Design Project Proposal

Northrop Grumman
Pedometer Energy Harvester - PEH

Submitted By

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November 11, 2010

From: Team Pinnacle – Bodunrin Jawando, Dhanushka Fernando

To: Whom it may concern,

Subject: Pedometer Energy Harvester – PEH

Enclosed is the Pinnacle's proposal design for the implementation of a **Pedometer Energy Harvester (PEH)** prototype for the 2010/2011 Senior Design Class project. After considering the current state of art in the field of Pedometer Energy Harvesting, *Team Pinnacle* has drawn up a detailed solution to the problem posted by the PEH. Our Engineering solution approach outlines the following information,

- Current Status of Art
- Expectations & Deliverables
- Solution approach
- Relevant Engineering knowledge
- Primary solution
- Simulation
- Deliverables
- Testing and verification
- Future improvements & Alternative solutions

The research for this proposal was based on the requirements of the problem statement provided by the Northrop Grumman. Also, the development of PEH consists of various energy harvesting methods that are currently available in the market. See the *References* section of this proposal for more information.

Introduction

Objective

The objective of this proposal is to outline the design challenge Pedometer Energy Harvester (PEH) proposed by Northrop Grumman and demonstrate a portable solution to the problem statement.

Background

In 2007, the Energy Independence and Security Act was established in response to the increase in demand for electricity and the desire for more environmentally friendly energy sources. The purpose of this policy was to produce green and cost-efficient power from renewable energy sources. As a response to *Go Green* many researches and privately funded organizations started to look for alternative energy sources. As a result many invested on win energy, solar energy, Biomass energy, geothermal energy etc. that has minimum or no pollution to the environment. Even though human energy is not sufficient to power a mass electrical network, it has the potential to charge our electrical components such as iPods and cells phones. Several energy-harvesting ideas are out there that will be discussed under *Status of Art.* Energy harvesting is the use of ambient energy to provide electricity for small and or mobile equipment, whether electrical or electronic. It is concerned with providing relatively maintenance free, long life equipment, reducing the need for batteries[++].

Outline

In this proposal, we will discuss the current state of art as well as the design requirements and constrains on our final solution. Next we will provide the technical aspects involved in our proposed design as a solution to the problem statement. The implementation of the proposed solution will be discussed in more details under *Solution Approach* and *Task & Deliverables.*

++ May or may not use rechargeable batteries

Problem

Problem Definition

The problem we are attempting to solve here is to design a system that uses pedometer-type energy harvesting method to detect & convert human motion into usable electrical energy and provide a portable power source.

Design Requirements

Following the requirements set by Northrop Grumman, the PEH should:

- Generate 5Vdc @50 – 100mA (or 12V version)
- Charge battery up to 5 WHr
- Operating Temp: -10 – 40 Celsius
- Deliver Power: Nominal to a USB device, Large to battery reserve
- Provide external indicator of power condition

Current Status of Art

Several companies have developed pedometer type energy harvesting methods. They are namely Sanyo's *Pedometer Charger*, *Ugly Sneaker Power Generator* and *Knee Brace*. Taking in to consideration of deliverables of each approach, we found out that *Knee Brace* clearly stands out the crowd. We will discuss about the *Knee Brace* as the current status of art of the Pedometer type energy harvesting.

Knee Brace

Max Donelan, a kinesiologist at Simon Fraser University, to invent a device that harnesses the energy of walking. The Bionic Power © currently holds the copy right for this great invention. The unit weighs 1.7 lbs per leg and it wraps around the wearer's knee and generates power. According to *New York Times* ratings, the Knee Brace has become one of the best innovations of 2008.

PowerWalk™ M-Series: The latest product prototype based on our bionic energy harvesting technology.

The Bionic Energy harvester (Knee Brace) consists of 2 leg harvester units and a control module. It intelligently targets peak generation during regions of the stride where the muscles are normally performing a braking action. This results in considerably reduced user effort and even assistance to the user on down slopes. The effort level can be adjusted on the fly to meet the user's needs through a simple user interface. For flexibility, the control module can also draw power from any low voltage AC or DC source for battery charging (i.e. vehicle battery, solar array, fuel cell etc.).[1]

Data sheet of the Bionic Energy Harvester Performance:

Nominal power output:	8-14W (1.5m/s walking speed, level ground)
Maximum power output:	25W (15 degree down slope)
Effort Level setting:	10 levels
Output voltage:	5V to 16.8V (2 to 4 Li Ion cells)
Maximum output current:	5A
Battery chemistries supported:	Lithium Ion (others available upon request)
LCD Indicator:	Charge complete, charging, fault, output power
Connections:	Left leg, Right Leg, Battery
Fault Protection:	Reverse polarity, open/short circuit, over/under voltage, and temperature faults
External Power Input:	8V to 24V: Solar, vehicle, fuel cell

[1] This material was added in response to the comments made in the Proposal presentation on Dec 1, 2010

Operational speed	0.5 to 3m/s (slow walk to fast jog)
Device Dimensions/Weight:	
Braces size:	Small, Medium, Large, Extra Large
Strapping:	4 points, w/ quick release
Weight:	750 grams per leg
Environmental Conditions	
Operating temperature:	-20C to + 50C
Storage temperature:	-40C to + 70C
Relative humidity	10 – 95%
Sealing:	IP67 (immersion 1M for 1hr)
Reliability	
Service interval:	1 year (based on 8hrs/day 200days/year)
Product lifetime:	3 years

Relevant Knowledge and Course Work

Theory behind the Mechanism

Faradays law states "*if a flux passes through a turn of a coil of wire, a voltage will be induced in the turn of wire that is directly proportional to the rate of change in the flux with respect to time*". In equation form,

$$e_{ind} = -\frac{d\phi}{dt}$$

where,

$e_{ind} = voltage\ induced\ in\ the\ turn\ of\ the\ coil$

$\phi = flux\ pas\sin g\ hrough\ the\ turn$

Magnetism

Magnetism is the property of an object, which causes it to create a magnetic field in opposition to an externally applied magnetic field, thus causing a repulsive effect. Specifically, an external magnetic field alters the orbital velocity of electrons around their nuclei, thus changing the magnetic dipole moment.

The strength of the magnet is measured by the *permeability* of the magnet. Permeability is the measure of the ability of a material to support the formation of a magnetic field within itself. Magnetic Permeability is usually denoted by μ. Typically the magnetic permeability is a relative term denoted by μ_r.

$$\mu_r = \frac{\mu}{\mu_0}$$

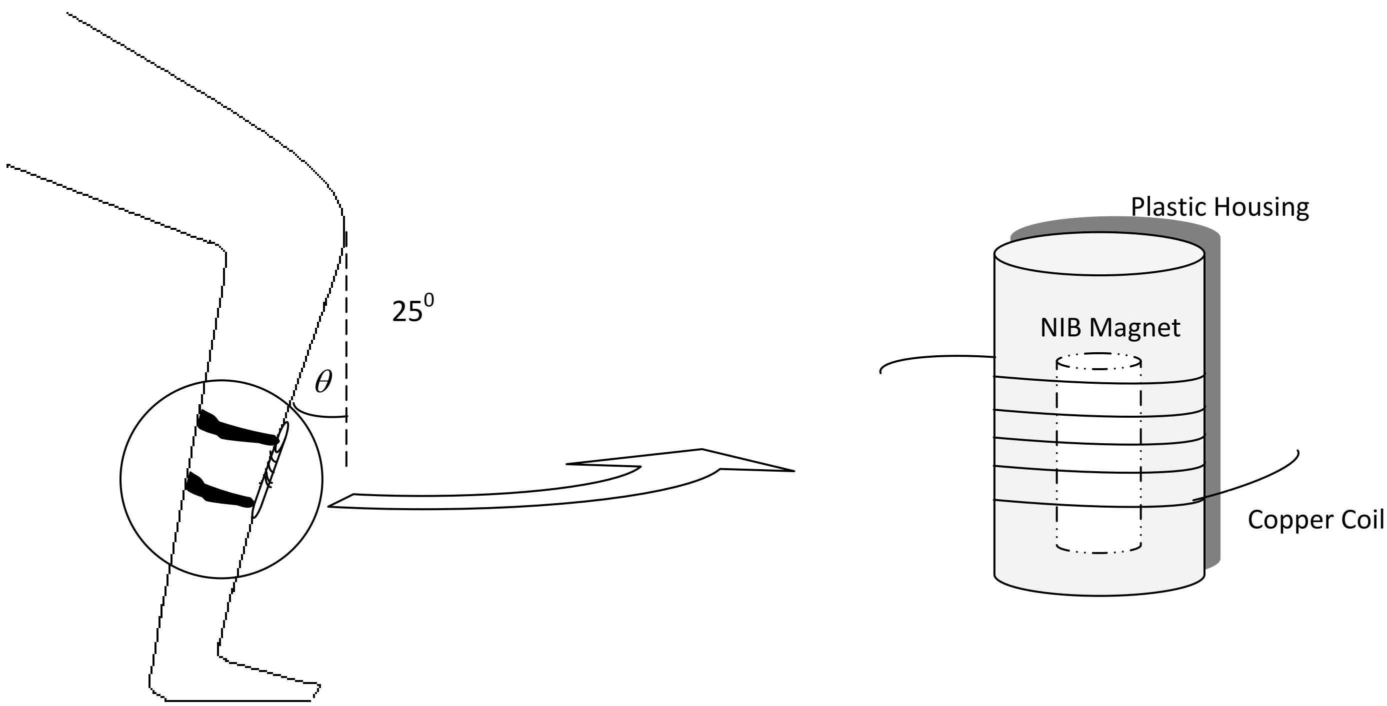
where,

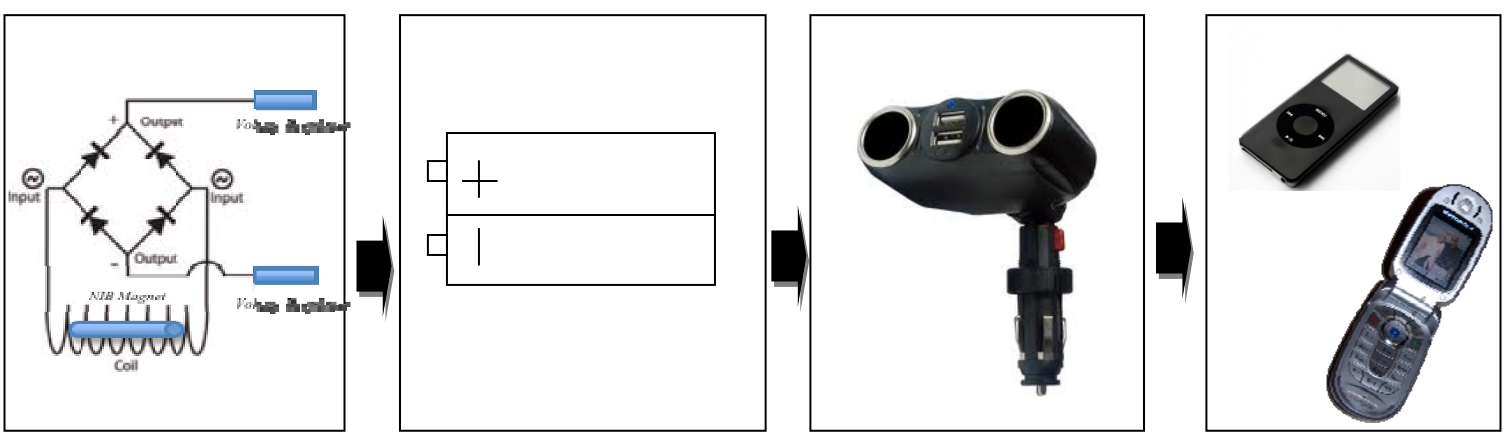
$\mu_0 = magnetic\ cons\tan t\ (4\pi \times 10^{-7}\ NA^{-2})$

Solution Approach

Primary Solution

We intend to use electromagnetic induction as a solution for the power generation for our pedometer energy harvester prototype. Using Faraday's Law of Induction, we desire to use a magnet that passes through a metal coil which, when you move, induces voltage in the coil generating electricity[2].





Transmission Circuit

Rechargeable Battery with

Multiple outlets for charging devices

Electronic devices

[2] This material was added in response to the comments made in the Proposal presentation on Dec 1, 2010

To determine N, the number of turns in the coil, we consider the following steps[3]:

$$e_{ind} = -N \frac{d\phi}{dt}$$

$where\ ,$

$N = Number\ \ if\ \ turns\ \ of\ \ wire\ \ in\ coil$

$\phi = BA$

$where\ :$

$B = Magnetic\ \ Flux\ \ Density$

$A = Area\ \ of\ \ the\ \ Magnet$

$As\ stipulated\ \ in\ the\ design\ \ requiremen\ \ ts, e_{ind} = 5$

$$5 + E_t = \frac{NBA}{t}$$

$E_t = Tolerance$

$Hence\ ;$

$$N = \left(\frac{5 + E_t}{BA}\right)t$$

$For\ \ the\ \ NIB\ \ Magnet\ ;$

$B = 13200\ \ Gauss$

$\quad = 1.32\ Tesla$

$A = 0.152\ m^2$

$\phi = BA$

$\quad = 1.32 \times 0.52$

$\quad = 0.2 Wb$

$According\ \ to\ Mechanics\ ;$

$$h = \frac{1}{2} g t^2$$

$$t = \sqrt{\frac{2h}{g}}$$

$$= \sqrt{\frac{2h\cos(\theta)}{9.8}}$$

$t = 1.36\ s$

$$\therefore N = \left(\frac{5 + 0.5}{0.2}\right)1.36$$

$$= 374\ \ turns$$

Magnet Specifications:

B_r = 13200 Gauss

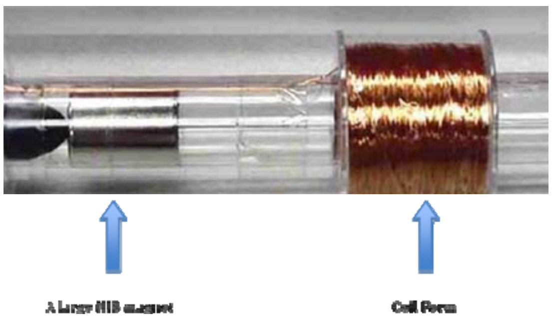
Dimensions: 0.5 inch diameter x 1.5 inch thick

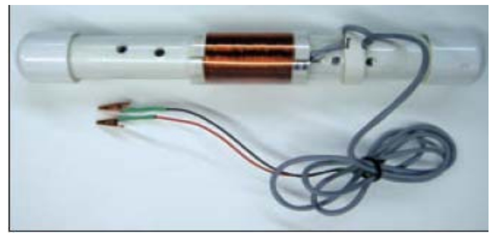
[3] This material is added by the comments made in Senior Design Proposal Presentation on DEC 1, 2010

Our Primary Solution Prototype has three main parts to it.

1. Power Generation
2. Power Transmission
3. Power Storage

Power Generation





Hardware Prototype of Generator

We are using the method that is already being used in *LED shake light*. We will have a large Neodymium Iron Boron (NIB) magnet passing through a metal coil to generate electricity through the induction.

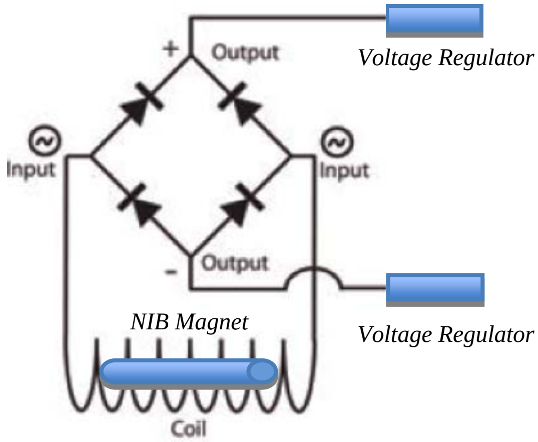
Magnet

Neodymium Iron Boron (and Samarium Cobalt) magnets are generally known as rare earth magnets since their compounds come from the rare earth or Lanthanoid series of the periodic table of the elements. They are the strongest known and were developed somewhere between the 1970’s and 1980's.

Coil Form

The heart of the FFL system is the coil (and magnet). The movement of the leg will be used to slide the magnet back and forth to induce voltage through the coil.

Power Transmission



The Power Transmission consists of 4 diodes. Diodes will control reverse flow of current, which would be a disadvantage of the system. Since the induced current is going to be dependent on the speed of movement of the magnet, there is a voltage regulator at the end. Zener diode is a good candidate for a voltage regulator. The purpose of voltage regulator is to control the output voltage of the generator.

Power Storage

Back-up Lithium Battery Pack

Outlets of Lithium Battery

We will be using *5V Pocket-size Rechargeable Lithium Battery Pack* as a solution for our energy storage. The specification of this Lithium battery is as follows

Battery Capacity:	26.6Wh
Battery output voltage:	5V
DC output:	100mA Max
Size:	5.2"x 3.1"x 0.6"
Weight:	0.606 lbs

Tasks & Deliverables

Tasks

No	Tasks	Start Date
1	Research on existing energy harvesting systems	10/23/10
2	Select the most viable solution	10/27/10
3	1st. draft of proposal writing	10/26/10
4	Submission of 1st draft of proposal	10/27/10
5	Development of presentation	11/03/10
6	Online submission of presentation	11/03/10
7	Revision of proposal	11/11/10
8	Submission of proposal (hardcopy)	11/17/10
9	Research tool kits to help understanding	11/15/10
10	Research on potential hardware to be used	11/20/10
11	Submission of final proposal	12/01/10
12	Acquire identified hardware	12/05/10
13	Commence development of design	12/09/10

Deliverables

After completion of this project, we expect that our deliverable meet the specified requirements set forth by Northrop Grumman:

- Detect & convert human motion into usable electrical energy
- Provide a portable power source that delivers power, nominal to USB device, large to battery reserve.

Budget[4]

Items	Cost($)
Magnet	10
Copper Coil	20
Housing	5
Battery	80
Diodes	5
Voltage Regulator	5
Adapter	25
Wires	3
Miscellaneous	2
Total	**165**

Conclusion

There is definitely use for a system like the Pedometer Energy Harvester, any alternate energy source provides an alternative to the already currently stressed popular sources. We believe that the concept of providing an "on-the-go" power source can be a lifesaver in many scenarios.

However, building a system that meets all the listed requirements is no easy task. We do believe that our design has what it takes to solve the problem without posing any safety hazards to users.

[4] This material was added in response to the comments made in the Proposal presentation on Dec 1, 2010

References

Emily Alden, Mark Kennedy, Wolfgang Lorenzon, and Warren Smith, *An Electromagnetic Induction Flashlight Experiment, University of Michigan,* Ann Arbor, MI;Vol. 45, November 2007: 492-495.

Richard J. Nelson, *The Forever Flashlight II - Batteries Not Required*, Excalibur Electronics, Inc, Miami, Florida.

PowerWalk™ M-Series, Data Sheet, BioniPower:http://www.bionic power.com/app_military.html.

Stephan J. Chapman, *Electric Machinery Fundamentals*, 4th Edition: 2005

Stuart M. Wentworth, *Fundamentals of Electromagnetics with Engineering Applications*: 2006

Attachment: Design Requirements

Design Requirement		
Design Project Title:	Pedometer Energy Harvester and USB/CL Power Hub (PEHUP)	
Team Name:	Pinnacle	
Team Members:	Bodunrin Jawando, Dhanushka Fernando	
Date:	10/26/2010	
Requirements	**Descriptions**	**Source**
Background (NEED)	Body power from pedometer type energy sources presents possibilities as energy harvest for the active.	
Objective (Problem)	Harvest energy from body power for recharging electrical accessories Detect and convert human motion into usable electrical energy Portable Power source	
Requirements	The PEHUP should: Generate 5Vdc @50 – 100mA (or 12V version) Charge battery up to 5 WHr Operating Temp: -10 – 40 Celsius Deliver Power: Nominal to a USB device, Large to battery reserve Provide enough external indicator of power condition	Northrup Grumman Design Document
Cost	TBD	
Safety	The PEHUP should: • adhere to all Electromagnetic Standards Committee safety standards (electromagnetic radiation and the associated processes) and not interfere with any of them. • adhere to IEEE Std. 1584, Guide for performing Arc Flash Hazard	IEEE and Electromagnetic Standard Committee.
Compliance	PEHUP should meet the electrical requirements as stated in most recent version of the following IEEE standards: • IEEEStd 1584, “Guide for performing Arc Flash Hazard Calculation” • International Electrotechnical Committee , “Electromagnetic Compatability”	IEEE, IEC
Energy, Power, and Environment	PEHUP should meet the environmental requirements as stated in the most recent version of the following IEEE standard: • IEEE Std 1100-2005, “Recommended Practice for Powering and Grounding Electronic Equipment"	IEEE
Size and Weight	15 lbs	
Deliverables	Demonstration prototype with 5V USB or 12V Cigarette Outlet	