage across diode will be less than 0.7 volt. However, it will be definite that voltage output after full wave rectifier will be less than voltage input to the rectifier. However, we are aware of our design is running based on very low amplitude. This will influence how full wave rectifier behaves. <u>Oscilloscope will be used to measure.</u>	
4	<i>Filter(0.22F)</i> -Smoothen out the voltage signal	Although, Pspice simulation assumes ideal no power loss, we expect some minor power loss in the actual design. Therefore, as long as the minor ripple voltage is formed near the -0.1 and -0.5V range of rectifier voltage output, we will conclude the filter is accurate. However, we are aware of our design is running based on very low frequency. This will influence how our filter works. To be specific, since time gap between signal to signal is too far, voltage across filter will just drop momentarily. <u>Oscilloscope will be used to measure.</u>	Yes
5	<i>Load: NiMH + resistor</i> -30 Ω -1.2V and 700mAh	The purpose of using this component is to verify that our electronic chip properly converts AC signal from magnet to DC and stores it to battery. We are using NiMH 1.2V 700mAh rechargeable battery. Since charging criteria current is 50mA. We add 30 Ω to generate 47mA to fit to the batter specification. <u>Oscilloscope will be used to measure.</u>	Yes

Appendix B – PCB layout



(Figure 18. PCB layout)

Above is our PCB layout. There are two modifications we made on actual PCB soldering. The first is usage of 0.22 F instead of 100 nF. The second is usage of 30 Ω resistor, instead of D1N5226 zener diode. Since both of them have same PCB layout holes, there was no problem of interchanging some modules.