ENSC 305W/440W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with proper justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent valid design specifications that will be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science.	**/20%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for functional specs.	**/15%**
Test Plan	Provides a functional test plan for the present project version. (Note that project success will be measured against this test plan.)	**/10%**
Conclusion/References	Summarizes functionality. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow in a logical manner.	**/05%**
Format Issues	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
Comments		

November 13, 2013

Mr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Design Specification for Power-Generating Shoes

Dear Mr. One,

This document is from ePower that states a set of technical guidelines for design of the eShoe. The eShoe is a pair of shoes with portable charger that will convert mechanical energy into electrical energy and it will be stored into a rechargeable battery.

The design specification described in this document indicates the process of how we achieve the specifications provided in our design specification. Moreover, this document applies to the proof-of-concept model only. Design improvements for future iterations of the eShoe are discussed, but will not be discussed in this stage of development.

ePower Incorporated consist of 4 talented senior engineering students: Janine Li, Eric Yang, George Gu, and Edward Huang. If you have any questions about the design specification or our company, please feel free to contact us by phone at 778-836-9730 or by email at jiayinl@sfu.ca.

Sincerely yours,

Janine Li
Chief Executive Officer
ePower Incorporated

Enclosure: Design Specification for Power-Generating Shoes

Design Specification for Power-Generating Shoes

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Submitted to: Mr. Lakshman One – ENSC440
Mr. Michael Sjoerdsma – ENSC305
School of Engineering Science
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Issued Date: November 14, 2013

i. Executive Summary

This design specification document provides a set of detail descriptions of the technical solutions to the design and development of our prototype. This prototype will be used for proof-of-concept purpose and meet the requirements as specified in the document *Functional Specification for Power-Generating Shoes* [1].

This Design Specification document is divided into two parts: mechanical design, electronic design and safety design. Each part will be discussed in detail.

The mechanical design mainly focuses on what we use for our design, how the entire system and every individual component work, and where do we install the entire components.

The electronic design includes dynamo design, energy storage circuitry design and charging circuitry design. Since the output voltage from the dynamo is AC and unstable, we need to convert it to DC and stabilize it. Since the rechargeable battery we will be using requires 5V voltage input, we have designed a 5V step-up voltage regulator.

In order to ensure eShoe will meet the goal, we have created a system test plan. The test plan includes individual component test and integration test. Once the integration test is done, we will continue testing our prototype for typical daily usage to meet our functional specification requirements [1].

We will meet the targeted delivery date of Wednesday, Nov 27th for the proof-of concept model of the eShoe.

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Glossary

AC Alternating Current

DC Direct Current

PCB Printed Circuit Board

1 Introduction

The eShoe is a pair of shoes that has no difference from other any kinds of shoes in appearance, but it will generate power by the power generator inside of the shoes while users are walking; thus, users will not feel desperate when their electronic devices are out of battery. This design specification describes the technical details for the design of each component of the eShoe.

1.1 Scope

This document specifies the design of the eShoe and explains how the design meets the functional requirements as described in the *Functional Specification for Power-Generating Shoes* [1] from proof-of-concept to final production.

1.2 Intended Audience

The design specification is intended to use by the members of ePower. Design engineers shall refer to the specifications as overall design guidelines to ensure all requirements are met in the final product. Test engineers shall also use the document to implement the test plan and to confirm the correct behavior of the eShoe.

2 System Specification

The eShoe will generate and store electrical energy to a rechargeable battery, and the battery can be used to charge their portable electronic devices. With eShoe, users can get “free” energy without the worry of the power source. The principle of eShoe is to covert the mechanical energy to electrical energy when users are walking. As long as users keep walking or running, the energy will be generated continuously.

3 System Design

This section provides a high-level overview of the entire designs including mechanical design, electrical design and safety design.

3.1 Mechanical Design

Figure 1 provides the overview of the proposed mechanical design for the eShoe. While designing the mechanisms to convert mechanical energy to electrical energy, we have considered the following options:

- piezoelectric transducers
- electrical generators

Upon further research and our own experiments, we found that piezoelectric transducers did not work efficiently. Even though each piezoelectric transducer was very thin and users would not feel tired while walking, the power created in each step was too limited. We also built a stack of piezoelectric transducers and paralleled them in the circuit in order to create more energy in each step. The power was larger than before, but it was still not enough to charge a battery. After considering the above points and our lack of experience with piezoelectric transducers, we had to give up this option. Since electrical generators can generate enough energy we need for battery and it is easy to get one at a low cost, they become the best choice for our design.

When users' feet hit the ground and release, the motion is up and down which is a linear motion. However, we have to provide circular motions in order to make an electrical generator generate energy. Also, the speed must be fast enough to make the electrical generator work. Figure 1 below shows the transformation from linear motion to circular motion.

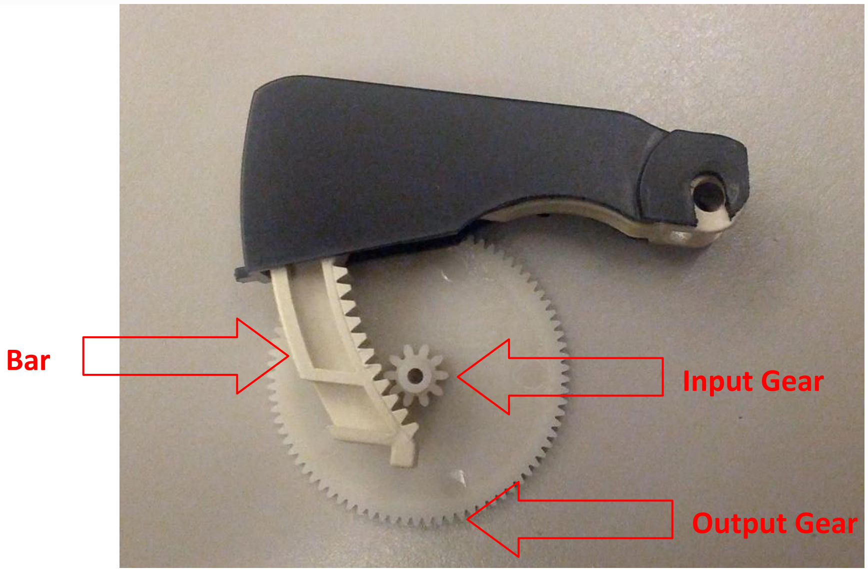

Figure 1: Linear Motion to Circular Motion

When the shoe hits the ground, the gravity will decrease the displacement between shoes and ground, and the spring inside will be compressed. When users release their feet, the spring will make the bar return to original place. Meanwhile, the teeth on the bar are always connected with the input gear. Every time the bar is moving up and down, the input gear will rotate clockwise and counter clockwise based the motion of the bar. At the same time, the output gear will be driven by the input gear. As shown in Figure 1, the input gear has 10 teeth while the output gear has 90 teeth. Both of them have the same angular speed, but the output gear can provide nine times faster speed than the input gear.

Moreover, considering the motion users provides has two opposite directions, we designed a ratchet, which is linked to an electrical generator, so that the electrical generator will rotate in one direction only. Figure 2 is the picture of the electrical generator with a ratchet.

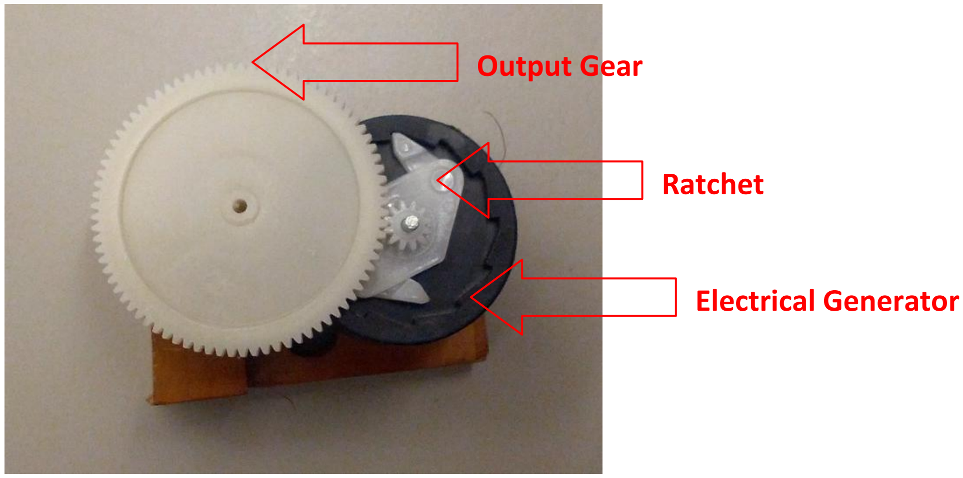

Figure 2: Ratchet Design

When the output gear drives the gear on the ratchet counter clockwise, the two teeth on the ratchet will also drive the electrical generator to rotate. However, if the ratchet rotates clockwise, it will not drive the electrical generator so that the electrical generator will only rotate in counter clockwise when users are walking.

Another consideration is the location we put the whole components in the shoe. Based on our knowledge and several experiments, we confirmed that it worked most efficiently at the heel of shoes. When it is at the heel, it is easier for users to give the pressure on it, because the most weight is at the back when people are walking. Also, the height of the whole components is about 5 cm in our prototype (the height can be reduced by using smaller gears in our production stage), so the heel of the prototype shoes must be at least 5 cm.

Moreover, a micro USB cable will come out from the back of shoes so that users can charge a rechargeable battery or an electronic device which can be fastened on their legs. The battery we use is shown in the following figure.

Figure 3: Rechargeable Battery

3.2 Electronic Design

This section provides an electronic design of the entire system including dynamo, energy storage circuitry and charging circuitry. Also each sub-section would describe the relationship between each component with figures.

3.2.1 Dynamo – Mechanical to Electrical Converter

A dynamo is an electrical generator that generates AC current. In the industrial history, dynamos are recorded as the oldest electrical generators and used to deliver power. The dynamo is made of stationary coils of wire and rotating magnetic fields to covert mechanical rotation into a pulsing AC current which developed base on the Faraday's Law. Faraday's Law indicates that if there is any change in the magnetic environment of a coil of wire, an AC voltage will be generated [2]. The following figure shows the side view of a dynamo electric machine.

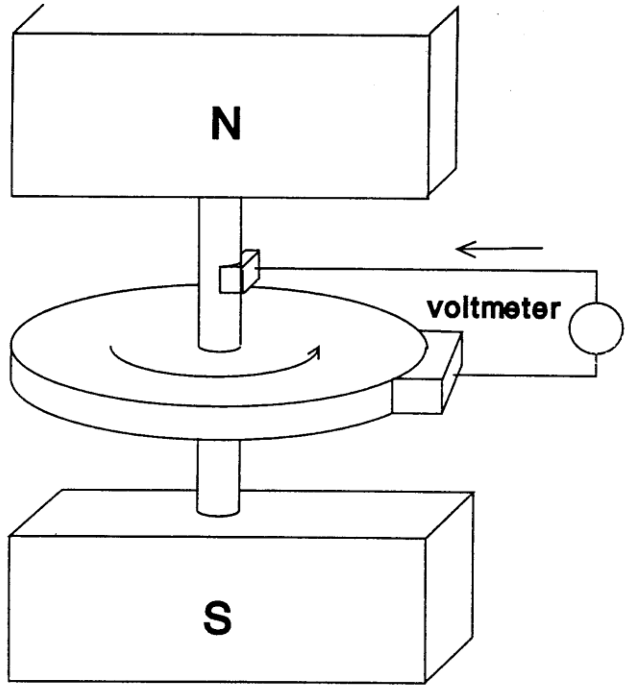

Figure 4: Dynamo Electric Machine [3]

Figure 5 is the side view of the dynamo coil that we will be using.

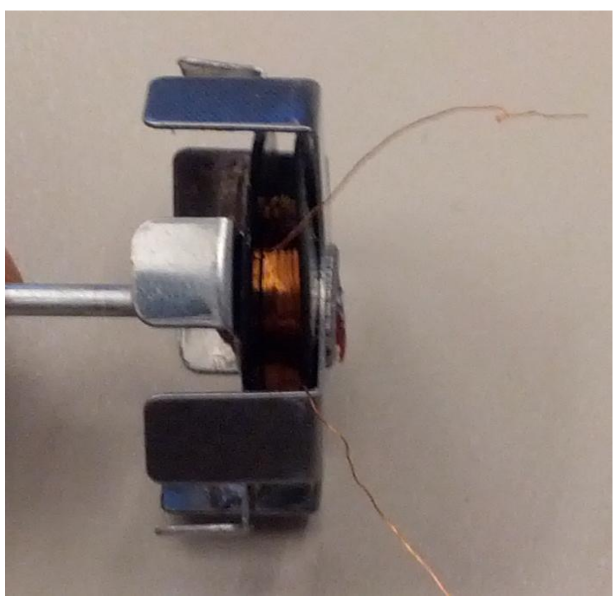

Figure 5: Side View of Dynamo Coil

3.2.2 Energy Storage Circuitry

Since the output from the dynamo is AC and the voltage produced is not stable, we need to convert and stabilize the output to DC. Therefore, we have designed a rectifier and a capacitor to store the energy. The rectifier we are using is a full wave bridge rectifier and the capacitor is a 1F super-cap. The diagram below is the schematic drawing. The AC power supply on the diagram is the dynamo we use as the mechanical to electrical converter, and the load on the diagram will be our charging circuitry (See 3.2.3 Charging Circuitry).

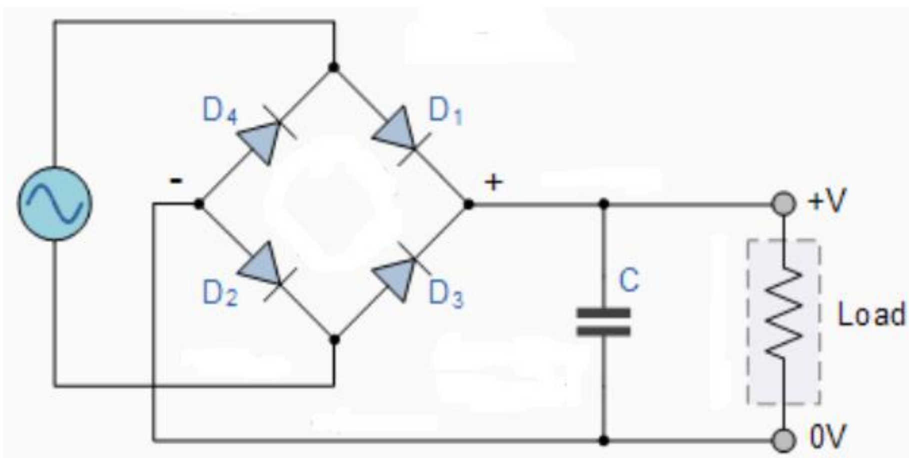

Figure 6: Full Wave Rectifier [4]

3.2.3 Charging Circuitry

The output of the bridge rectifier we tested was less than 4V but greater than 2V, and the charging voltage need to be about 5V in order to charge a rechargeable battery; therefore, a step up voltage regulator is required in our circuit to meet the design specification. After our research, we have decided to use NCP1402 step up voltage regulator, and the following is the schematic diagram of the voltage regulator. VOUT on the diagram will be connected to a rechargeable battery through a USB cable.

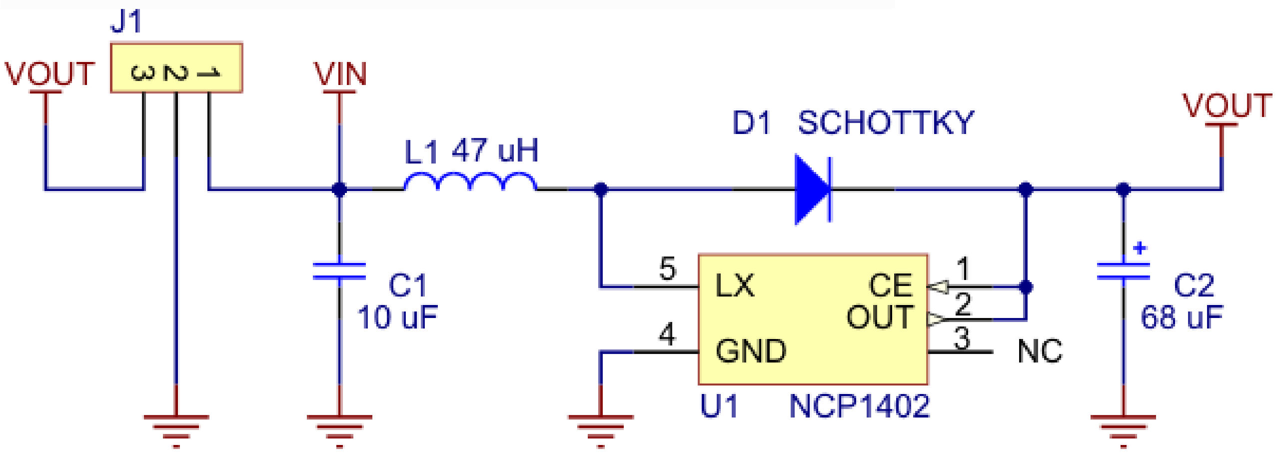

Figure 7: Step-Up Voltage Regulator Schematic Diagram [5]

The following diagram is the representative block diagram for NCP1402.

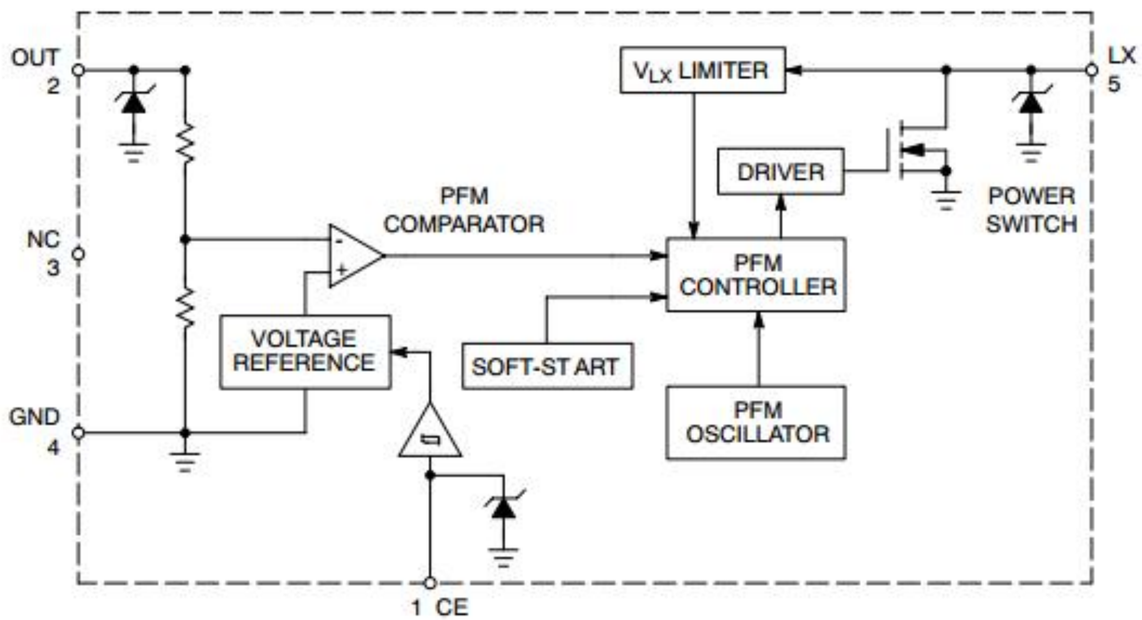

Figure 8: Representative Block Diagram [6]

3.3 Safety Design

All the components are designed to put around human's feet, so safety is an important consideration for the design and the following issues are considered:

- Electricity Leakage
- Electrical shock
- Water proofing

The rated voltages of all the components on the circuitry are under 25 V for safety [7]. The circuitry will be tested on breadboard first to check for short circuits. In the prototype, all the exposed junctions will be taped using electrical tapes. Also, the entire components will be enclosed in a plastic case to prevent any electrical shock and the device will be water resistant. In the final product, all the components will be soldered on a PCB and will be protected by an insulated cover.

4 System Test Plan

In order to make sure the product functions properly and stably, ePower has proposed a system test plan. The system test plan is divided into two parts: individual module testing and integration testing. Individual testing is conducted in order to make sure the proper functionality of each module we use, and integration testing will be conducted after every individual component is tested to ensure that the whole system works as expected.

4.1 Individual Module Testing

The Individual module tests are performed once the modules are built or bought. The tests include but are not limited to the following:

4.1.1 Mechanical to Electrical Energy Converter

- Able to convert the mechanical pressure into electrical energy
- Able to be reused so that it produces energy at every step people take

4.1.2 Energy Storage Circuitry

- Able to store unstable electrical energy
- Able to convert AC to DC

4.1.3 Charging Circuitry

- Able to convert the energy stored in the energy storage circuitry to a stable 5V DC voltage
- Able to fully charge a rechargeable battery

4.2 Integration Testing

After individual module testing has been completed, integration testing will be performed as follow:

- Integrate mechanical to electrical converter with energy storage circuitry to make sure the circuitry can store the energy produced by the converter
- Integrate the charging circuitry with above to make sure the energy stored in the storage circuitry can charge a rechargeable battery

4.3 Typical Usage Scenario

The eShoe prototype will be tested in many ways in order to simulate real world situations, so that we can ensure the output as expected and users will not feel uncomfortable wearing our shoes, and the tests include but are not limited to the following:

- Test on two or more people with different weights
- Test in sunny and rainy days
- Test on smooth grounds and rough grounds
- Test on uphill and downhill

Note: every test above will be tested with 1 minute of walking without battery attached, 30 minutes of walking with battery attached, and 30 minutes of running with battery attached

5 Conclusion

In order to meet the functional specification of the eShoe, the possible design solution is documented in this design specification. The possible design solution and components we need have been discussed in detail. We can ensure that all the required functionality of the eShoe will be presented after our test plan. The development of our prototype will match the specifications as many as possible. The design specification clearly lays out goals for the development of the eShoe prototype.

6 References

[1] ePower Incorporated, “Functional Specification for Power-Generating Shoes”, Simon Fraser University, Burnaby, BC, Canada, October 2013.

[2] "Dynamo" Internet: http://en.wikipedia.org/wiki/Dynamo, Oct. 28th, 2013[Nov. 8, 2013]

[3] David P. Stern, "The Dynamo Process." Internet: http://istp.gsfc.nasa.gov/earthmag/dynamos.htm, April 12, 2007 [Nov. 8, 2013]

[4] Wayne Storr. "Basic Electronics Tutorials." Internet: www.electronics-tutorials.ws/diode/diode_6.html, Nov. 2nd, 2013 [Nov. 10, 2013]

[5] Pololu Corporation. "Pololu Robotics & Electronics." Internet: www.pololu.com/picture/view /0J1185, 2013 [Nov.8, 2013]

[6] Pololu Corporation. "Pololu Robotics & Electronics." Internet: www.pololu.com/file/0J167/NCP1402-D.pdf, 2013 [Nov.8, 2013]

[7] M. Voigtsberger, “Small Contact Voltage Exposures Not Lethal to Human.” Internet: http://ecmweb.com/shock-amp-electrocution/small-contact-voltage-exposures-not-lethal-human, Sept. 20th 2012 [Oct. 15, 2013]

