2014 -2015

[BOOST BATTERY]

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<table>
<tr><td colspan="2">Boost Battery</td></tr>
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Lacy Sigman</td><td>Dr. Ahmad Nafisi
1. I agree to supervise this senior project.
A.N.____
2. The specifications are [1]-[2]:
☐ Abstract—Describes what project should do, not how.
☐ Bounded—Identify project boundaries, scope, and context
☐ Complete—Include all the requirements identified by the customer, as well as those needed to define the project.
☐ Unambiguous—Concisely state one clear meaning.
☐ Verifiable—A test can prove if system meets specification.
☐ Traceable—Each engineering specification serves at least one marketing requirement.</td></tr>
<tr><td colspan="2">ADVISORS: Please initial above, if you agree to supervise this senior project. Also, please check applicable boxes above. Comment below, if requirements or specifications require revision.</td></tr>
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Abstract

In modern times, the problem of a depleted battery confronts us too often. Whether it appears with a smartphone or with any other electronic device, the situation frustrates all consumers. This project designs and constructs a compact portable battery charger that charges through kinetic energy. Thus, one can perform everyday activities, such as walking or running, and charge up a backup battery with no extra effort or time. Additionally, an attachable band harvests thermal energy to maximize the amount of clean power generated. Energy harvesting from kinetic motion and thermal differences provide users with power when no actual power suppliers are nearby; a crucial advantage especially for emergency situations.

So much of the energy we expend throughout our day escapes into the environment. As renewable energy becomes more necessary in today's culture, Boost provides an option for those trying to cut back on electricity costs or those trying to reduce their carbon footprint. Now, with this power bank, the heat and movement of your body directly charge your phone or personal electronic device. The user can even harness the energy of their pet by attaching it to their dog or cat if they do not feel up for running any further.

Chapter 1

Introduction

Two of the most reliable forms of energy harvesting today are kinetic and thermal energy. Solar energy only works efficiently with sunlight, wind only works with a breeze, and hydro only works with water flow. Kinetic and thermal energy, however, generate by simply shaking one's arm or placing a hot cup of coffee on a pad. Our design project seizes this advantage and provides its users with a system to harvest energy at any time or place. This potentially benefits all six billion cell-phone customers and any other consumer with a USB-enabled electronic device [16]. Ideally, users can charge the battery at both active and rest times of the day.

In this project, we aim to innovate, design, build, test, and produce an efficient energy harvesting portable battery. It harnesses energy from everyday kinetic motions and temperature differences. Two forms of energy harvesting mean a quicker charge of battery and therefore more convenience for users. The project also documents how much power we store from 10,000 steps and an average temperature difference of 20°C [23]. The successful implementation of our design may lead to advances in clean energy generation and easily accessible power.

Today's portable battery chargers can charge a smartphone about 1-5 times before needing a grid-powered supply source, unlike the kinetic energy portable battery charger; ideally, Boost has infinite off-grid charges [25]. The device also potential displays battery life so the user knows how long the device lasts. Similar devices exist in the current market; however, most products remain military focused or very costly. Our product benefits consumers by decreasing cost and size while still yielding enough storage to charge a smartphone for at least one cycle.

Our solution trumps the creation of a larger capacity, grid-powered battery as an answer to the problem. A smaller, human-powered battery provides the user with the satisfaction of reducing their respective carbon footprint throughout their everyday tasks. If someone does not value the smaller size of their carbon footprint, the diminishing electricity costs in charging their phones for hours a day may instead appear enticing. Also, since device size can decrease as a result of continual charging; assuring the user of a smaller, cheaper, consistent energy source.

Future Considerations

The Boost Battery project shows the potential of a low-powered, portable, energy-harvesting device. With more time, research, and a larger budget, the concepts can evolve into an efficient, user friendly device ready for market. Currently, limited by a budget, custom parts for battery management, charging, and discharging are difficult to acquire. In the future, manufacturing a customized PCB with low-voltage Schottky Rectifiers and toroidal transformers could significantly increase product efficiency while decreasing it's size. One part in particular is the UPS115UE3/tr7 Schottky Rectifier from Digikey.

The thermoelectric material could also be expanded upon given a decade of research. Currently, the chips sewn into a breathable material limit the flexibility of the armband as well as the space allotted for thermoelectric material. Certain products in research labs have high potential for wearable, flexible, thermoelectric generation. One product that would work well in this application is a flexible, glass fabric designed in the Korean Advanced Institute of Science and Technology. This glass fabric holds ceramic and alumina material between substrate layers, creating n-type and p-type thermoelectric materials. By incorporating a fully thermoelectric, wearable material, 100% of the band area could potentially harvest energy, creating a significantly more effective product surface. This would minimize space and maximize efficiency.

The output waveform from the coils is on the order of 250mV when the magnet is pulled through solely by the force of gravity. To compensate for this in the future, the incorporation of high-permeability core toroidal transformers. Doing this will step up the output voltage of the coils for efficient rectifying. CWS Bytemark has a variety of small cores with high permeability cores, such as iron powder, mega-flux, and Hi-Flux, that can be used in future designs.

Chapter 2

Customer Needs Assessment

This product aims to benefit any customer who owns a portable USB-enabled device. Specifically, users who view these devices with high priority and use them intensely, such as travelers or business managers, value this product the most. These customers value convenient charging without requiring a stationary plug. Advocates of renewable energy and environmental groups also find the kinetic powered portable battery charger appealing and sustainable.

As a result, we create a light, compact, and safe device. The battery charges efficiently in the background of daily routines so users can power their devices with no additional hassle. Portability remains essential to these travelers; therefore, size and weight play larger roles for customer needs. Additionally, safety for both humans and electronics are highlighted because customers wear these devices regularly and plug it into their precious devices.

After interviewing numerous potential customers, we found that eight of ten preferred a design that straps and fits into one's pocket rather than one at that fits into his or her shoe. Additionally, all ten participants agreed that hybrid kinetic and thermal generation trumps individual generation because it offers resting and active energy harvesting.

Market Research

Table 1: Boost Market Competition

Competing Companies and Products	Unique Specifications	Major Disadvantage(s)
Ampy via Kickstarter [10]	● Inductive kinetic generation ● Synchronized phone app ● 1000mAh ● Half the size of an iphone ● $85	● Not a company yet – more expensive manufacturing ● 1000mAh storage
Tremont nPower Peg [25]	● 2000mAh ● 10 inches by 1 inch diameter ● $130	● Size – over 10 inches long ● Price
SolePower[25]	● Crystal Shoe insole ● Capacitive storage elements ● $46	● Not a company yet – more expensive manufacturing ● Only one location for product (shoe)
Other Concept Projects [25]:	● Kinetic Watts Maker ● Viber Burst Charger ● HuMo Jacket Harvester	

Market Size, Strengths and Weaknesses

Currently the commercial market has 3 key devices that charge USB-enabled devices from kinetic energy. These products focus primarily on commercial use, not military, and range between $46 to $85 dollars (See Table 1). Several of these have existed in the market for years, although none have taken a majority market lead. Since no one product has a hold in this area, yet new devices keep arising, this market shows huge potential. The niche for a new device that succeeds where others failed lies with Boost Battery. If we address the concerns other products produced, our battery can make massive ripples in the clean energy industry.

Still, the recent rising popularity of these devices means consumers only just began to realize the importance of such devices. The unfamiliar application leads consumers to confusion about the need to pay certain application costs, monetarily and physically. Addressing this confusion by designing for the everyday businessperson or college student gives the Boost Battery the market advantage. These categories of people physically have a lot to carry and have minimal access to charging ports. Key strengths of our product include low cost, user friendliness, and high storage capacity. The thermal harvesting strap/band also provides Boost Battery with a unique advantage; it has the ability to provide power even when the user becomes immobile, such as sitting at a desk or in an airplane seat. This device must display these unique specifications in order to win the market over.

The current market lies roughly at $1-10 million dollars based upon the size of key market players (Ampy, Tremont Energy and SolePower as seen in Table 1) [3, 6, 10, 26, 27]. However, according to Gartner Counseling, estimated over 968 million smartphone sold globally in 2013. If we believe Gartner's estimation, our charger's sale, if focused on smartphones alone, should match roughly 968 million devices per year at first, then gradually decrease to around 500 million per year after that. This initial spike then decrease in sales happens in consumer electronics; since few people have the new type of device at first, many rush to buy it. Until devices start breaking down or new models come out, sales gradually decrease to roughly 50%. Therefore, TAM for kinetic chargers has a possibility of roughly $33.9 billion dollars if each device costs $35 [14].

Ampy (Top Competitor)

Ampy, our strongest competitor, benefits from its physical size and marketing technique. It takes advantage of both the health and crowdfunding movements hitting the nation and targets our technology driven society. However, compared to the other competitors, Ampy has the smallest energy storage capacity. If we can combine the size and marketability of Ampy with the battery capacity of nPower Peg, our product can dent the market. Kickstarter and other crowdfunding websites provide possible methods of initial funding and social outreach since they are geared towards innovative, technology-driven people who tend to use more personal electronic power [10, 27]

Requirements and Specifications

Balancing consumer needs and maintaining the project's major goals determine the requirements and specifications. The marketing requirements contain the general goals of the product, while the engineering specification evaluates how we achieve those goals.

Table 2: Boost Battery's Specifications [3, 26, 27]

Marketing Requirements	Engineering Specifications	Justification
6	Total product costs under 40 dollars per unit	Sum of part's costs (labor excluded)
4,5	Displays battery life in quarters (25%) increments	Provides users with knowledge of remaining battery life
1,4	Product weight under 8 ounces.	Total weight of the device should be less than 8 ounces (~the weight of a smartphone). This excludes external cables
2,3,7	Circuit Protected Lithium Ion battery capacity of at least 2000 mAh	Lithium -ion battery to ensure quick charging and discharging cycles. Battery capacity of 2000mAh to charge a modern smartphone at least once
2,3	Regulated Input and Output currents of 2.1 Amps and voltages of 5V	Effectively charges and delivers power at safe voltages and currents for connected electronics and humans.
2,5	One micro USB port and one 2.1A USB port	The micro USB port charges the portable battery charger and the 2.1A USB port outputs power to external devices
2,4	Casing must dissipate heat	Casing must keep the product cool and safe to touch/use.

1,4	Dimensions under 2” x 2” x 6”	Compact for convenience
3,7	Harnesses at least 3 wH with 10000 steps and an average temperature difference of 20°C	Clean energy harvesting must generate suitable power

Marketing Requirement Areas

1. Portable and durable
2. Safe for humans and devices
3. Charges quickly and efficiently
4. Sleek
5. Simple to use
6. Affordable
7. Capable of fully charging smartphone at least twice

Chapter 3

Functional Decomposition

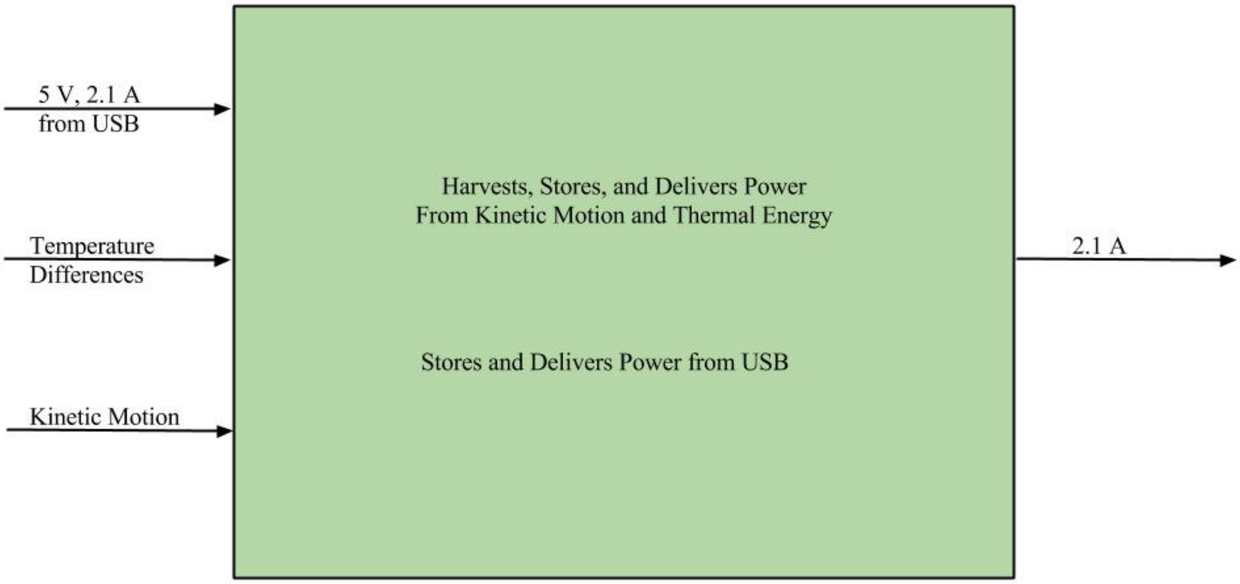


Figure 1: Boost Battery Level Zero Block Diagram

Table 3: Boost Battery Level Zero Functionality Table

Module	Boost Battery
Inputs	• Kinetic motion • Temperature difference • 5V, 2.1 A from USB
Outputs	• 2.1A USB output for electronic devices
Function	• Harvests, stores, and delivers energy from kinetic motion • Stores and delivers power from USB

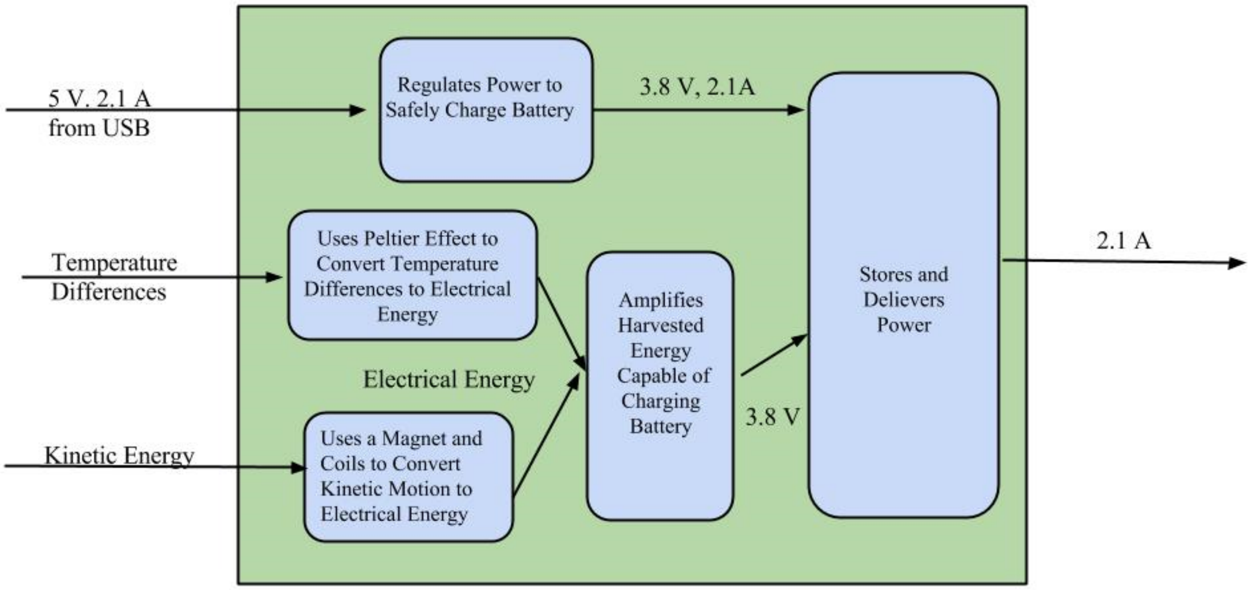


Figure 2: Boost Battery Level One Block Diagram

Table 4: Boost Battery Level One Functionality Table (Voltage Regulator)

Module	Boost Battery
Inputs	● 5V, 2.1 A from USB
Outputs	● 3.8V, 2.1A
Function	● Regulates input power to safely charge battery

Table 5: Boost Battery Level One Functionality Table (Peltier Chip)

Module	Boost Battery
Inputs	● Temperature Differences
Outputs	● Electrical Energy (~ 0-300 mV)
Function	● Uses Peltier and Seebeck Effect to Convert Temperature Differences to Electrical Energy

Table 6: Boost Battery Level One Functionality Table (Coils and Magnet)

Module	Kinetic Powered Portable Battery
Inputs	● Electrical Energy from Thermal Harvester
Outputs	● Electrical Energy
Function	● Converts Differences in Temperature to Electrical Energy

Table 7: Boost Battery Level One Functionality Table (Li-Ion Battery)

Module	Kinetic Powered Portable Battery
Inputs	● 3.8 V, 2.1 A from USB ● 3.8 V, varying current from DC-DC converter
Outputs	● 2.1 A USB for electronic devices
Function	● Stores and delivers power

Inductive Charging in a Kinetic Device

[17][18] defines the following terms, graphs and tables:

B vs H Curve - The result of plotting the value of the magnetic field (H) that is applied against the resultant flux density (B) achieved. This curve describes the qualities of any magnetic material.

BH_{max} (Maximum Energy Product) - The magnetic field strength at the point of maximum energy product of a magnetic material. The field strength of fully saturated magnetic material measured in Mega Gauss Oersteds, MGOe.

Br_{max} (Residual Induction) - Also called "Residual Flux Density". It's the magnetic induction remaining in a saturated magnetic material after the magnetizing field withdraws. This the point shows when the hysteresis loop crosses the B axis at zero magnetizing force, and represents the maximum flux output from the given magnet material. By definition, this point occurs at zero air gap, and therefore unseen in practical use of magnet materials.

Gauss - Unit of magnetic induction, B. Lines of magnetic flux per square centimeter in the C.G.S. system of measurement. Related to lines per square inch in the English system, and Webers per square meter or Tesla in the S.I. system.

Magnetic Field (B) -

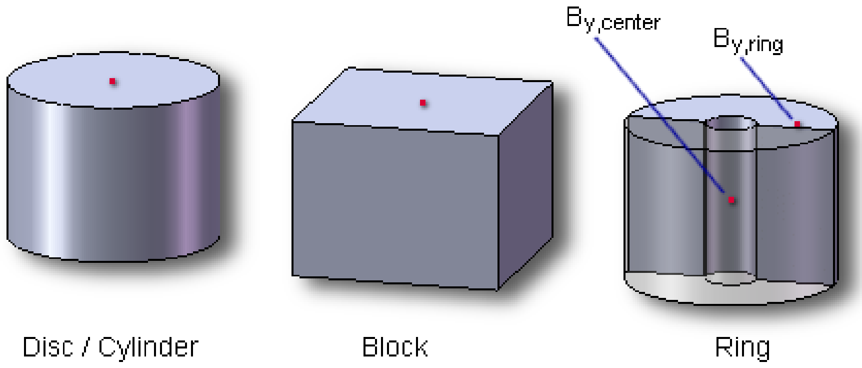


Figure 3: Magnetic Field of Various Volumes

The surface field or magnetic field refers to the strength in Gauss. For axially magnetized discs and cylinders, magnetic fields lie on the surface of the magnet, along the center axis of magnetization. For blocks, it exists on the surface of the magnet, also along the center axis of magnetization. For rings, you may see two values. $\mathbf{B}_{y,center}$ specifies the vertical component of the magnetic field in the air at the center of the ring. $\mathbf{B}_{y,ring}$ specifies the vertical component of the magnetic field on the surface of the magnet, mid-way between the inner and outer diameters.

Magnetic Field Strength (H) - Magnetizing or demagnetizing force, is the measure of the vector magnetic quantity that determines the ability of an electric current, or a magnetic body, to induce a magnetic field at a given point; measured in Oersteds

Permeance Coefficient (P_c) - Also called the load-line, B/H or "operating slope" of a magnet, defined by the line on the Demagnetization Curve where a given magnet operates. The value depends on both the shape of the magnet, and its surrounding environment. In practical terms, it's a number that define how hard the field lines go from the north pole to the south pole of a magnet. A tall cylindrical magnet has a high Pc, while a short, thin disc has a low Pc.

Pull Force - The force required to pull a magnet free from a flat steel plate using force perpendicular to the surface. The limit of the holding power of a magnet.

In our device, the strength of the magnet, number of coils of wire, and the velocity by which the magnet travels through the coils determines the amount of charge our coil generates.

The specifications in Table 8 model the magnet we used to perform much of our prototyping

Table 8: Magnetic Properties [4]

Property	Value
Diameter [in]	.75 in
Thickness (Length) [in]	1 in
Material	NdFeB
Coating	Ni-Cu-Ni
Magnetization Direction	Axial
Weight [oz]	1.92 oz
Pull Force [lbs]	36.6 lbs
Surface Field [Gauss]	6180 G
Maximum Energy Product; BH_{max} [Mega Gauss Oersteds]	42 MGOe
Residual Induction; Br_{max} [Gauss]	13,200 G

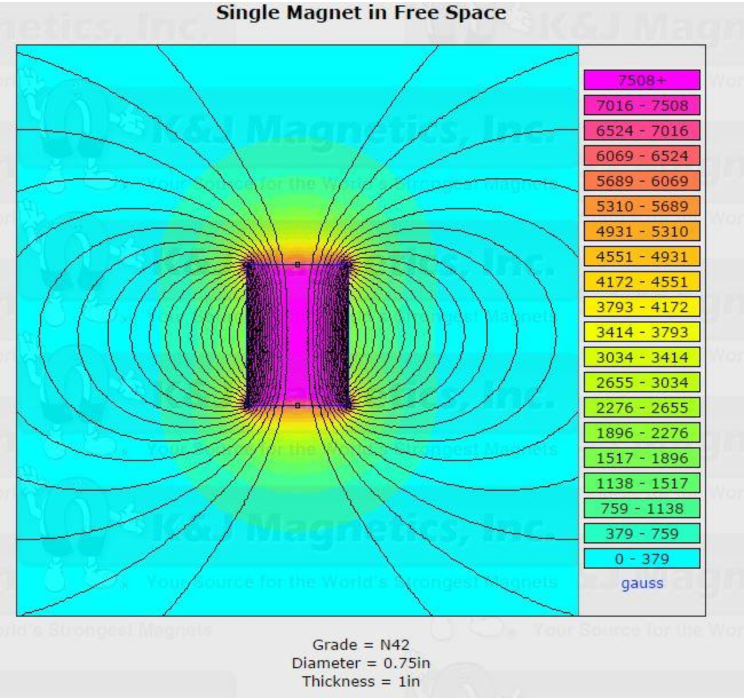


Figure 4: Magnetic Field

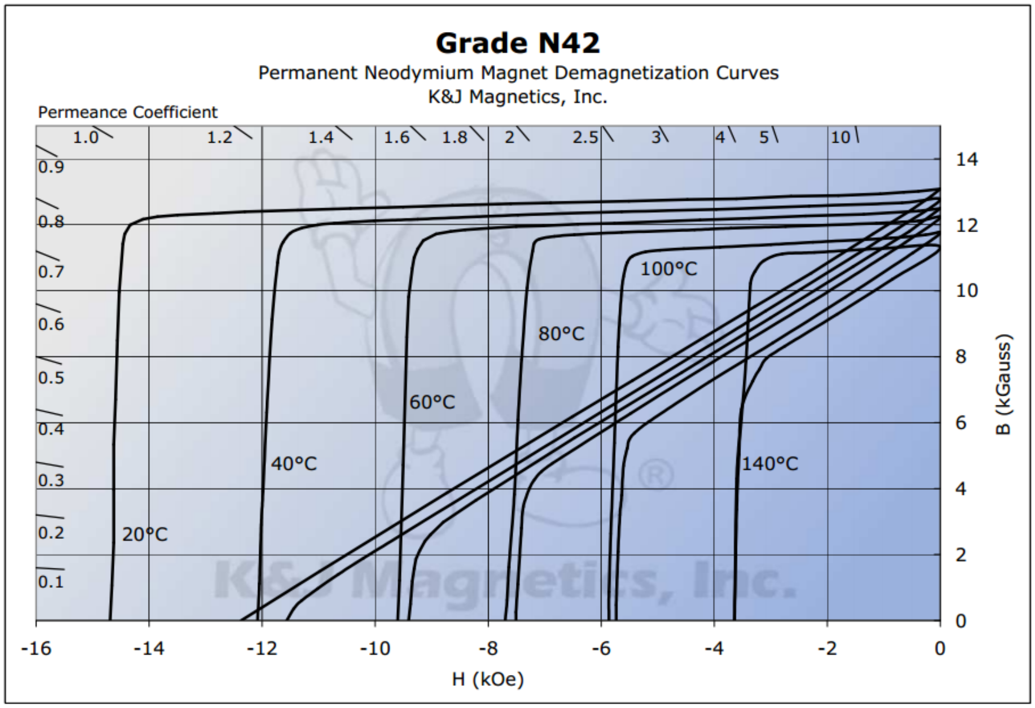


Figure 5: B/H Curve

Therefore, it's more efficient to implement the 30 gauge magnet wire. This wire is coated with the thinnest coating of insulation as possible to allow for the maximum number of turns in the smallest volume. We have a spool of ~66.67 feet of this wire, giving us a coil of approximately 318 turns with an inside diameter of 0.8 in.

$$R = 66.67 * 0.10319$$

$$R = 6.878\Omega$$

Table 9: Wire Properties

Specification	Value
Length	66.67 ft; 800 in
Resistance	.10319 Ohms/ft[18]

With the calculated magnet and coil Properties, an hour of vigorous shaking produces up to 702 watts of power for one hour. Two possible designs for our project include: one larger inductor coil with one magnet, or two smaller inductor coils with two separate magnets. We have not yet tested the efficiency of two coils versus one in everyday movement, but if our design needs more room for the circuitry, two smaller inductors provide extra space.

The shape and design of the inductor "tubes" may be most efficient as a curved cylinder with elastic stoppers on each end. This shape provides a bounce-back effect on the magnet, amplifying the motion of your body (keeping more momentum of the magnet in play). The curvature of the cylinder enables Boost to harness horizontal energy as well as vertical energy as the curve contributes centrifugal force to the system. We must test this curved formation and compare to strictly horizontal or strictly vertical orientations and calculate which proves the most efficient.

Testing of Coil and Magnet

A coil of approximately 7000 winds was made using 44 gauge wire and subsequently shellacked using clear nail polish to prevent damage to the wire insulation and to prevent vibration in the coils.

Testing of the prototype coil was conducted by dropping a magnet of varying size through. No downward velocity was added to the magnet when dropping as to not skew results by a large amount. The oscilloscope was connected directly across the the two ends of the wire coil.

After analyzing the results, the requirement of a step up transformer and ultra low voltage diodes was realized. The use of the 9/16” x 9/16” magnet was decided to be the most efficient magnet for the size allocated to the design.

Table 10: Inductive Coil Test Results

7000 Coils	Vmax (mV)							Avg
Magnet Size	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**	**Test 6**	**Test 7**	
9/16 x 9/16	**258**	**267**	**212**	**237**	**267**	**150**	**254**	**235**
3/4 x 3/4	**466**	**508**	**463**	**480**	**461**	**454**	**480**	**473.14**
3/4 x 3/8	**166**	**315**	**412**	**339**	**190**	**186**	**383**	**293.38**

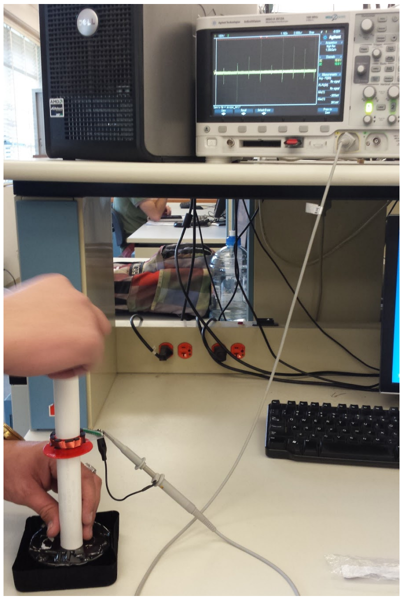
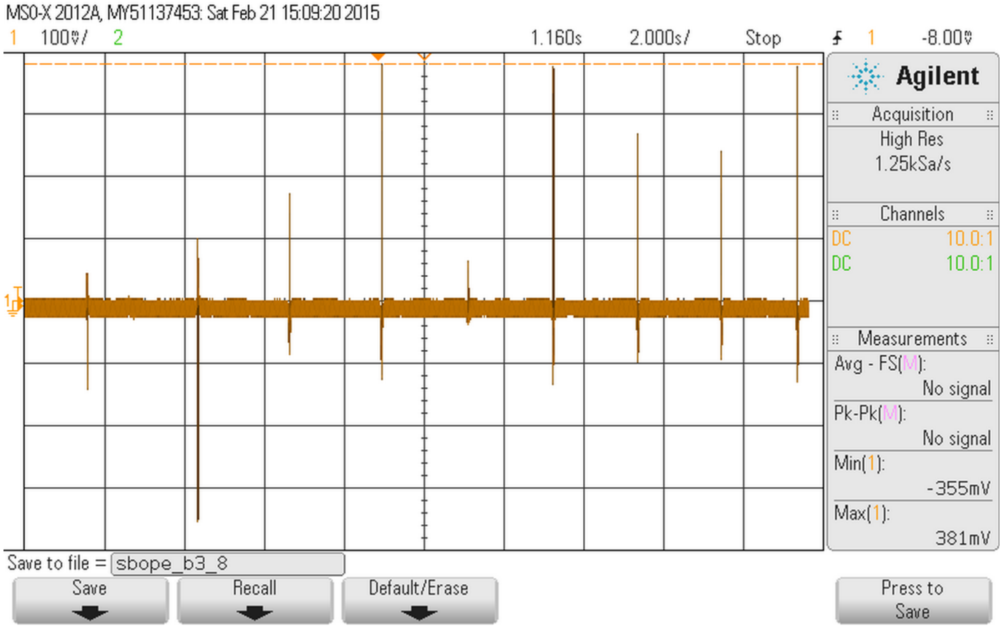


Figure 6: Testing Environment



MSO-X 2012A, MY51137453: Sat Feb 21 15:09:20 2015

1 100mV/ 2 1.160s 2.000s/ Stop 1 -8.00mV

Acquisition: High Res 1.25kSa/s

Channels: DC 10.0:1, DC 10.0:1

Measurements:
Avg - FS(M): No signal
Pk-Pk(M): No signal
Min(1): -355mV
Max(1): 381mV

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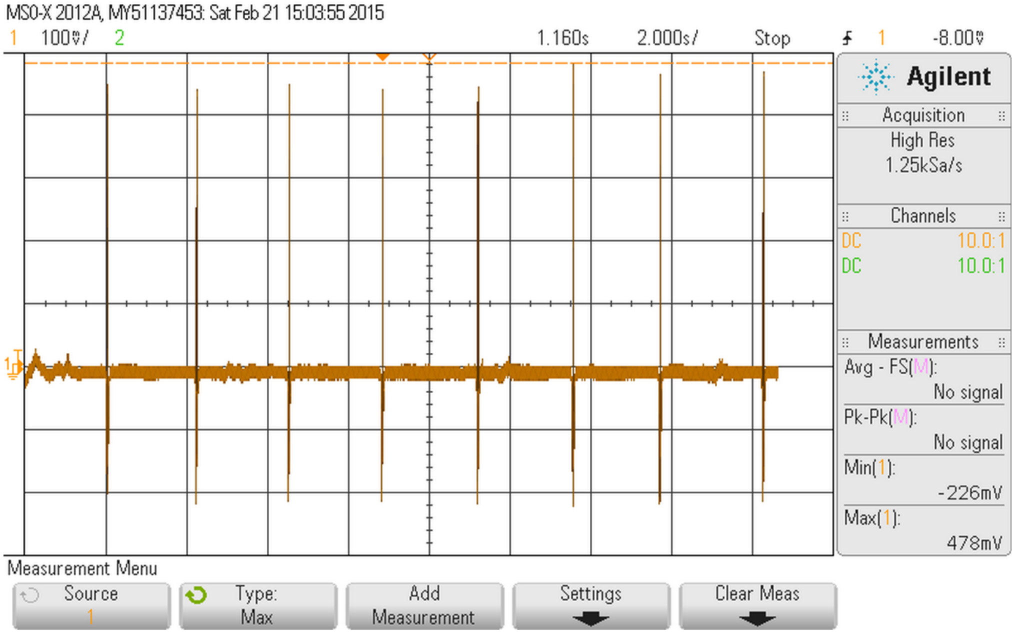
Figure 7: Seven drops of ¾” x ⅜” Magnet



MSO-X 2012A, MY51137453: Sat Feb 21 15:03:55 2015

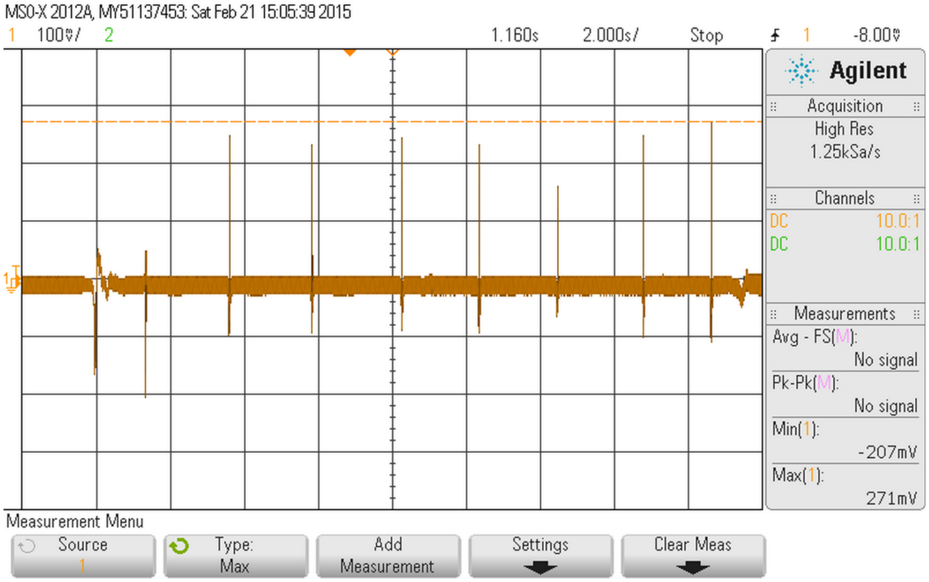
1 100mV/ 2 1.160s 2.000s/ Stop 1 -8.00mV

Acquisition: High Res 1.25kSa/s

Channels: DC 10.0:1, DC 10.0:1

Measurements:
Avg - FS(M): No signal
Pk-Pk(M): No signal
Min(1): -226mV
Max(1): 478mV

Figure 8: Seven drops of ¾” x ¾” Magnet


MSO-X 2012A, MY51137453: Sat Feb 21 15:05:39 2015

1 100mV/ 2 1.160s 2.000s/ Stop 1 -8.00mV

Acquisition: High Res 1.25kSa/s

Channels: DC 10.0:1, DC 10.0:1

Avg - FS(M): No signal

Pk-Pk(M): No signal

Min(1): -207mV

Max(1): 271mV

Figure 9: Seven drops of 9/16" x 9/16" Magnet

Thermal Charging in an Arm Band

Thermal energy harvesting occurs from several different thermoelectric effects. Figures and Tables obtained from [23]. Read definitions for the effects below [22]:

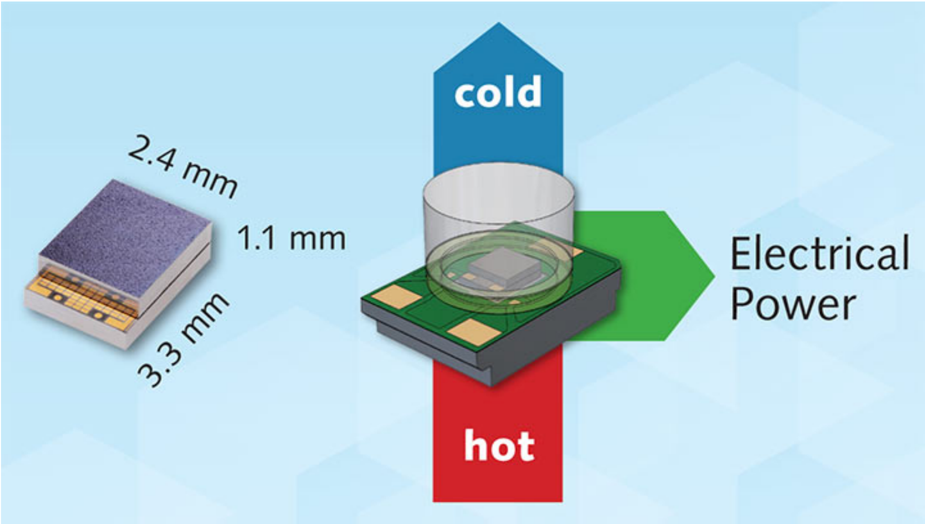


Figure 10: Graphic Depiction of a Peltier Device

Peltier Effect - the presence of heating or cooling at an electrified junction of two different conductors - when a current flows through a junction between conductors A and B, heat generates or dissipates at said junction

$$\dot{Q} = (\Pi_A - \Pi_B) I$$

Q = heat generated at junction per unit time
πa(πb) = peltier coefficient of conductor A(B)
I = current from A to B

Seebeck Effect - the conversion of temperature differences directly into electricity

$$\mathbf{J} = \sigma(-\boldsymbol{\nabla} V + \mathbf{E}_{\mathrm{emf}})$$

J = current density
σ = conductivity

$$\mathbf{E}_{\mathrm{emf}} = -S \boldsymbol{\nabla} T$$

S = seebeck coefficient
Δ T = temperature gradient

Thompson Effect - the heating or cooling of a current-carrying conductor with a temperature gradient.

Since we do not want to heat up or cool down our users' skin, the Seebeck effect provides the best energy harvesting method. With an armband, most of the time ambient temperature ranges below 80^0F, or 26.7C [28]. Body temperature remains approximately at 37 C (98.6^0F). This results in a significant temperature difference. When placing a peltier device between the two opposing temperatures, electricity ensues. A peltier device works by having a "hot" and "cold" side; applying this heat difference induces current to flow and creates a voltage. This current would then charge up any device, like a battery. See Figure 11.

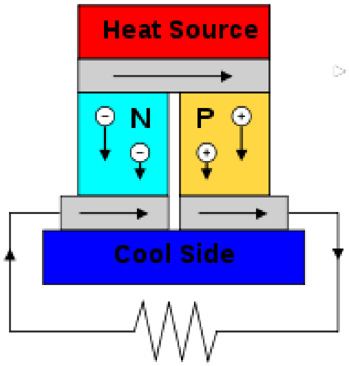


Figure 11: Graphic Depiction of the Seebeck Effect

In an armband, the inside lining of the band would consist of the “hot” sided peltier plates, while the outside of the band holds the “cold” plates. Two options for implementing the peltier device exist: flexible thermal material, or rows of small fixed devices. They could provide more comfort to the user; however the few that exist remain primarily experimental and have less efficiency than the solid plate counterparts. These devices come very small, on the 1mm^2 scale, which makes implanting them in a wearable, water resistant fabric much simpler.

Based upon two thermoelectric companies, we found several products that would produce the necessary energy to charge 1000mAh [26, 27]. Our research so far concludes that it takes 7+ devices to create this necessary charge at a temperature difference of 10 C in under an hour for charge time. The smaller the devices, the more we can implement. However, low peltier device efficiencies means theoretical calculations produce a high energy estimate. The Carnot efficiency (maximum efficiency) cannot be exceeded. This efficiency comes from $\frac{T cold}{T\ hot - T\ cold}$ [28] . Micropelt produces chips that, per unit, produce the following outputs. The power per unit increases significantly, however our device would need to implement at least 20 of these to create a reasonable charge time [19, 20].

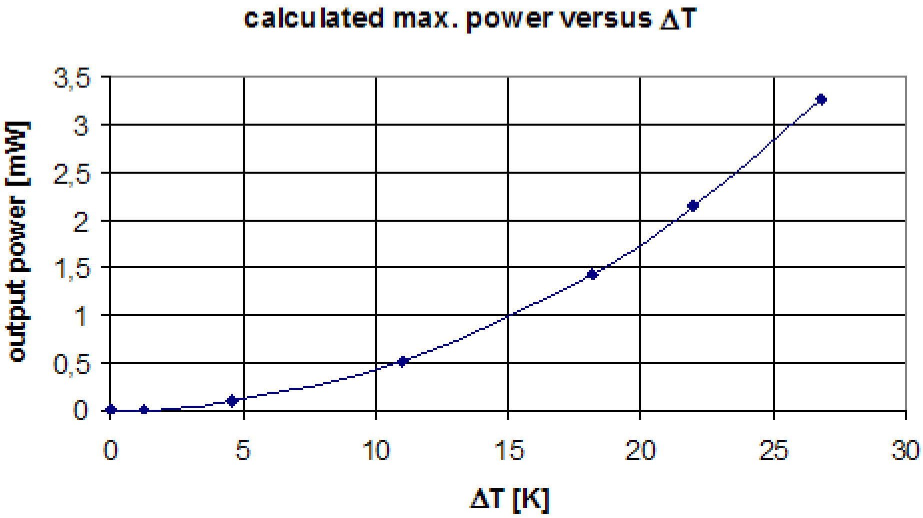


Figure 12: Output Power Based on Temperature Difference in One Micropelt Device

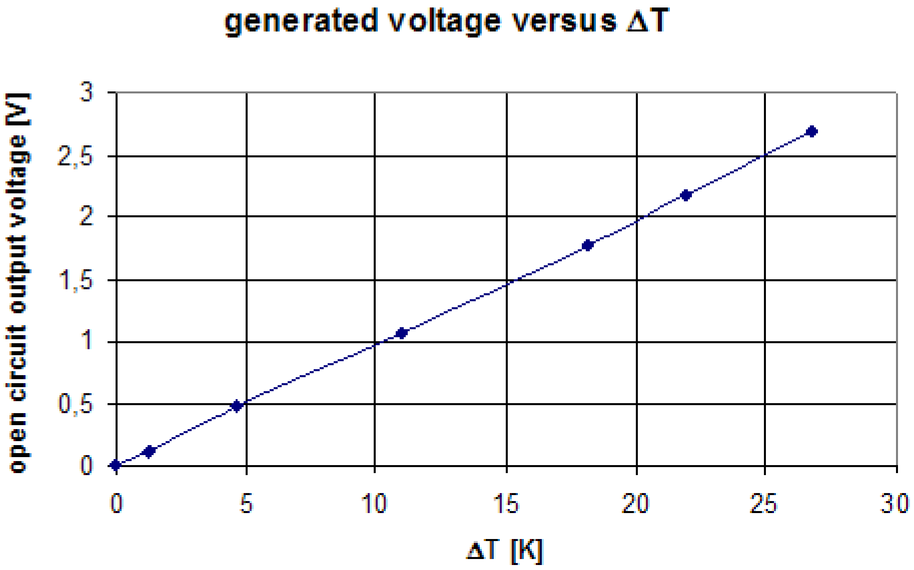
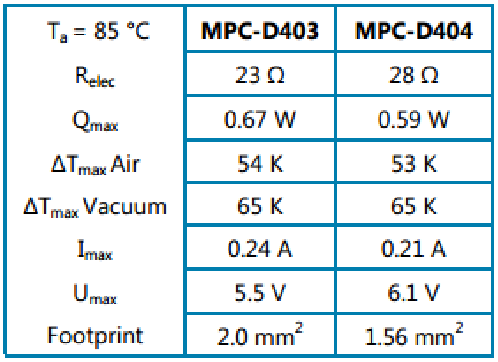


Figure 13: Output Voltage Based on Temperature Difference in One Micropelt Device



T_a = 85 °C	MPC-D403	MPC-D404
R_{elec}	23 Ω	28 Ω
Q_{max}	0.67 W	0.59 W
ΔT_{max} Air	54 K	53 K
ΔT_{max} Vacuum	65 K	65 K
I_{max}	0.24 A	0.21 A
U_{max}	5.5 V	6.1 V
Footprint	2.0 mm^2	1.56 mm^2

Figure 14: Micropelt Device Electrical Specifications

Ferrotec produces slightly larger chips that would theoretically require 7 devices per armband to create 1000mAh in under a half hour. By choosing the temperature gradient, we found the following device and consequently number of modules to fit our specifications.

Table 11: Ferrotec Thermoelectric Chip Specifications

Model Number	N	Qc	CoP	I	V	Base W	Base L	Top W	Top L	Height
9502/065/012 M	7	31.9	0.47	1.2	8	12.1	11.2	12.1	11.2	2.65

Table 12: Ferrotec Thermoelectric Chip Output Power Testing With Resistive Load

With Resistive Load:	Temp Cold(C)	Temp Hot(C)	Temp Difference(C)	Vresistor Max(V)	Max Current A (R= 1Ohm)	Max Power (W)
Forearm with 3 chips	23.3	33.6	10.3	0.159	0.159	0.025281
Neck with heat sink 3 chips	24.1	34.6	10.5	0.08	0.08	0.0064
Coffee cup 3 chips	42.6	61.2	18.6	0.163	0.163	0.026569

Research and Testing for Other Partners

With two partners on leave for co-ops, scheduling issues presented themselves throughout the design process. Before they left, Alvin Ng and Russell Wong joined researching efforts. Alvin worked on company outreach and current market solutions with Lacy. He discovered our main competitor, Ampy, which provides concrete data points and market goals to make our own product viable. Their research also contributed to potential thermal power production. Russell Wong's research contributed to the discussion with Sam about coil shape and location. Taking information from past senior projects, he found documents on the most lateral, metronomic bodily movement to produce the most magnetic induction. The upper arm, because of short travel distance and constant movement while walking, proved the best location for a horizontally situated coil. From there, all partners began determining realistic power outputs and low powered devices to connect with.

Alvin Ng and Russell Wong will take over the system integration portion of the project as seen in Figure 2. This quarter's focus has been on researching low-powered rectification, amplification, and methods for harnessing the body's movement. Also, we determined actual power outputs of our thermal and inductive circuitry while minimizing overall project size and complexity. Now that parts are ordered, Alvin Ng and Russell Wong will need to step up the output voltage and currents from the harvesting circuits using toroidal transformers. From there, they will take power measurements and learn how to provide enough power to operate the dynamic components while still having output power to store in the lithium ion batteries. Given the LTC4070 low powered battery charging/shunt circuit, certain parameters such as our low Vcc affecting discharge rate will be challenging.

These considerations will be our other partners' main priority when they return. The purpose of integrating the system will be to prove our concept that micro-energy harvesting is not only possible, but realistic. However, once the system is put together, testing will be a major contribution to the assessing the project's overall success. Alvin Ng and Russell Wong will need to test the following: power generation from the thermal armband in one hour, power generation from the inductive coil for one hour, power consumption of the full system, and battery charge after an hour of average use. Since this project aims to make a marketable device, other factors such as comfort, thickness, weight, and design will need to be taken into consideration. Weight and thickness can be numerically quantified; however, the others can be measured by taking a sample pool of 20 people and assigning a value to each category from 1-10, 1 being the lowest and 10 the highest. By integrating the different system blocks and performing these tests, our partners will be able creating a usable, alpha prototype comparable to current market solutions.

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This project document provides a full project plan to a portable battery charger.

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This patent provides a method of converting kinetic energy to electrical energy and storing it in a battery.
The United States Patents and Trademarks Office examined and approved this patent

[8] Maria Gorlatova, John Sarik, Guy Grebla, Mina Cong, Ioannis Kymissis, and Gil Zussman, *Movers and Shakers: Kinetic Energy Harvesting for the Internet of Things,* Columbia University, 2014. Available: <http://arxiv.org/pdf/1307.0044v3.pdf>

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Provides multitudes of usable components and helpful tools for device design.

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Appendix A – Analysis of Senior Project Design

Boost Battery

Sam Rauch, Alvin Ng (Absent), Russell Wong (Absent), Lacy Sigman

Dr. Ahmad Nafisi

I. Summary of Functional Requirements

This portable battery stores energy harvested from kinetic motion. It also is capable of porting power to any USB-enabled electronic devices. Energy indicators display remaining battery capacity to users.

II. Primary Constraints

Significant challenges associated with a kinetic energy harvesting device involve making a cost efficient device small enough for users to comfortably wear or carry throughout the day. Other obstacles involve implementing a method to gather and store sufficient kinetic energy and dissipate any heat associated the process. Additionally, in order to provide quick charging we must manage input and with output currents to satisfactory levels.

III. Economic

The Boost Battery provides employment opportunities for its development, manufacturing, sale, and maintenance. The project employs bright and ambitious engineers to creatively design an innovative product that benefits both its users and the environment. The product's manufacturing requires the needs to purchase machinery and components from other companies. Similarly, we require a marketing and sales team to help our product break into the already existing industry. Maintenance of our product requires suitable recycling for lithium-ion batteries and waste prevention strategies for broken or replaced devices. Referencing the products available on online electronic component distributors, Mouser and Digikey, we can estimate the cost of manufacturing our device [19][20].

a. Estimated cost of components: ~$50/unit (at low volume)
b. Estimated development time: 1-2 years
c. Other required development costs: labor ($37.5/hr)

Costs

Table 13: Boost Battery Low Volume Cost Estimates

Components	Number	Cost ($)
Sonata® 5300 Rechargeable Lithium- Ion Cell	1	$20
DC-DC Converter	1	$10
3/8” x 1” Neodymium Magnet	1	$5
40 Gauge Wire	1	$10
USB Connector	1	$1
Micro USB Connector	1	$1
Voltage Regulator	1	$0.80
Total		$47

Table 14: Boost Battery Miscellaneous Costs

Description	Number	Cost ($)
Labor	4 employees	$9300
Shipping & Handling	6 components	$10
Total		$9310

At low volume, components are most expensive. The device hardware costs $47 with pricing based on average market costs available for each item [19][20]. Other expenses include labor rates of $37.5 dollars per hour and hardware shipping costs of 10 dollars. Salary estimates obtained from Glassdoor's slightly above average entry-level salaries for electrical engineers

[21].

At higher volume (i.e. 200,000 units), product pricing reduces by half (~ 25 dollars per unit) with a slight increase in shipping costs [20].

Schedule

The following figures outline the work schedule and delivery dates for the Boost Battery project. The fall 2014 quarter focuses on documentation for the project as well as research on the subsystems, cost analyses, and specifications. Prototyping and initial testing consumes the first five weeks of the winter 2015 quarter, followed by five weeks of troubleshooting, redesigning and integration. Setbacks with realistic functions of components forced us to research new ways of designing our solution. With two of our group members gone working in co-ops, they have decided to pick up where we leave off at the end of this quarter. Our scheduling was set back mainly due to this fact, but the incorporation of the work completed this quarter will be easily implemented to any future work.

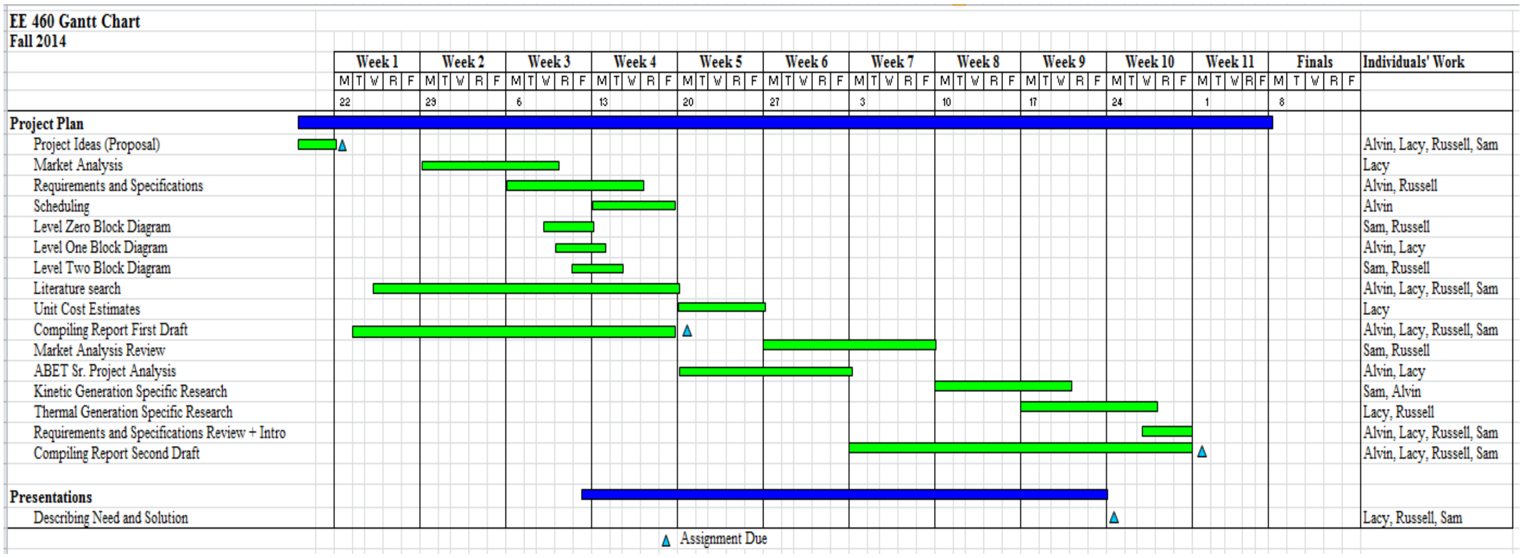

Figure 15: Fall 2014 Project Gantt Chart

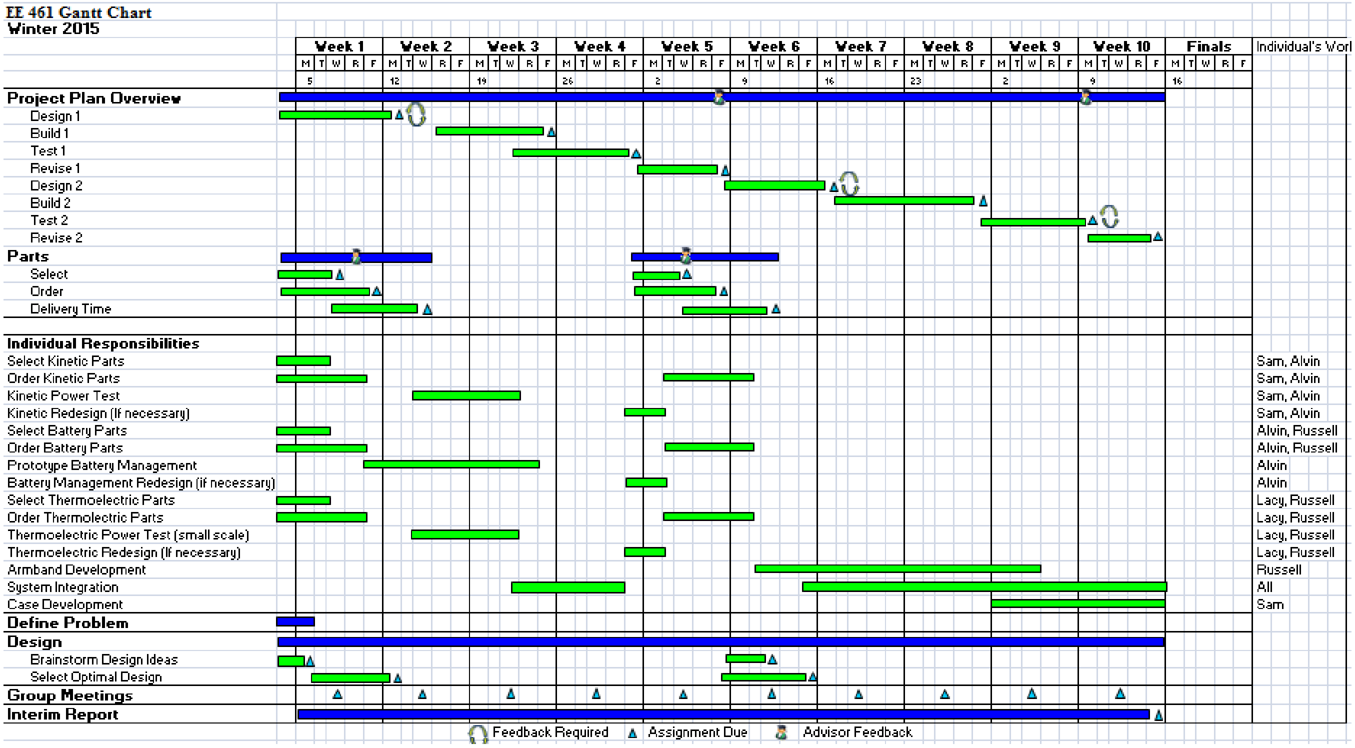

Figure 16: Winter 2015 Gantt Chart

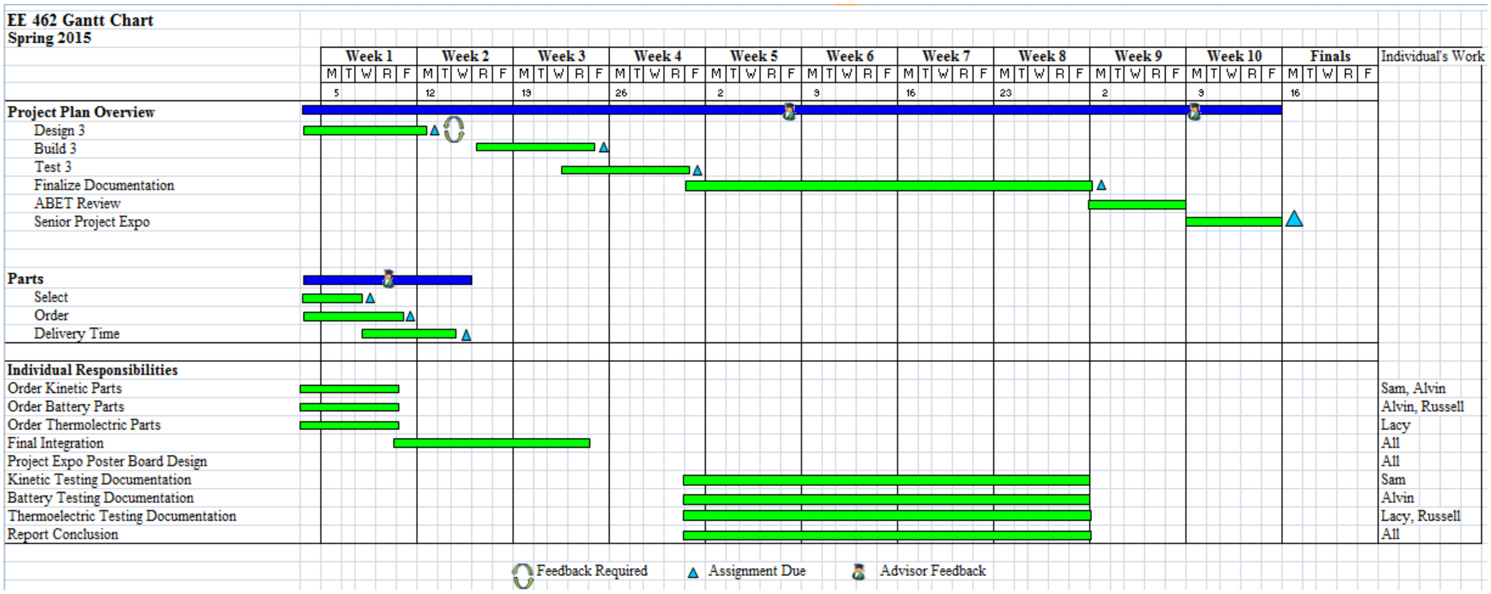

Figure 17: Spring 2015 Gantt Chart

Table 15: Boost Battery Deliverables

Delivery Date	Deliverable Description
Week 8 (F)	Report V1
Week 12 (F)	Report V2
Week 6/7 (W)	Design Review
Week 9/10 (W)	EE 461 demo
Week 10 (W)	EE 461 report
Week 10 (S)	EE 462 demo
Week 9/10 (S)	ABET Sr. Project Analysis
Week 9/10 (S)	Sr. Project Expo Poster
Week 10 (S)	EE 462 Report

***** F =Fall, W= Winter, S = Spring*****

IV. Manufacturing Cost for Commercial Basis [19,20]

a. Estimated number of devices sold/year: 200k units
b. Estimated Manufacturing cost per device: \$20 - \$25
c. Estimated purchase price for each device: \$40
d. Estimated profit per year: \$8M
e. Estimated cost for user to operate device per unit time: \$00.04/day

V. Environmental

This product provides an alternative to conventional charging by incorporating charging from naturally created, clean energy. As a result, it decreases energy usage from non-renewable sources, such as oil and gas power plants. Likewise, the manufacturing of the product attempts to minimize waste. To offset any environmental harms (i.e. material waste and machine emissions), the final design uses at least 20% recycled material and have easily replaceable components. Thus, our device reduces damage to the environment and benefits the ecosystem for all of our planet's inhabitants.

VI. Manufacturability

Most manufacturing is outsourced until our company can affordably provide our own in-house production. Our team purchases cheap but effective component from online services such as Mouser or Digikey. The services of other companies create and populate our PCB board to meet our design and specifications. All components undergo reflow soldering to save time and reduce risk of error that easily results from poor self-soldering. Likewise, minimal components and simplistic packaging ease mass production of circuit board and casing. In order to address many of our assembly challenges (i.e. enclosure, indicator, and control issues), we hire expert product engineers and to increase simplicity, any connector with an USB as one head is capable of drawing power from our device.

VII. Sustainability

a. Considering this device generates electricity through mechanical stress, potential issues for longevity involve durability of the casing and the internal material. Other limiting factors include manufacturing defects, excess heat generation, or battery life. We must also account for human error, such as dropping or damaging the case. Our product address these challenges by using robust, heat dissipating, and water-resistant material. Additionally, an efficient, long-lasting lithium-ion battery ensures consistent performance and a resourceful design offers easy replacements [5].

b. When designing the device, our team maximizes recyclable material and replaceable components. Additionally, we introduce methods to properly dispose of waste (i.e. the lithium ion batteries) to customers.

c. Expansions or additional components provide customers with better and more features without the need to purchase another product. This saves the time, material, and labor needed to design and develop an entirely new product.

VIII. Ethical

Production of this product agrees with the IEEE Code of Ethics as “consistent with the safety, health and welfare of the public” [15]. Using a kinetic charger has positive implications because it increases awareness about energy consumption for the everyday person. A phone app that informs users of how much energy one generates hopefully motivates more active and power-conserving users. Consequently, we hope that they inspire others to do the same. By making clean energy easily accessible, consumers can conveniently generate power whenever and wherever they want. Thus, the Boost Battery fits both the consumer’s psychological and ethical egoism frameworks of encouraging a healthier, more ecological, and more efficient lifestyle. In terms the utilitarianism framework, our product aims to benefit not only our users and their environment but also everyone in contact with them

Our company also avoids what IEEE calls “real or perceived conflicts of interest” [15]. Often times when attempting to build a competitive and innovative product, companies tend to choose parts and prices incongruent with bettering the environment. Therefore, our team must remember to produce a sustainable and affordable device. As a result, we follow both the Golden and Platinum rules because cheaper products save money, something all consumers and suppliers wish to do.

IX. Health and Safety

The charger produces excess heat while generating electricity on a person's body. This, if not managed, could lead to heat-related safety issues for the user. Other issues involve current limitations, water protection, and grounding issues with the casing, which could lead to electric shocks. Thus, implementing a heat dissipating, water-resistant material packaging and protection circuits guards both users and their devices. Lastly, our lithium ion battery has circuit projection to signal when to stop charging and to regulate power flow.

X. Social and Political

Our product provides users with energy at all times. Consequently, our device offers an everlasting social connection, assuming the user charges smartphones (one of the largest source for human connection via social media, messaging, or email). Unfortunately, the existing technology attachment perpetuates.

Politically, this device may reduce the need for oil and gas by "cutting energy waste in homes" [13]. As stated in Ethics, it hopefully increases awareness and leads to more energy-efficient lifestyles, which agrees with Obama's Clean Energy Act. Additionally, we hope our product also helps inspire more active lifestyles.

Stakeholders for our project include a wide variety of people, emphasizing its potential for positive impact. Any consumer who uses a USB-powered device finds advantages in having an extra battery supply; those who have multiple devices, have their utility multiplied as well. Similarly, active consumers have a method to harvest all the energy they put into training while less active consumers have motivation to exercise! Still, our product only benefit active consumers since it charges from thermal energy and even a micro USB port.

XI. Development

Wearing this device on the body creates friction, and therefore heat. During development, we found that capturing excess heat for additional energy benefits our product more than just letting it dissipate, unused, into the environment. Also, knowledge of design and simulation tools such as Cadence and LTspice is imperative because our product requires chip and circuit design. Lab equipment experience helps troubleshoot circuits during testing phases. Other essential knowledge we gain from this project includes how to convert from mechanical/thermal energy to electrical energy, how to store and reproduce energy, and how to develop a safe, durable product [17][18] [22][23].