Self-powered kit for lighting system

by

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16499

Dissertation submitted in partial fulfilment of

the requirements for the

Degree of Study (Hons)

(Electrical & Electronics)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Electrical & Electronics Engineering Programme

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in partial fulfilment of the requirement for the

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Approved by,

_____

(AP DR. MOHD HARIS MD KHIR)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(MOHAMMAD NAAIM BIN MADZIR)

ABSTRACT

Conventional portable light source which normally call a flashlight usually use conventional batteries as a power source. This batteries need to be replace each time the power from the batteries is fully drain. This will lead to excessive production of batteries if the batteries not be recycled. Excess manufacturing and poor disposal management of conventional type batteries will lead to serious issue such as the toxic material in the batteries will absorb in the soil and flow to the water supply and will be absorbed by the plant and end to the fruit. This wills then harmful to the human. Thus, the conventional method to power up portable light source needs to be replace with self-powered light source to prevent excessive use of conventional batteries. Renewable energy concept can be used in the design of self-powered light source and some method can be introduce such as solar, heat thermal, and cranking using dynamo. This study is aim to investigate and experiment another renewable energy which is by using electromagnetic theory to power up a portable light source. Expected deliverable of this project for is up to testing and experimenting some of the concept of electromagnetic theory to come out with the best design as a self-powered generator to the flashlight.

ACKNOWLEDGEMENT

With the Name of Allah the Most Gracious, the Most Merciful

The success and the final outcome of Final Year Project entitle "Self-powered kit for lighting system" require a lot of assistance and guidance from many people. Finally I am able to complete my Final Year Project. I would like to give gratitude to my Universiti Teknologi PETRONAS, especially Electrical and Electronics department for giving me opportunity in being part of this course and thus, able to complete my final year project.

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Not to forget, my parents, Madzir bin Wan Zakaria and Azizah bt Othman who are very supportive. Their encouragement and motivation has been one of the keys that strengthen me in enduring this period of completing my final year project. It is hoped that this project paper would give better understanding of the power industry towards a better tomorrow.

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ABBREVIATIONS AND NOMENCLATURES

LED	-	Light Emitting Diode
V	-	Voltage (Volt)
F	-	Farad
MEMS	-	Micro Electrical Mechanical System

CHAPTER 1

1.0 INTRODUCTION

1.1 BACKGROUND

Most of the time, needs of light come naturally especially in a dark situation or environment. Most of the common kit being used as a light source is a flashlight or torch. Definition of flashlight is a kit which is portable and battery-operated devised used for illumination [1]. Basic concept of flashlight includes batteries, switches, and bulb or Light Emitting Diode (LED). The flashlight with LED typically called Cree led flashlight [2]. The first batteries flashlight was invented by Joshua Lionel Cowen on 1898 and he is the original owner of American Eveready Battery Company [1]. This project involves in designing and fabricating a self-powered energy generator using electromagnetic theory which can be used as a lighting system during emergency situation. Using this system, conventional chemical based battery in no longer required. The purpose of this study is to studied and implement new concept which is by using Electromagnetic Theory to generate energy to power a flashlight.

1.2 PROBLEM STATEMENT

Dependable to the conventional batteries to light up a flashlight seem to be not relevant and wasting material to manufacture. Besides the energy store in the batteries and quantity user can use the energy seems to be illogical as the longer time takes to light up a flashlight, the numbers of batteries used will increase as the power store in one battery is limited. Additionally, conventional battery based flashlight uses chemical based batteries which will have the issue of power drain over time although the batteries not being use for some time. Consequently, a lot of money needs to

spend to equip flashlight with the conventional batteries. Furthermore conventional batteries contain a toxic heavy metal that has potential toxicity that will create pollution and extremely harmful if not properly disposed.

1.3 OBJECTIVES

The objectives of this project are:

1) To obtain results of experiments and testing in finding optimal design for self-powered generator to power a flashlight.
2) To integrate charging and storing circuit for the system.
3) To finalised optimal design to be use as a flashlight.

1.4 SCOPE OF STUDY

The self-powered Kit basically is a design of portable light source which usually call flashlight. The design consist of several part which are Energy harvester, Circuitries, Storing mechanism, and Light Emitting Diode (LED) which then will be put together as a finalised design for self-powered flashlight.

The Energy harvester uses electromagnetic theory concepts which consist of magnet and coated wire. The concept of harvesting is basically by using magnetic flux cutting to generate a power. Several experiments may be conduct to design an ideal power generator.

Targeted duration of this project may take roughly 8 month to complete that equivalent to 2 semesters in Universiti Teknologi PETRONAS system.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 VIBRATION ENERGY HARVESTER

As stated by Williams and Yates [3], three methods can be used to harvest energy from vibration which is piezoelectric materials, electrostatic generation, and electromagnetic induction. While each of these methods can be used to scavenge electrical energy from surrounding vibrations thus provide a useful amount of electrical energy [4].

There are some advantage and disadvantage by using electromagnetic theory method that stated by R. Gherca and R. Olaru in their research [5]. The advantages are, by using electromagnetic, no external voltage source need to be applied and no smart material need to be used in the system. Plus, this system well suit for operation at relative low frequencies. The disadvantages are, it is bulky in size and difficult to integrate with Micro Electrical Mechanical System (MEMS) and it is expensive to integrate with MEMS as to create a micro magnet take a huge expenditure.

There are two type of electromagnetic generator which is by using rotation and linear motion as stated by one research [6]. By rotation, energy is harvest by converting fixed-direction motions into electricity via linear-to-rotary mechanism for example of application is hydro and wind generator. With linear motion, the energy harvesting efficiency is normal higher than rotary generator under vibrations excitation with the same velocity inputs. Linear motion generator very suitable for harmonic motion condition for example ocean wave.

2.2 FARADAY'S LAW

This law show the relation between electric circuit and magnetic field [7]. Production of electromotive force (emf) in a conductor is called Electromagnetic induction and it is a result of a changing magnetic field across conductor [8]. Faraday has introduced two laws which is; Faraday's first law, an emf will be induced in a coil if there is any change in magnetic field of a coil of wire, and the Faraday's second law stated, the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil [7]. This concludes that if magnets go across a solenoid of coil, and emf will produce. This emf then will be connected to the electric circuit to be use.

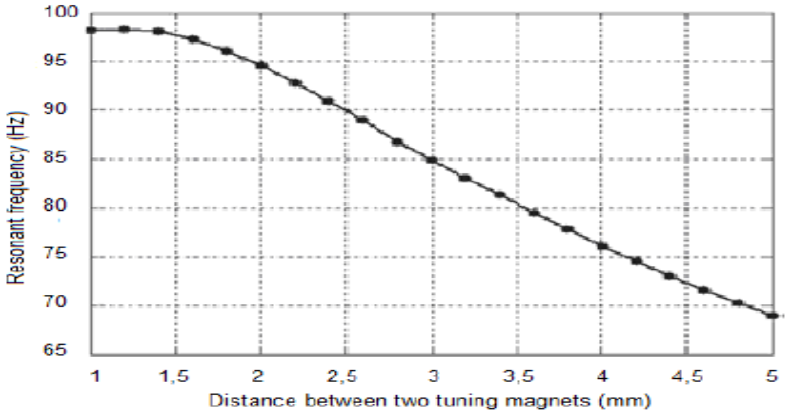
There are several ways to improve and increase the emf induced which are by increasing number of turns, by increasing magnetic field strength and by increasing the speed of the relative motion between coil and magnet [7].

2.2 MAGNET LEVITATION

When a magnet is brought near a superconductor, it will repel because induced supercurrent will produce mirror images of each pole [9]. Similar to when two magnets with same poles face together, it will repel each other because of the mirror images. All this phenomenon is happen because of electrical resistance between two magnets is zero hence supercurrent is generated in the material to exclude magnetic fields from magnet brought near it [10]. The current which cancel the external field produce magnetic poles which mirror the poles of the permanent magnet, hence repelling them to provide lift to levitate the magnet [10].

Based on a conference paper (October 2012) [5] that doing experiment regarding energy harvesting from linear and nonlinear oscillations in the generator that use the magnetic levitation conclude that the increase of the system damping by reducing the distance between the fixed magnets leads

to increasing the resonant frequency and harvested power for the same input amplitude.

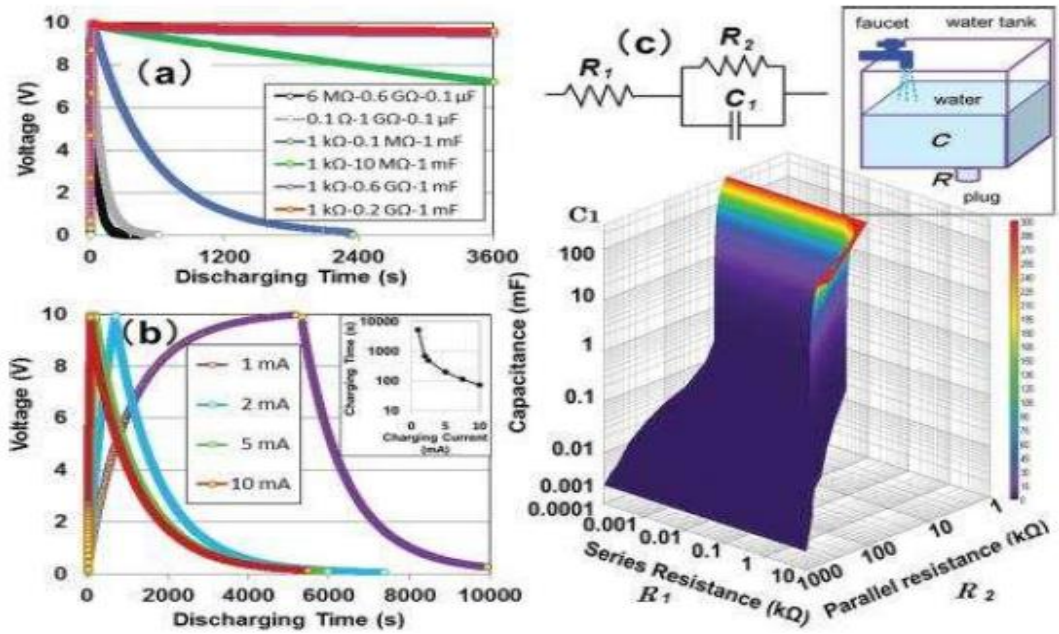


e 3. Resonance frequency vs. distance between two magnets |

FIGURE 1: Graph of resonance frequency vs. distance between two magnets

2.3 CAPACITOR CHARGING

Based on researchers, Prof. Mikio Fukuhara, Tomoyuki Kuroda, and Prof. Fumihiko Hasegawa, at Tohoku University in Sedai, Japan, (December 2014) they found that RC combination are the best in term of quick charging and long-term discharging consist of circuits with small resistor, large resistor, and large capacitor [11]. They also agreed that some of these circuits could be charged in less than 20 seconds and hold the charge for up to 40 minutes, while having relatively large capacitances up to 100 miliFarads (mF) [11].



(a) and (b) The charging/discharging curves for various resistor-capacitor combinations. (c) Three-dimensional funnel-shaped surface contour displaying energy-rich discharging after complete charging. Credit: Fukuhara, et al. ©2014 AIP Publishing LLC

FIGURE 2: Experimental result of the capacitor charging research **[11]**

Based on the research, they have come out with some circuit design as picture below [11]:

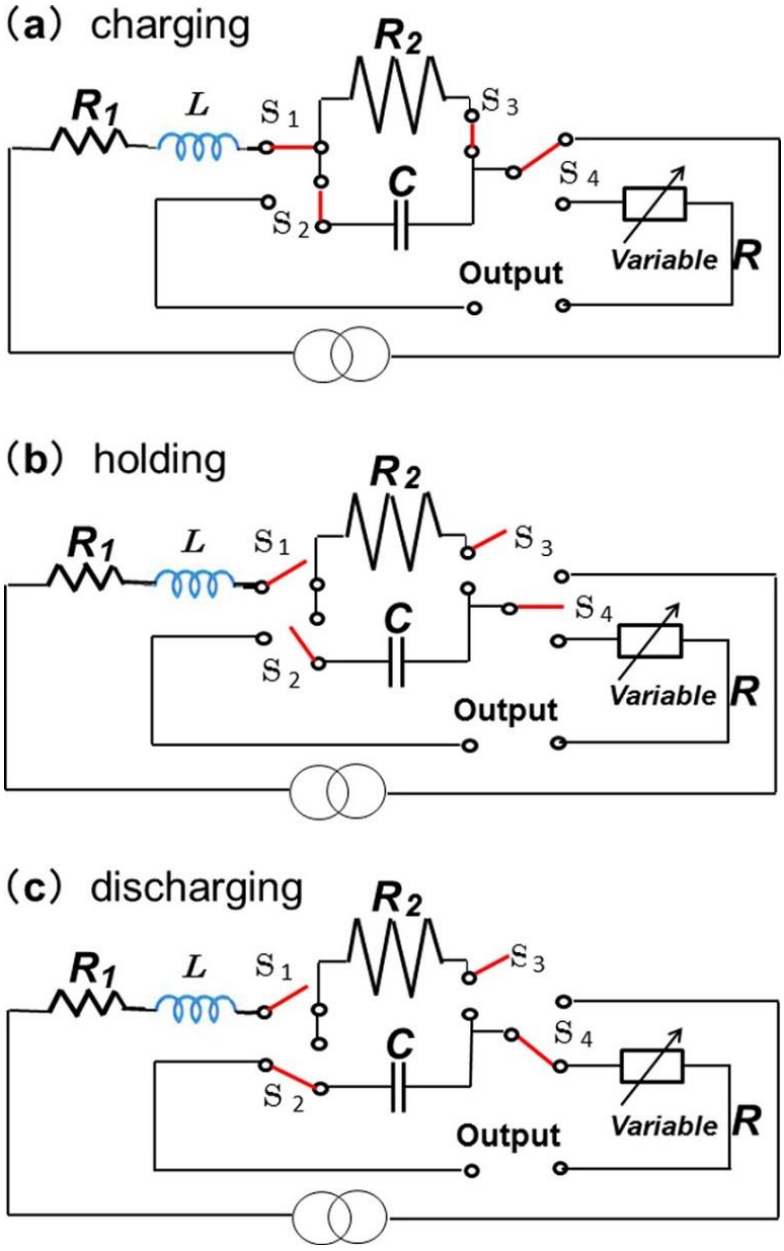


FIGURE 3: The research proposed RC circuit

(a) The capacitor is quickly charging by closing switches S1, S2, S3, and S4. (b) To store the charge put it on holding mode by open all the switches. (c) We can control the discharge by close switches S2 and S4 and then using variable resistor to control the discharging [11].

2.4 FREQUENCY UP-CONVERSION METHOD

A novel method, called frequency up-conversion, utilizing the magnetic pull force between a permanent magnet and a magnetic material to up-convert the operation frequency of the harvester, has been proposed by Kulah and Najafi [12]

Frequency up-conversion is an idea of in a mechanical frequency increased generator; a low-frequency resonator absorbs energy from environmental vibration. Then at later stage, it is transferred to a high frequency oscillator. The energy of the high-frequency oscillator is the transferred to the electrical domain [13].

Based on research paper by K. Ashraf [14] , in performance comparison, there are two issues; first, average power flow into a harvester strongly depends upon the characteristics of the vibration source. And second, the average power flow into the harvester is proportional to the mass times the internal displacement range, or 3/4volume. Therefore, dividing the average power by the volume (power density) will require large harvester.

Based on Zorlu, the power density of the device can be increase as the volume is scaled down [15]

CHAPTER 3

3.0 METHODOLOGY

3.1 PROJECT FLOW

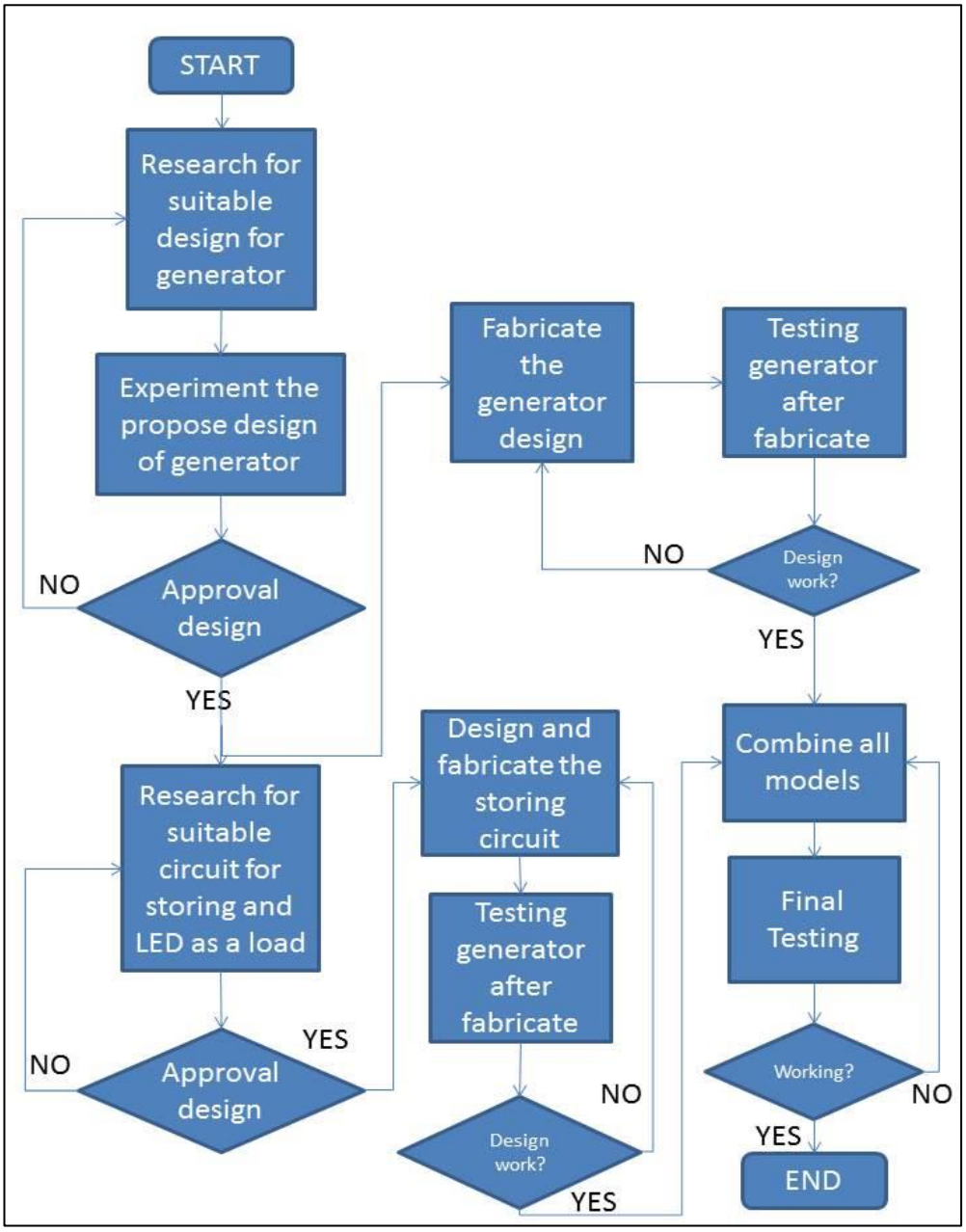


FIGURE 4: Project Flow Chart

3.2 PROJECT MAIN STAGES

3.2.1 EXPERIMENT

In experiment stage, various type of design has been created to find the best and most optimize design of generator to generate power for small equipment as the purpose of this project is to create self-powered kit for lighting system which is flashlight. Experiment has been done to create most optimize generator design in term of increasing electromagnetic force (emf) induced based on some criteria that is:

- Increase magnetic field strength
- Increase size of coil
- Increase speed of relative motion
- Increase number of turns

There are some limitation in fulfil all criteria listed for example in term of increasing magnetic field strength and increasing size of coil due to limited resources. To conduct this project, both criteria will be fixed and only vary other two criteria which is increasing speed of relative motion and increasing number of turns.

In this experiment stage, value and type of magnet strength has been fixed which is by using 2800Gs magnet strength equivalent to 2.8 Tesla and it is nickel-plated neodymium magnet. In this project, two categories of magnet will be used which is static magnet and moving magnet. Static magnet has a size of 1.3 cm diameter and moving magnet has a size of 0.6 cm diameter. For one prototype, two static magnets and eight moving magnet is being used.

FIGURE 5: Magnet use in the experiment stage

Besides, size of coil has been fixed to 0.2 mm. there are several choice that can be consider to pick as the best coil size which is 0.1 mm, 0.2 mm, and 0.7 mm size. The reason is 0.2 mm size is most suitable for small prototype design because of limited space. This is due varying number of turns for generator. Larger size of coil will use larger space compare to small size of coil although number of turns is same hence will create a big generator to be install in a small equipment. Moreover, thickness of the winding will affect the generator as magnet used have limited magnetic flux and bigger size coil will exceed this field although same number of turns is applied compare to smaller size coil. This will not make system efficient as the flux will not be fully cut the winding to produce energy. Besides, small coil size will not give better output compare to bigger size coil in a same number of turns. As the entire pro and cons of coil size has been fully understand, small size coil which is 0.2 mm has been used in this experiment compare to 0.1 mm and 0.7 mm coil size.

FIGURE 6: Coil size used.

As for this project, due to limited resources, the magnet strength and size of coil used is sufficient to prove the concept and harvesting energy for small equipment as flashlight. In this experiment stage, 2 type of nickel-plated neodymium magnet with 2800Gs strength and 0.2 mm coil size will be used.

In order to fulfil the objective of using electromagnetic theory to harvest the energy by using vibration, a medium for magnet to move and cut flux have been created. One solenoid for each pole has been used and the solenoid is design to fit the moving magnet for flux cutting. In this experiment, magnet levitation concept has been use as to create space between magnets for moving magnet to vibrate.

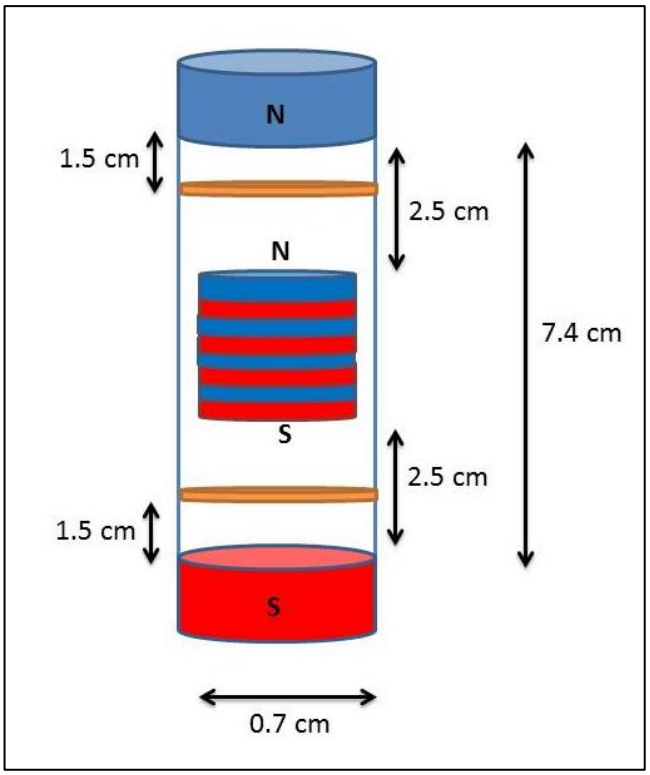


FIGURE 7: Solenoid dimension

Figure 7 shows a dimension of a solenoid used. Solenoid body use a plastic material to avoid any magnetic interference between magnet and solenoid body. Two permanent magnets have been used at end-to-end of solenoid body and eight moving magnets stack together is place in between two permanent magnets. The moving magnet is stack according to permanent magnet pole to create a repellent between permanent magnets and moving magnets. At the both end of moving magnets, the pole needs to be similar to permanent magnet facing the end of moving magnets. Distance of 2.5 cm is provided between permanent magnet and moving magnet to give space for moving magnet to vibrate and to make permanent magnet stay in the middle of solenoid due to repellent between two permanent magnets and moving magnets. This is to create magnet levitation between two permanent magnets and moving magnets. Height of eight magnet stack together is 2.4 cm which is 0.3 cm each. The summation of moving magnet height and space between permanents magnets and moving magnets is 7.4 cm. this dimension is used as a solenoid height.

The moving magnet diameter is 0.6 cm. The width of the solenoid need to be as close as possible to the diameter of moving magnets to prevent moving magnet move in many angle rather than 90 degree from the bottom of permanent magnets. The illustration of moving magnet move in different angle shows in Figure 8.

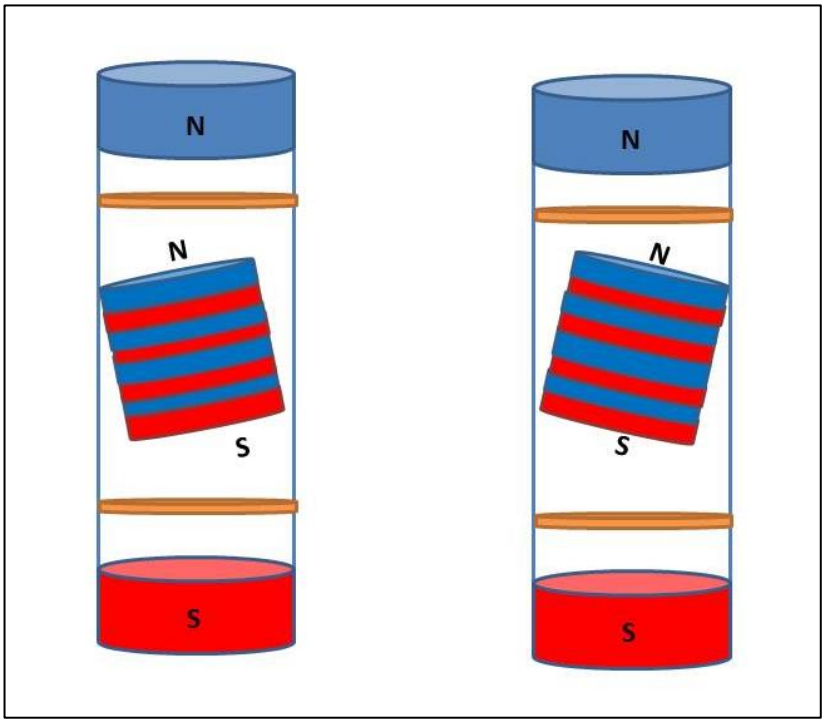


FIGURE 8: Moving magnet move in different angle

By considering this issue, the space between moving magnet and solenoid wall need to be as close as possible. The solenoid width is designed to be 0.7 cm which gives extra 0.05 cm in between moving magnets and solenoid wall at left and right side of the moving magnets. The space cannot be too close as it might disturb natural movement of moving magnet hence creating extra friction to the magnets movement.

In addition, 1.5 cm gap between each permanent magnet is cut a bit to make a hole. It is use as an air flow to the solenoid body as to prevent air damping to the movement of moving magnets. This is due to the permanent magnet body is sealed by both end of permanent magnets. The result of the solenoid body experiment is shown in Figure 9.

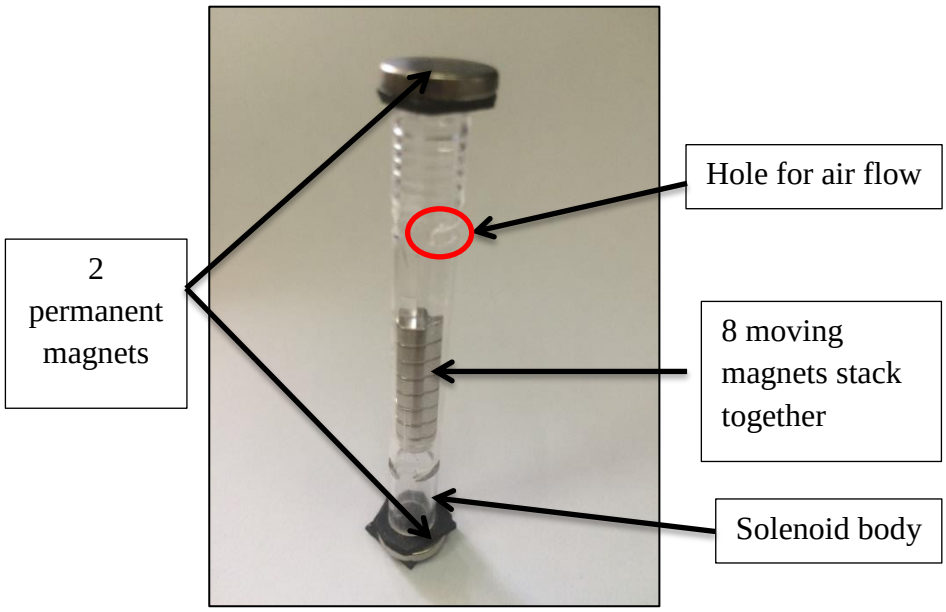


FIGURE 9: Real solenoid body

3.2.2 IMPLEMENTATION

In this stage, the solenoid body need to be winding with coil to create a linear generator. For this stage, two manipulated variable is vary to find the most optimize design to be install in the prototype and the variable are as follow:

a) Varying speed of relative motion
b) Varying number of winding turns.

With this, several methods is used for separate manipulated variable. There are five methods is experiment for the first manipulated variable which is varying speed of relative motion and two methods for the second manipulated variable which is varying number of winding turns. The reason of variety type of design to be experimented is to make sure best design can be obtain.

a) Manipulated variables 1 (Varying speed of relative motion)

To meet the manipulated variable which is varying speed of relative motion, variety experiment has been done to amplify speed of moving magnet move and vibrate in the solenoid. Some extra mechanism has been install and vary the material of the mechanism to get the up convergence in speed which is by doubling speed frequency of moving magnet from the relative motion. First model to be experiment is not using any extra mechanism install to the solenoid to amplify the movement. This first model will be label as "No up convergence". This model will have only force by magnet repelling to make the moving magnet move. The illustration of first design is shown in figure 10:

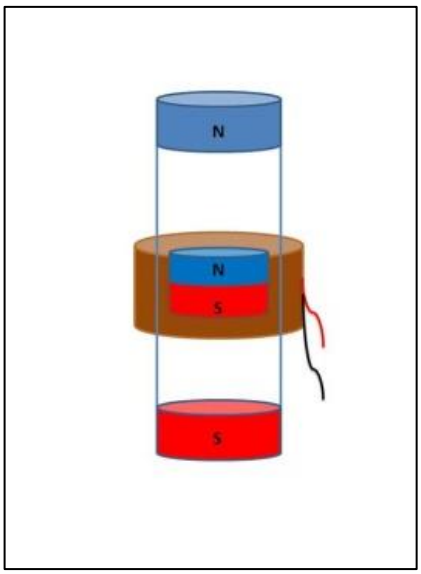


FIGURE 10: First model of solenoid that been experiment

The other models which are equipped with extra mechanism which called stopper has been install on both end side of moving magnet and also varying the distance from moving magnet is to provide external force to the magnet so that the speed of moving magnet will be double each time it hit the stopper. In other word, the force repel by the moving magnet when it hit the

stopper will be sum up with permanent magnet repelling which will create double speed of moving magnet. This method is used to create Up Convergence which is to double the frequency of relative motion of moving magnet. The illustration of up convergence is shown in Figure 11:

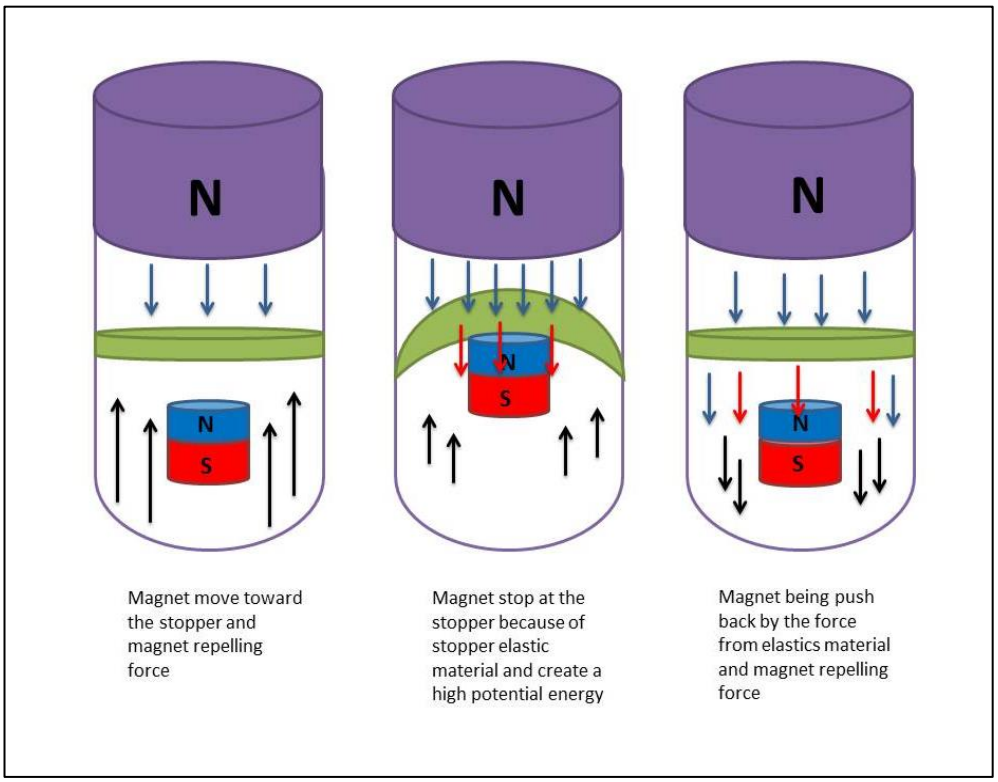


FIGURE 11: Speed up Convergence illustration

Indication from figure: Blue arrow (magnet repelling force), red arrow (stopper repelling force), Black arrow (magnet speed and movement),

In Up Convergence method, when magnet moves toward stopper, it will obtain higher potential energy and will bounce back toward other direction. The force from a permanent magnet repelling together with stopper repelling force will create double speed for moving magnet to bounce back toward other direction.

By using Up Convergence method, five different models are designed. The first Up Convergence design is by using balloon as a material for stopper. There are two models that using balloon as stopper and the

differences between two is the distance of stopper being placed from a moving magnet. The third design is by using rubber ban as a stopper. The fourth and fifth design is using rubber glove material as a stopper. The different of first, second, third and fourth design compare to fifth design is the condition of stopper being placed. First four design, the stopper being place as stretch as possible and the fifth design will not being put too stretch. The stopper condition will be loose a bit. The stiffness of material which are balloon, rubber band and rubber glove is different that will create different result. The models illustrations are shown in Figure 12:

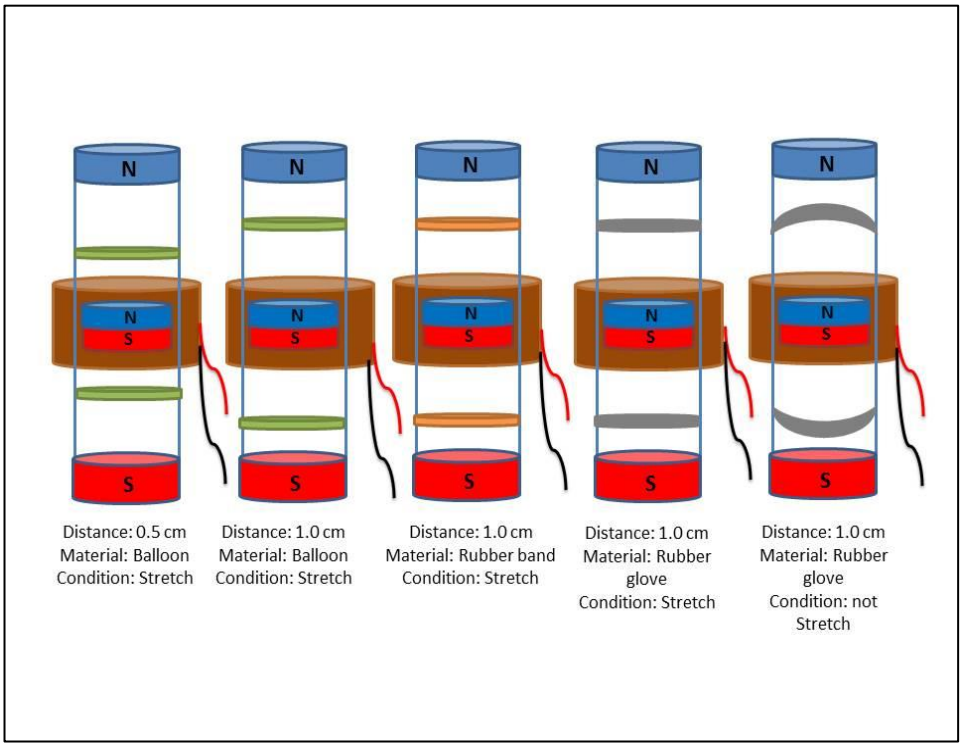


FIGURE 12: Different model of Up Convergence.

All of five models including no-up convergences design are winding with 500 turns each. The solenoid also has been fix with the design explain before in this chapter. The entire solenoid use same type of magnet and its magnetic strength which is 2800Gs equivalent to 2.8 Tesla. The entire model is winding properly to make sure no lost in connection between 500 turns and connectivity check has been done for each solenoid. The winding then being

secure with tape to keep the winding safe from damage. End of each turn then being connected to wire to make testing stage easy as to connect the wire to the equipment to obtain results. The entire models then being tested separately and value of voltage has been obtained.

b) Manipulated variables 2 (Varying number of winding turns.)

Experiment has been done toward the first manipulated variables to obtain best design, the second manipulated variables then being experiment to obtain best number of turns to be winding to the solenoid to create a generator. In this stage, some of the criteria need to be consider which are:

- Coil size used.
- Magnetic field of moving magnets.
- Winding method.

All of these criteria have been studied to find best way to winding the solenoid so that it will create most optimized design for generator.

Coil size.

As explain before in this chapter, size of coil is important because it will affect the way generator will be in term of size, weight and look. Bigger size of coil will give a thicker winding to the solenoid compare to smaller coils although number of turns is similar. This bigger and thicker winding then will occupy more space in the prototype which is flashlight and bigger prototype casing will require. Compare to smaller coils winding, it will give thinner winding compare to bigger size coils and require less space in

prototype. Thinner winding also will give lighter weight to the prototype and prototype will have a better look.

Magnetic fields of moving magnets.

Each magnet has its own magnetic field and this magnetic field is depending on the magnetic strength. As for the magnet use in this project has a magnetic strength of 2800Gs equivalent to 2.8 Tesla, magnetic field illustration is shown in Figure 13.

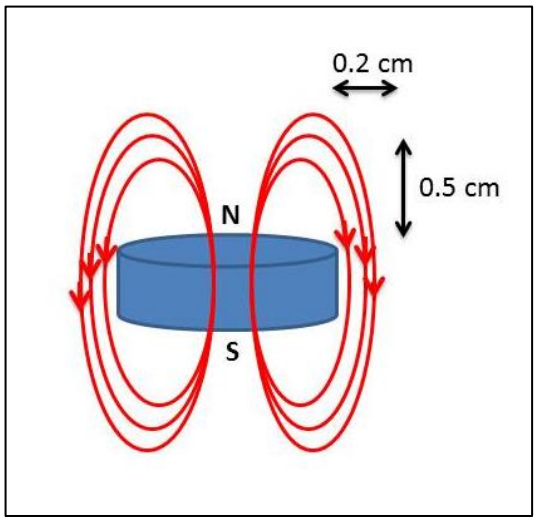


FIGURE 13: Illustration of magnetic field for single magnet

Based on figure 13, magnetic field area can reach 0.5cm away from the top of magnet and 0.2 cm away from the side of the magnet. The illustration of magnetic field is on the 8 magnets are in Figure 14.

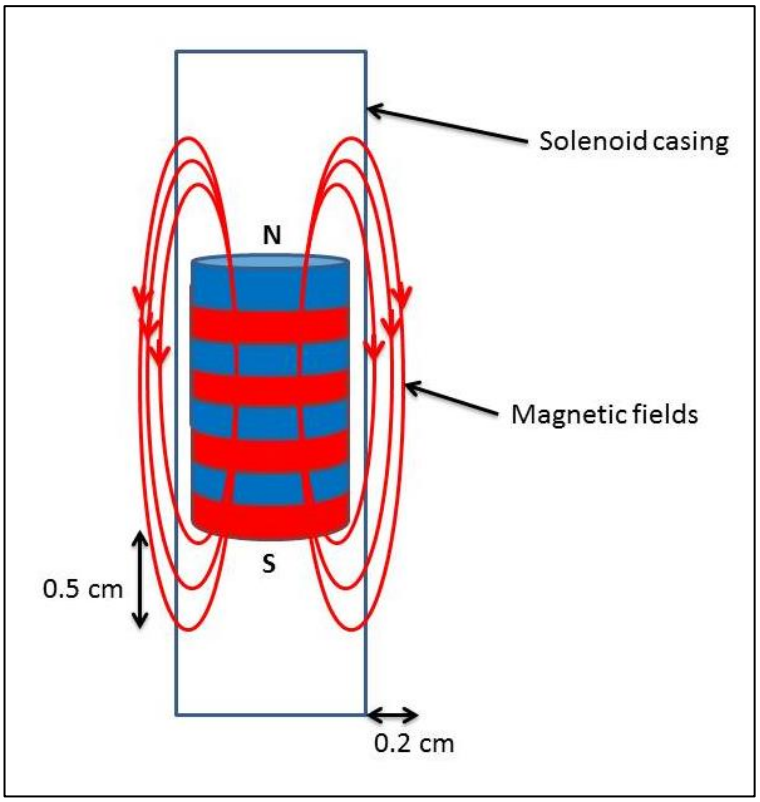


FIGURE 14: Illustration of magnetic field for 8 magnets stacks together.

Based on figure 14, magnetic field area is larger at the top of magnet compare to the side. This magnetic characteristic is a challenge in completing this project as number of turns cannot exceed the magnetic field are to make sure all of coil will be cut by magnetic flux when the magnet moving.

Method of winding

Method of winding is important as it will affect the result obtain by the generator. There are two types of winding which are center and end-to-end windings. The illustration of these is shown in Figure 15.

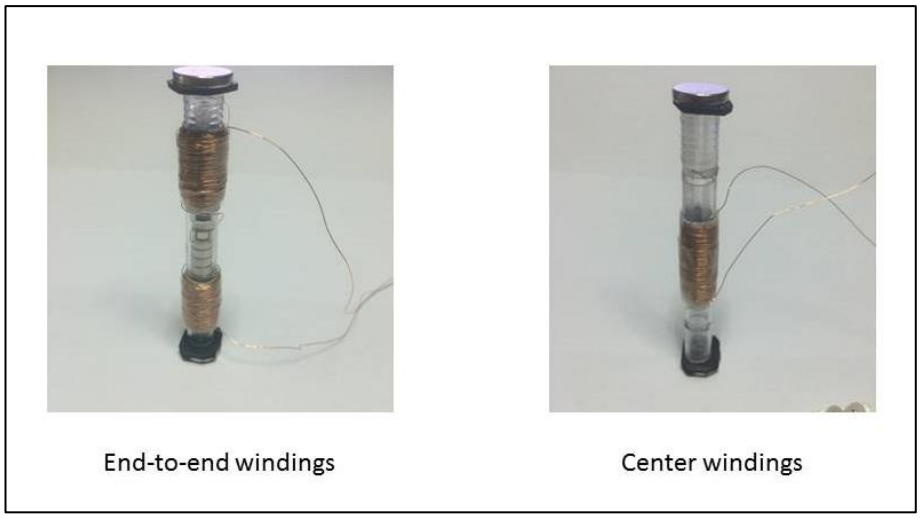


FIGURE 15: Winding methods

Two types of windings will be use in this project for experiment. Both method is use to find the most optimum method for winding to produce high voltage output.

Beside generator, one type of circuit from ready product has been found and the circuit can be used. Figure 16 shows the prototype circuit using some parts from existing product.

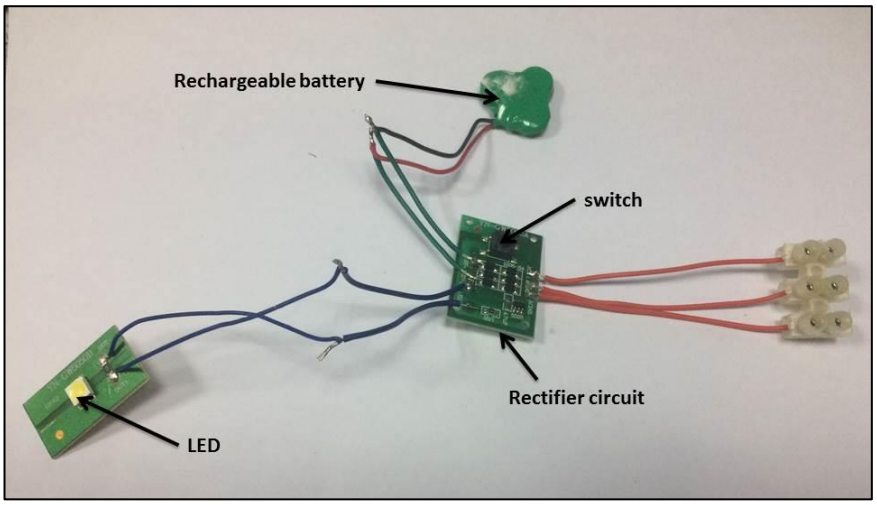


FIGURE 16: Circuit recommendation

3.2.3 TESTING

The entire experiment prototype will be tested and the value of voltage generated will be recorded.

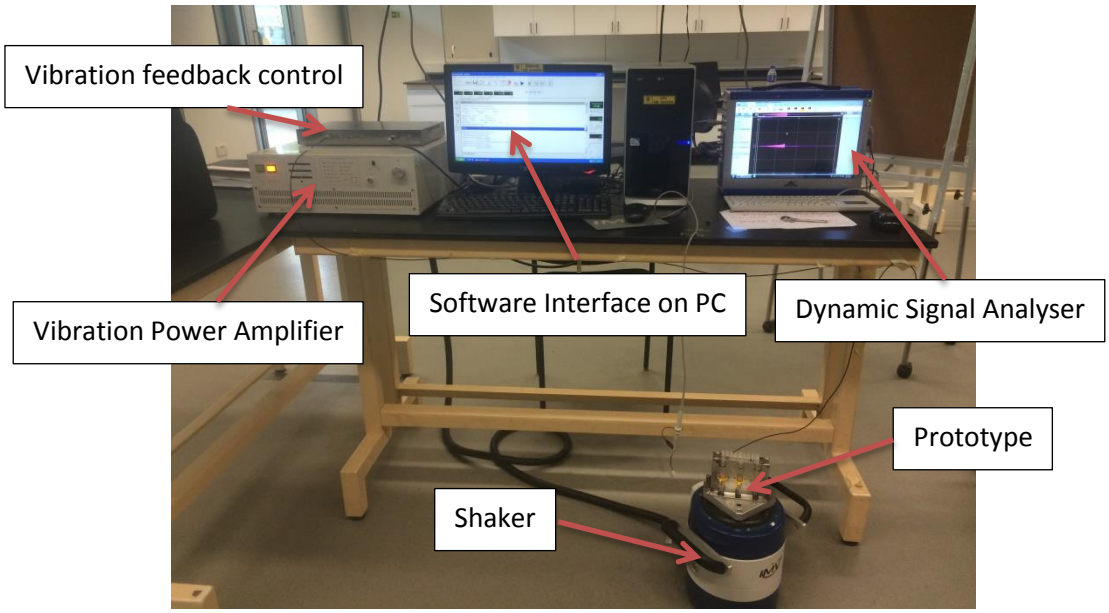


FIGURE 17: Test setup

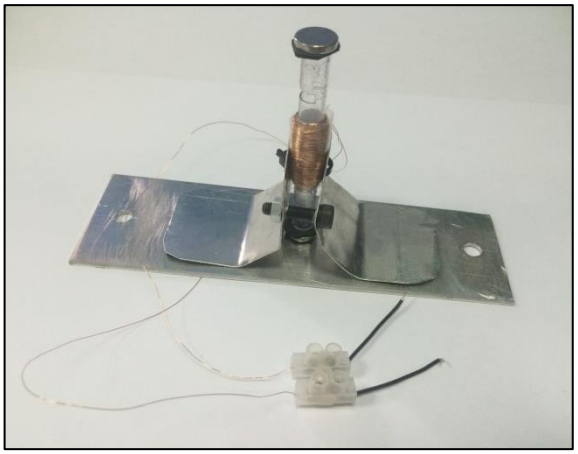


FIGURE 18: Prototype testing base

In the testing stage, shaker machine is used to get vibration motion of prototype. The model is placed on top of shaker machine and tightly attaches the models with shaker machine to give full vibration energy transfer from

shaker to model. This is for obtaining reliable result and to prevent extra movement from the models that will affect the output results.

Connection both end of winding is connected base on model design. The both end coated coil of winding is removed by using sand paper. The end part of coil then being connected to wire connector and the other end of wire connector is connected to the single core wire for testing purpose.

The single core wire then being connected to the Dynamic Signal Analyzer to obtained result of the output voltage generate by the generator. Several testing is done for all types of prototype created.

Some testing to the circuitries also has been done to obtain fully optimized storing circuit to be used in this prototype. Two tests will be conduct which are storing by using super capacitor and storing using rechargeable battery.

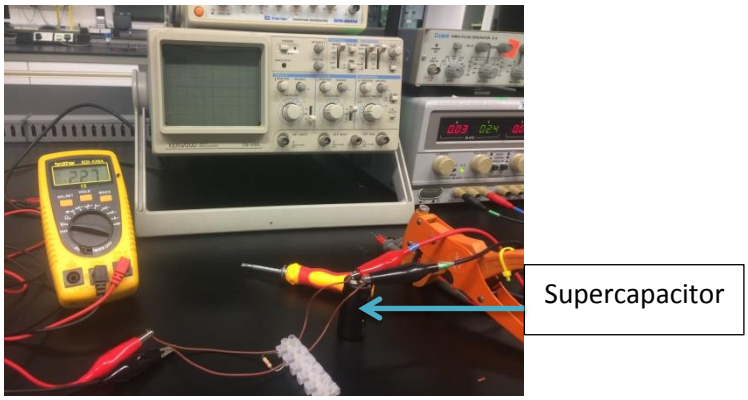


FIGURE 19: Supercapacitor testing

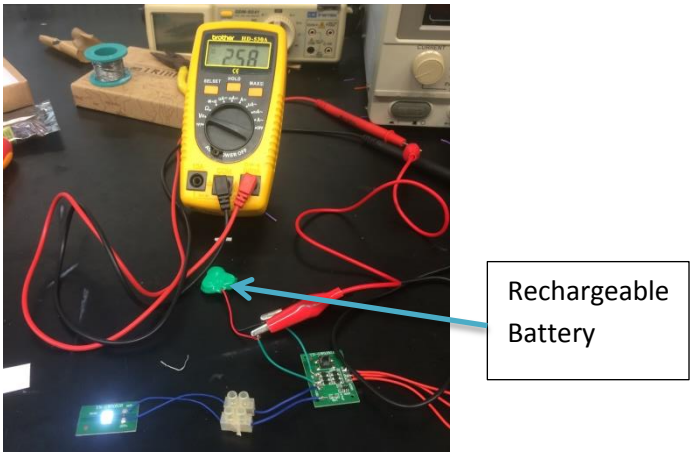


FIGURE 20: Battery testing

3.2.4 FABRICATING

In this stage, Energy Harvester (Generator), Storing Circuitries and LED are combined together as a complete lighting system. The optimized Energy harvester and storing circuit that have been done several testing is connect together by using Rectifier to convert from AC power supply from the energy harvester to be store in the storing circuitries that only accept DC source.

This energy that has been store than is connected to the load which is LED to get a light as and end output of the system. Overview of complete setup of lighting system is shown in Figure 21.

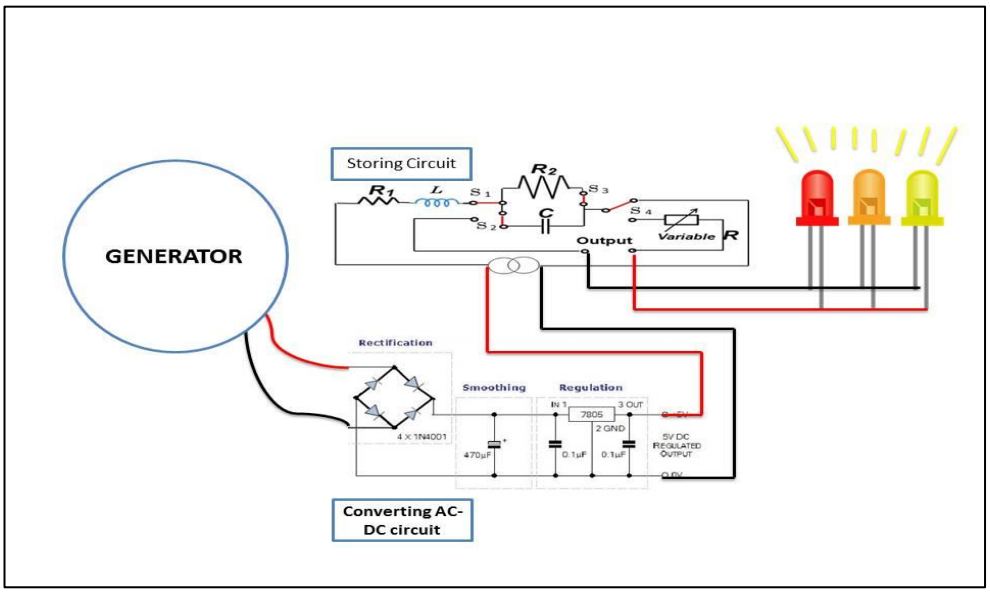


FIGURE 21: Illustration of complete connection of project

3.3 TOOLS & SOFTWARE

In order to complete this project, several tools has been used to make sure this project can be completed smoothly and in a time frame. Tools and software required shown in Figure 22.

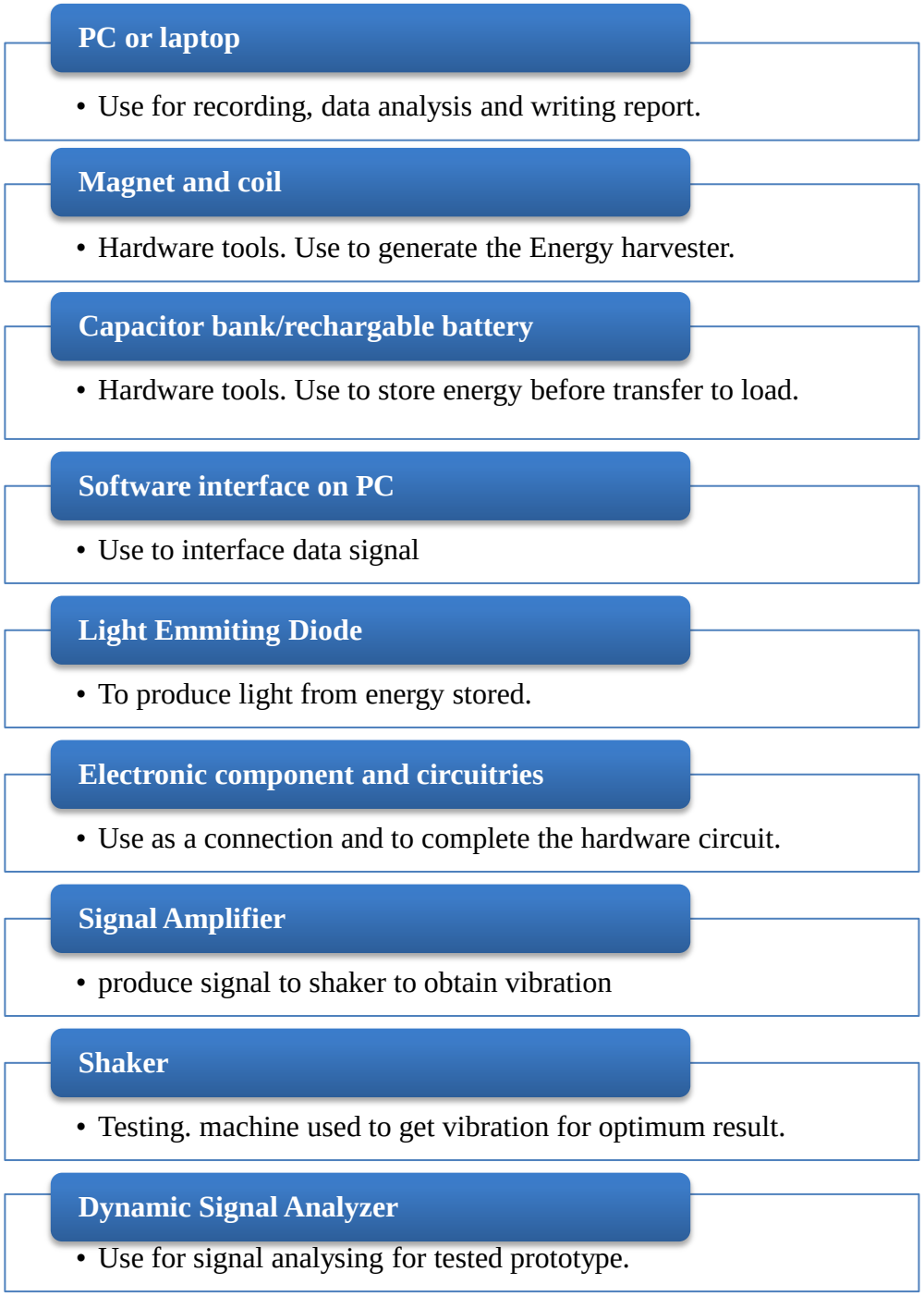


FIGURE 22: List of Tools & software use in this project

3.4 KEY MILESTONE

Final Year Project 1

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Secure topic for FYP 1		2 Oct												
2	Submission Extended Proposal						30 Oct								
3	Proposal Defence									18 Nov					
4	Submission of interim Draft Report													17 Dec	
5	Submission of interim final report														24 Dec

TABLE 1: Key milestone for Final Year Project 1

Final Year Project 2

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Submission of Progress Report								9 Mar							
2	Poster Presentation											30 Mar				
3	Draft report													11 APR		
4	Final report														18 APR	
5	VIVA															25 APR

TABLE 2: Key milestone for Final Year Project 2

3.4 GANTT CHART

Final Year Project 1

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Confirmation topic for FYP 1														
2	Collect Information and study theories														
3	Experimentation & Testing the generator design (Vary Speed)														
3	Proposal Defence														
4	Completing interim Draft Report														
5	Submission of interim final report														

TABLE 3: Gantt chart for Final Year Project 1

Final Year Project 2

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Finalise design for Vary Speed															
2	Experimentation & Testing the generator design (Vary winding method)															
3	Experimentation & Testing the storage															
4	Submission of Progress Report															
5	Experimentation & Testing the generator design (Multiple design)															
6	**Poster Presentation**															
3	**Draft report**															
3	**Final report**															
4	**VIVA**															

TABLE 4: Gantt chart for Final Year Project 2

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 GENERATOR TESTING

Some of the models with several methods have been tested. All of the methods include model with no up convergence and five models with up convergence method which are two models by using balloon as a stopper with different distance from moving magnet, two models is using rubber glove material and the fifth models is using rubber ban as a stopper is tested. All designs use 200 turns winding. Every output graphs was analysed.

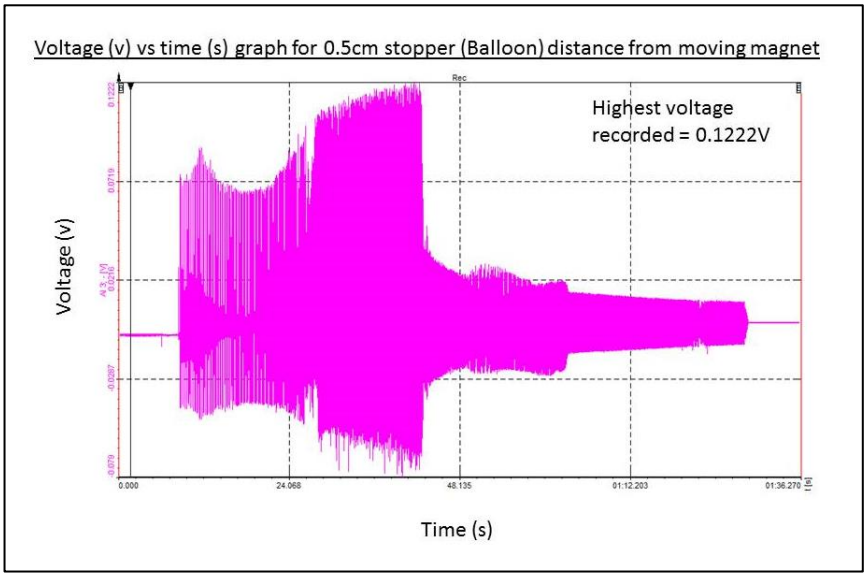


FIGURE 23: Voltage (v) vs time (s) graph for 0.5cm stopper (Balloon) distance from moving magnet

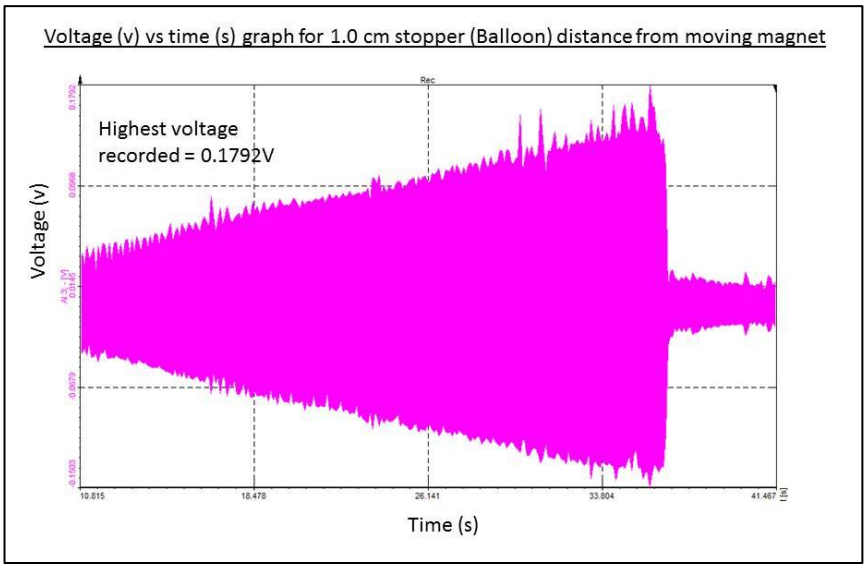


FIGURE 24: Voltage (v) vs time (s) graph for 1.0 cm stopper (Balloon) distance from moving magnet

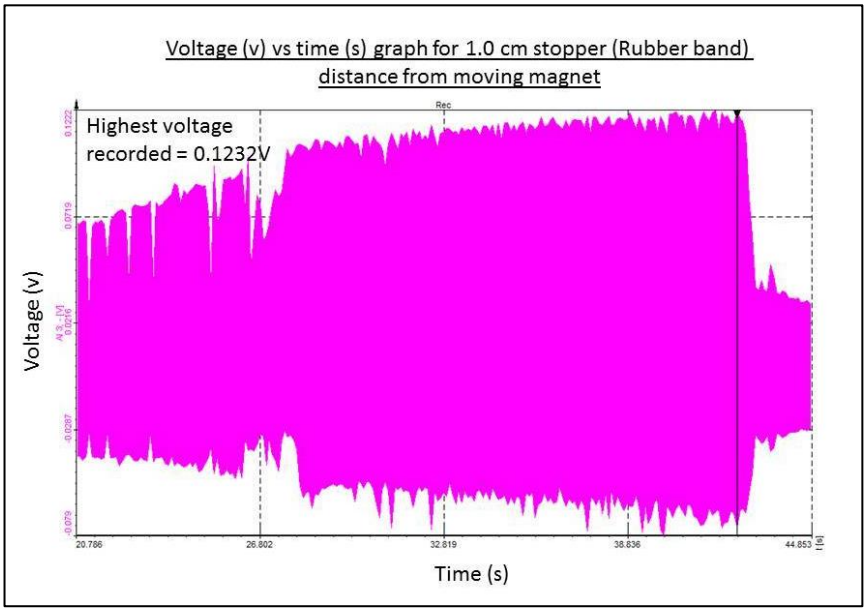


FIGURE 25: Voltage (v) vs time (s) graph for 1.0 cm stopper (Rubber band) distance from moving magnet

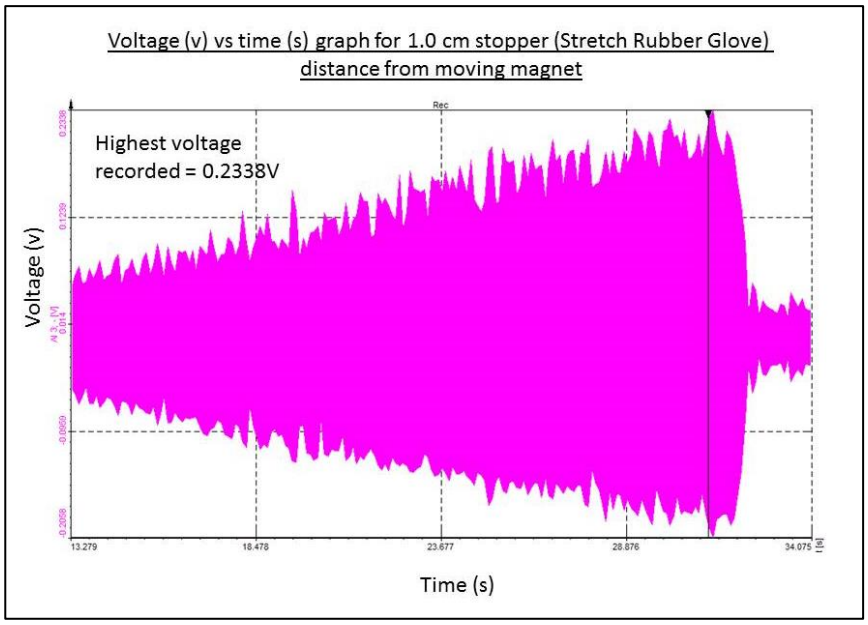


FIGURE 26: Voltage (v) vs time (s) graph for 1.0 cm stopper (Stretch Rubber Glove) distance from moving magnet

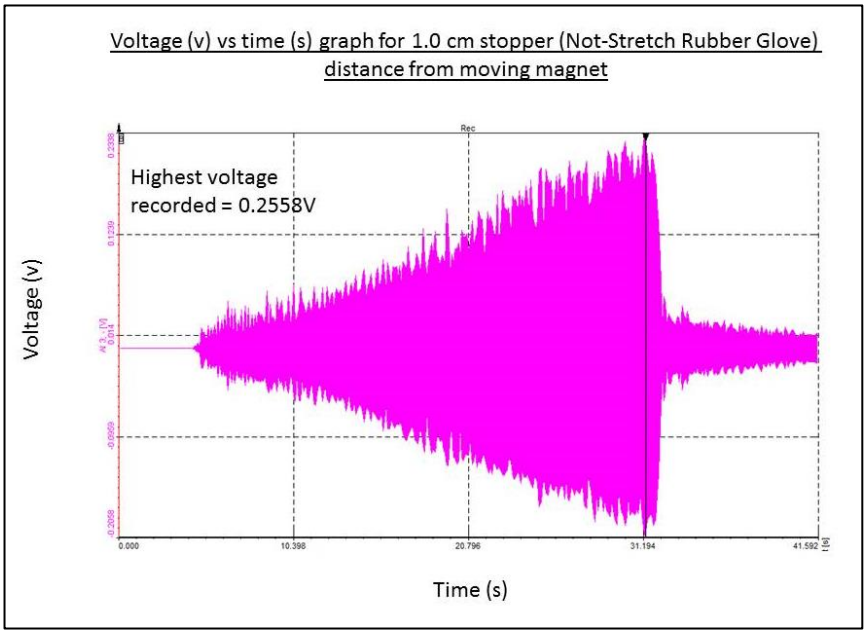


FIGURE 27: Voltage (v) vs time (s) graph for 1.0 cm stopper (Not-Stretch Rubber Glove) distance from moving magnet

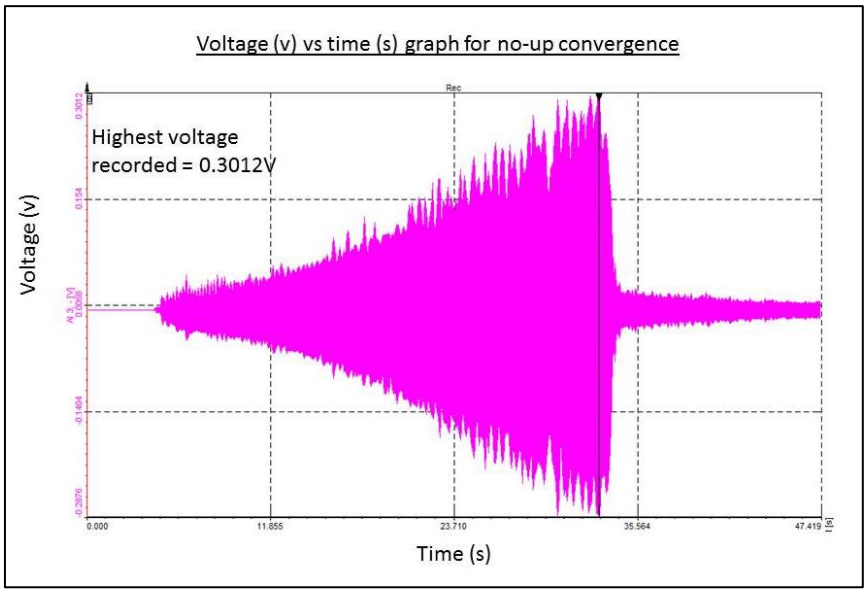


FIGURE 28: Voltage (v) vs time (s) graph for no-up convergence

All the voltage data of testing have been recorded and tabulate in Table 1.

TABLE 5: Average voltage generate by different method.

Type	Maximum Voltage Generate
Method: No up convergence	0.3012V
Method: Up convergence Material: Balloon Distance: 0.5 cm from moving magnet Condition: Stretch	0.1222V
Method: Up convergence Material: Balloon Distance: 1.0 cm from moving magnet Condition: Stretch	0.1792V
Method: Up convergence Material: Rubber band Distance: 1.0 cm from moving magnet Condition: Stretch	0.1232 V

Method: Up convergence Material: Medical rubber glove Distance: 1.0 cm from moving magnet Condition: Stretch	0.2338V
Method: Up convergence Material: Medical rubber glove Distance: 1.0 cm from moving magnet Condition: Not Stretch	0.2558V

The result concluded that model with no up convergence give higher output result compare to other models that use up convergence method. The up convergence method used in this project experiment failed due to result obtain and initial expectation is different. The moving magnet did not move faster if up convergence is applied besides, the up convergence damping the movement of the magnet.

Conclusion can be made to choose the design to use in this project. No up convergence method is chosen as final design as it gives higher output compare to other models that use up convergence method.

In the next step, the result is taken by experimenting and varying the method of winding the generator. Some of calculation has been done to find the best output produce by the generator.

Theoretical calculation has been done to some of final model. This calculation is a reference to the final generator design that will be built after considering many factor and criteria throughout this project. This calculation used basic faraday's law equation as in Equation 1 to get an expected voltage output based on theoretical calculations.

Faraday's law formula:

$$e = -N\frac{\Delta(\beta A)}{\Delta t}$$

EQUATION 1: Faraday's law equation.

The calculation is done for two types of models which are the first models is center coil design and the other models are end-to-end coil design. For the both coil design, fixed parameters are magnetic strength diameter of coil and area of coil. 500 turns is used for center coil model and 250 turns coil is used for each end-to-end coil which will give 500 turns in total. The calculations are as follow:

Calculation for centre coil design

$No\ of\ turns = 500 \quad radius = 0.0075m \quad height = 0.03m$

$\beta = 2.8\ tesla$

$cylinder\ area,\ A = 2\pi rh + 2\pi r^2$

$= 2\pi(0.0075)(0.03) + 2\pi(0.0075^2) \qquad \frac{\Delta\beta}{\Delta t} = 2.8T/s$

$A = 1.76715\ \times 10^{-3}m^2$

$voltage\ generate = -500 \times 1.76715\ \times 10^{-3} \times 2.8\ =\ |2.47|V$

Calculation for end-to-end coil design

$No\ of\ turns = 250 \quad radius = 0.0075m \quad height = 0.02m$

$\beta = 2.8\ tesla$

$cylinder\ area,\ A = 2\pi rh + 2\pi r^2$

$= 2\pi(0.0075)(0.02) + 2\pi(0.0075^2) \qquad \frac{\Delta\beta}{\Delta t} = 2.8T/s$

$A = 1.29591\ \times 10^{-3}m^2$

$voltage\ generate = -250 \times 1.29591\ \times 10^{-3} \times 2.8\ =\ |0.9|V$

$with\ two\ coil\ for\ end\ to\ end = 0.9 \times 2 =\ 1.8\ V$

Based on the calculations, center coil can generate up to 2.47 V and end-to-end coil can generate up to 1.8 V per generator. Conclusion result shows that center coil give higher output voltage compare to end-to-end coil. However, both designs are tested to compare theoretical calculation result with experimental result.

The experiment has been done by using shaker to produce vibration and dynamic signal analyser to capture waveform to both designs which are center coil design and end-to-end coil design to compare which design give better output result in term of producing energy if being experimented hardware. 500 turns is use in center coil design and 250 turns each for every end for end-to-end coils design which give total of 500 turns for both design.

Result for center coil design and its natural frequency are shown in Figure 29.

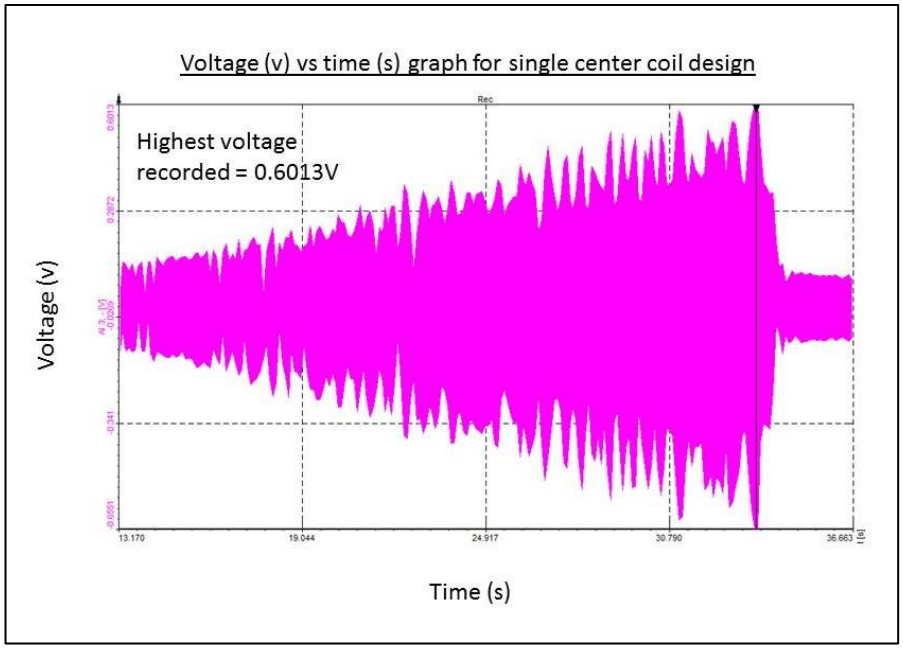


FIGURE 29: Voltage vs Time graph for output voltage produce by center coil design.

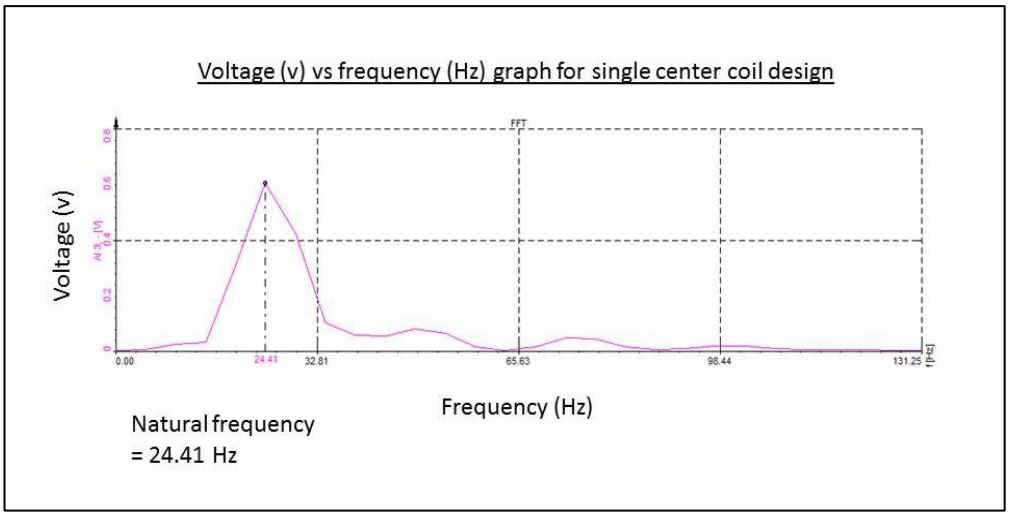


FIGURE 30: Voltage vs frequency graph for single center coil design

For center coil design, the output result produce by single generator is 0.6013V. By using fast furrier transform, natural frequency can be captured is 24.42Hz for this design generator. Conclusion from the result is, for this type of generator, highest voltage output produce is 0.6013V at 24.42 Hz.

Result for end-to-end coil design and its natural frequency are shown in Figure 31.

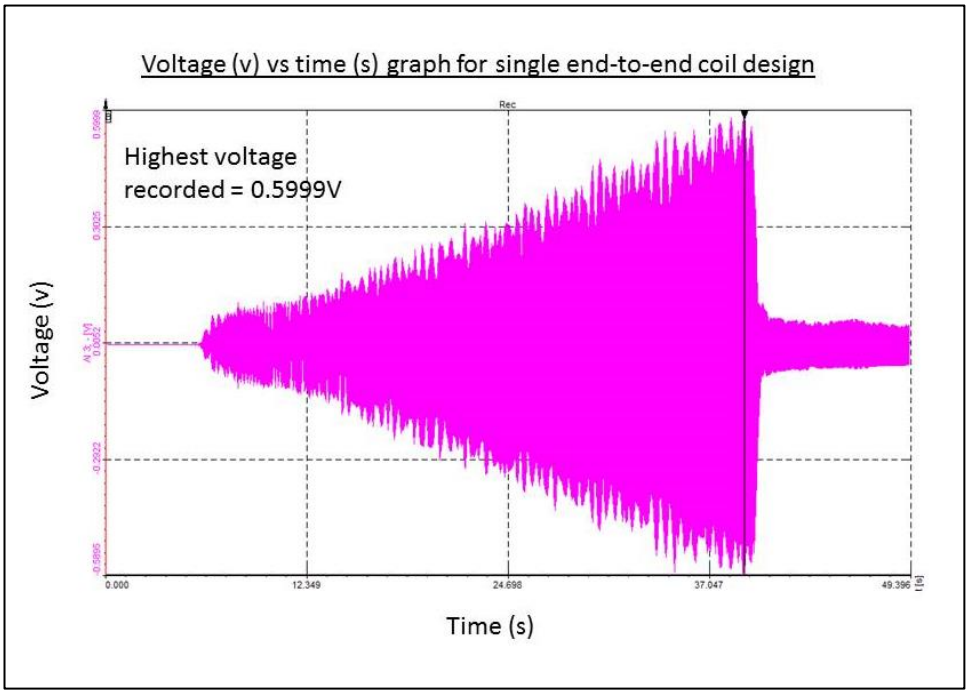


FIGURE 31: Voltage vs Time graph for output voltage produce by end-to-end coil design.

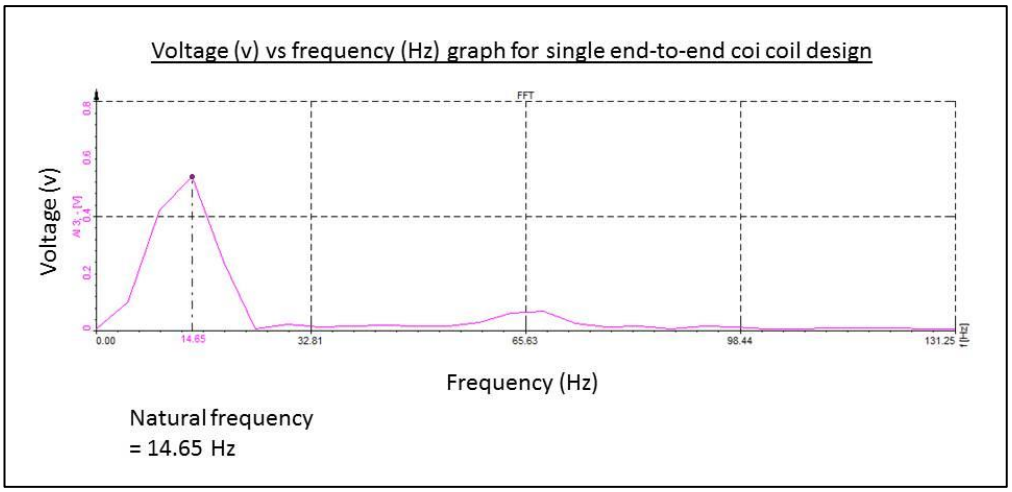


FIGURE 32: Voltage vs frequency graph for single end-to-end coil design

For end-to-end coil design, the output result produce by single generator is 0.5999V. By using fast furrier transform, natural frequency can be captured is 14.65Hz for this design generator. Conclusion from the result is, for this type of generator, highest voltage output produce is 0.5999V at 14.65 Hz.

By comparing both designs, center coil give higher output voltage compare to end-to-end coil. As conclusion, center coil design is experimented further by combining multiple center coil design together and connected it in series to produce voltage up to 1.5V.

Three center coil design is experimented by connecting three of this model into series. The result for voltage output and its natural frequency is shown in Figure33.

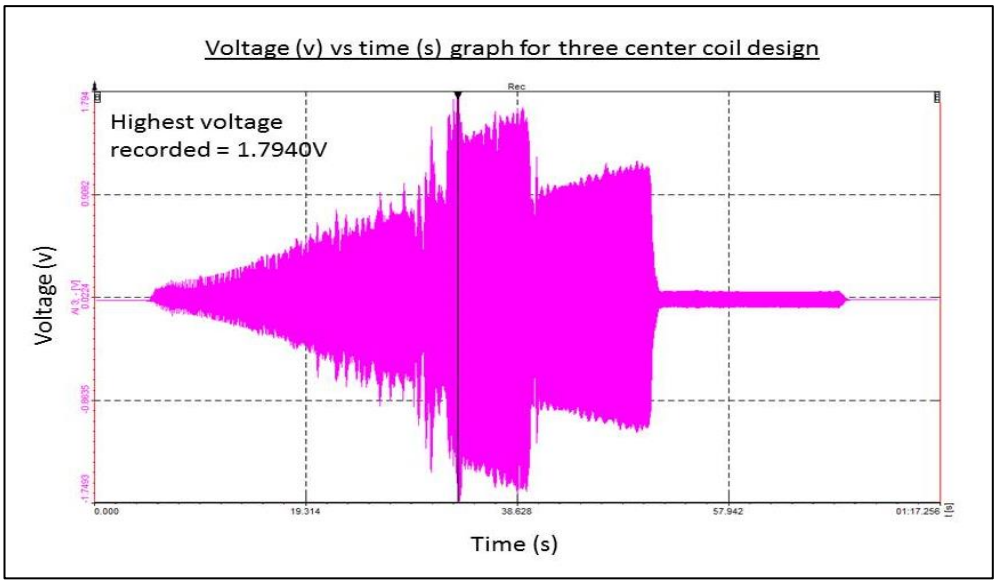


FIGURE 33: Voltage vs Time graph for output voltage produce by three center coil design.

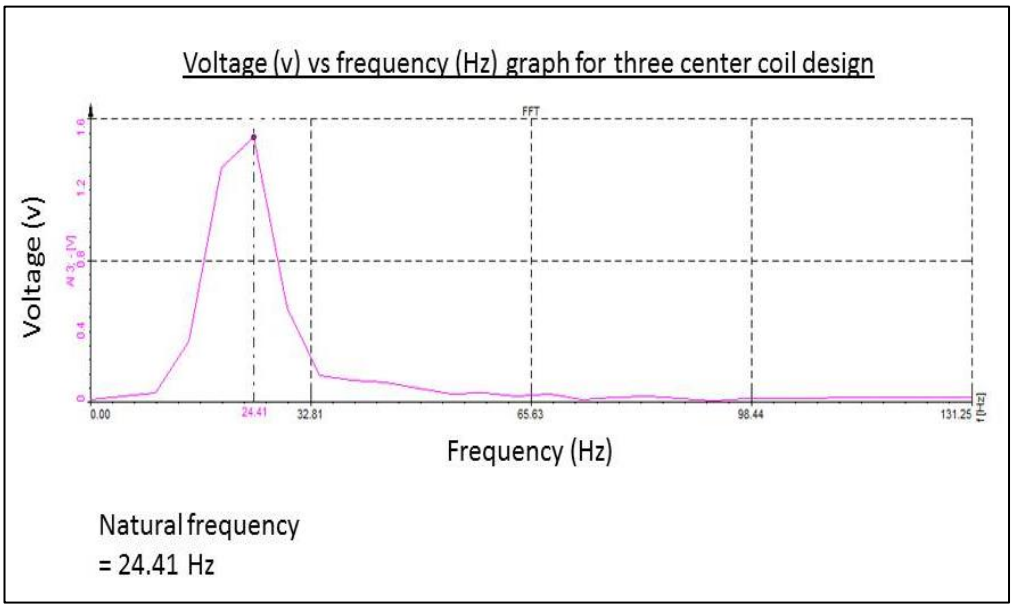


FIGURE 34: Voltage vs frequency graph for three center coil design.

By experimenting with three center coil generator, the output voltage result produce by these type of generator connected in series can give an output up to 1.7940V. By using fast furrier transform, natural frequency can be captured is 24.41Hz for this design generator. Conclusion from the result is, for this type of generator, highest voltage output produce is 1.7940V at 24.41Hz.

Output voltage produce by combining three center coil generator in series is sufficient as it exceed the target output voltage for this project which is 1.5V.

4.2 STORAGE TESTING

Two type of storing circuit has been tested which is by using 2.7V, 100F supercapacitor and 3.6V rechargeable batteries. Based on the testing result, 3.6V batteries cannot be use as the voltage produce by the generator is low and cannot reach the voltage of batteries hence energy cannot be store as different in voltage level.

However, supercapacitor can be use although the voltage is lower. The supercapacitor have a characteristic of fast charging and slow discharging, this will make a perfect storage for this project.

4.3 LED TESTING

Testing for load which is LED have been done and four voltage level indicate the brightness of the product LED. Testing has been done by varying voltage from lower up to higher voltage product LED can support by using DC power source from DC power supply machine. Testing results are as Figure 35.

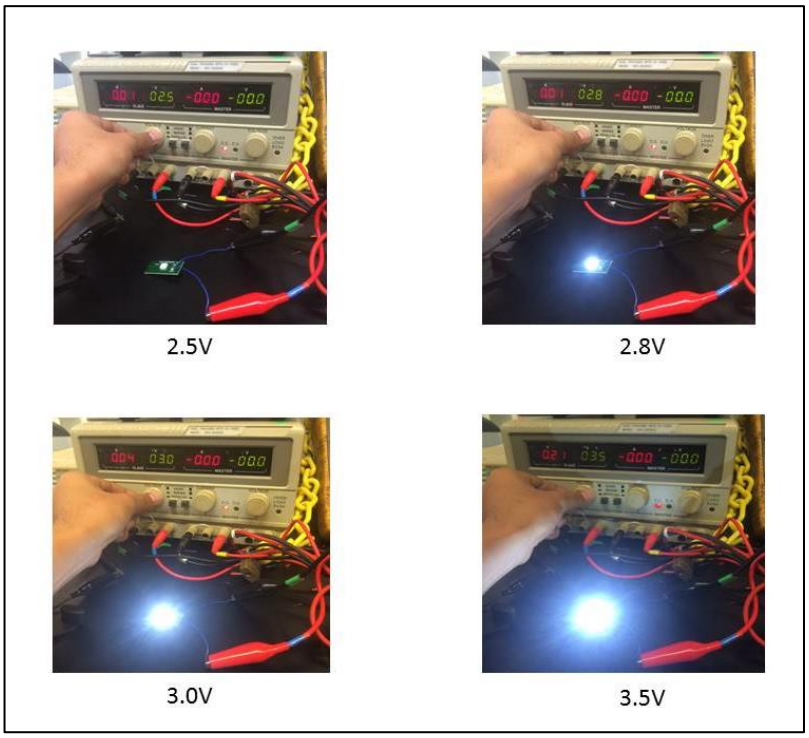


Figure 35: Different voltage testing for product LED

Based on test result, the LED is OFF mode from 0V to 2.5V. LED start to light up at voltage of 2.8V. The brightness of LED is at average when voltage reaches 3.0V. The highest voltage for LED to provide brightest light source is at 3.5V and the brightness is at maximum.

However this type of LED cannot be use is this project as voltage produce is lower and the LED might drain power faster. Hence, normal LED will be use.

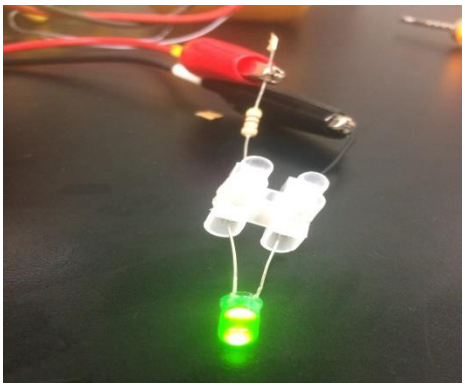


FIGURE 36: LED testing

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objective of this project is to design and fabricate a self-powered generator to power a flashlight from a small scale generator. Besides, integrate charging and storing of energy circuit for the system. Therefore, with guidance and various types of experiment and testing, the optimization of each part of the project can be achieved and one prototype of self-powered kit for lighting system can be finalised. This will then help society toward a better life which the use of conventional batteries will reduce hence, reduce pollution created by the batteries waste.

5.2 RECOMMENDATION

Some recommendation can be made in order to improve this project for further research. The four elements that need to be study further are as follow:

- Increase magnetic field strength
- Increase size of coil
- Increase speed of relative motion
- Increase number of turns

By improving this entire element, optimize design of linear motion electromagnetic generator can be achieve and better output can be harvest from this generator.

REFERENCES

[1] ""Flashlight." How Products Are Made," 2001. [Online]. Available: http://www.encyclopedia.com/topic/Flashlight.aspx. [Accessed 20 October 2015].

[2] flashlight22, "A Backgroung In Major Criteria In Cree Flashlight," 2013. [Online]. Available: https://www.wattpad.com/37253000-a-background-in-major-criteria-in-cree-flashlight. [Accessed 20 october 2015].

[3] R. Y. C.B. Williams, "ANALYSIS OF A MICRO-ELECTRIC GENERATOR FOR MICROSYSTEMS," in *The 8th International Conference on Solid-state Sensors and Actuators, and Eurosensors IX*, Stockholm, Sweden, 1995.

[4] P. B. S, J. T. M and M. W. N, "Energy harvesting vibration sources for microsystems applications," *Meas. Sci. Technol.,* vol. 17, pp. R175-R195, Dec 2006.

[5] R. Gherca and R. Olaru, "Power Analysis for an Electromagnetic Generator With Magnets Destined to Vibration Energy Harvesting.," in *International Conference and Exposition on Electrical and Power Enegineering (EPE 2012)*, lasi, Romania, 2012.

[6] X. Jiang, Y. Li and J. Li, "Design of a Novel Linear Permanent Magnet Vibration Energy Harvester," in *2013 IEEE/ASME International Conference*, Australia, 2013.

[7] "Faraday Law of Electromagnetic Induction," 2011. [Online]. Available: http://www.electrical4u.com/faraday-law-of-electromagnetic-induction/. [Accessed 23 October 2015].

[8] 6. e. The Columbia Encyclopedia, ""induction (in electricity and magnetism)"," 2015. [Online]. Available: http://www.encyclopedia.com/doc/1E1-induct-ele.html. [Accessed 23 October 2015].

[9] C. R. Nave, "Magnetic Leviation," 2014. [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/solids/maglev.html#c2. [Accessed 26 October 2015].

[10] C. R. Nave, "Leviation Currents," 2014. [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/solids/maglev.html#c2. [Accessed 26 October 2015].

[11] L. Zyga, "Can Capacitor in Electrical Circuits Provide large-scale energy storage?," 2 December 2014. [Online]. Available: http://phys.org/news/2014-12-capacitors-electrical-circuits-large-scale-energy.html. [Accessed 25 October 2015].

[12] H. Kulah and K. Najafi , "Energy Scavenging From Low-Frequency Vibrations by Using Frequency Up-Conversion for Wireless Sensor Applications," *IEEE SENSORS JOURNAL*, vol. 8, pp. 261-268, MARCH 2008.

[13] A. K., "Analysis of frequency up-conversion based vibration energy harvesting," in *Micro and Nnoelectronics (RSM), 2011 IEEE Regional Symposium on*, Kota Kinabalu, 2011.

[14] K. Ashraf, "A wideband, frequency up-converting bounded vibration energy harvester for a low-frequency environment," in *SMART MATERIALS AND STRUCTURES*, 2013.

[15] O. Zorlu, "A Vibration-Based Electromagnetic Energy Harvester Using Mechanical Frequency Up-Convergence Method," *IEEE SENSORS JOURNAL*, vol. 11, FEBRUARY 2011.