"I hereby declare that I have read this report and it is in my opinion that this report comply with the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)."

Signature : ....

Supervisor's Name : GAN CHIN KIM

Date : 4 MAY 2006

SELF POWERED DISTANCE DETECTOR USING VIBRATION BASED POWER GENERATION

ANNE WONG SIAW FUNG

This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Industrial Power)

Fakulti Kejuruteraan Elektrik
Kolej Universiti Teknikal Kebangsaan Malaysia

MAY 2006

"I hereby declare that this report is a result of my own work except for the excerpts that have been cited clearly in the reference."

Signature : ....

Student's Name : ANNE WONG SIAW FUNG

Date : 3 MAY 2006.

This is dedicated to all those who have contributed.

ACKNOWLEDGEMENT

First, I would like to thank the Almighty One for giving me the patience, wisdom and perseverance to complete this project. I would also like to take this opportunity to express my gratitude to my supervisor, Mr. Gan Chin Kim for his guidance an also invaluable advice in helping me to complete this project successfully. Last but not least, I would like to thank the staffs of Faculty of Electrical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia and also my fellow comrades in 4BEKP for their support and friendship.

Thank you.

ABSTRACT

Low power design trends raise the possibility of using ambient energy to power electronic devices. A distance detector system is used to demonstrate the feasibility of operating an electronic device from power generated by vibrations in its environment. Vibration is any form of periodic motion. Its frequency can be discrete, represented by a pure sine wave or complex and represented by a combination of fundamental and harmonic frequency components. The generator consist of a mass is tied to the rotor of the generator. When the generator is shaken, the vibration will cause the rotor to turn which will then turn the motor of the generator. The generator is then connected to the SuperCap circuit. The electrical energy produced from the generator will charged the SuperCaps where it will be used to power the distance detector circuit.

ABSTRAK

Reka bentuk peralatan kuasa rendah masa kini, telah meningkatkan kemungkinan untuk menggunakan sumber kuasa dari persekitaran untuk menjana peralatan elektronik. Sistem alat pengesan jarak digunakan untuk menunjukkan kebolehan menggunakan kuasa yang dihasilkan daripada gegaran untuk menjana alatan elektronik. Gegaran merupakan suatu gerakan berkala walau dalam apa jua bentuk. Selain mempunyai frekuensi yang diskret, ia juga mempunyai gelombang sinus atau gelombang yang kompleks dan diwakili oleh kombinasi asas dan harmonik komponen frekuensi. Penjana yang digunakan pula menpunyai pemberat yang diikat pada rotor penjana tersebut. Apabila penjana tersebut digoncangkan, hasil daripada gegaran yang terhasil akan memutarkan rotor yang kemudiannya akan memutarkan motor penjana. Penjana tersebut disambungkan kepada litar SuperCaps. Kuasa elektrik yang terhasil daripada penjana tersebut akan mengecaj litar SuperCaps, dimana ia akan digunakan untuk menjana litar pengesan jarak.

TABLE OF CONTENTS

LIST OF EQUATIONS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Various schemes of ambient energy have been proposed to eliminate the need for batteries in a portable system. Ambient energy is energy that is in the environment of the system and is not stored explicitly. The most familiar ambient energy source is solar power, but other examples include electromagnetic fields, temperature difference, energy produced by human body, and the action of gravitational fields [1].

The approach chosen for this project is to harvest ambient energy sources for power involves transduction of mechanical vibration to electrical energy. The electrical energy produced from the vibration will then be use to power the distance detector. Since ambient energy sources are by definition uncontrolled, a mechanism for converting the energy to a form usable by the distance detector is required.

For this project, a generator based on transducing mechanical vibration is used. The generator can be enclosed to protect it from the harsh environment, it function in a constant temperature field, and it can be activated by shaking it. The mechanical vibration produce by the shaking will be converted into electrical energy. This electrical energy will then be used to power the distance detector.

1.2 Objectives

The main objective of this project is to use alternative energy supply to be supply to the distance detector, which for this project vibration is used. Aside from that, the goal of this project is also to convert the kinetic/mechanical energy from vibration into electrical energy. Last but not least, the most important task is to build a complete prototype of the self-powered distance detector powered by vibration-based power generation.

1.3 Theory and Background

To convert mechanical energy into electrical energy, one should be able to realize the movement between the mechanical parts of the generator. As vibrations consist of a travelling wave in or on a solid material, it is often not possible to find a relative movement within the reach of a small generator.

Figure 1 shows the mechanical drawing of a generator. This device consists of a mass m connected to a spring k. The other end of the spring is attached to a rigid housing. When the housing is vibrated, the mass moves relative to the housing and energy is stored in the mass-spring system. A wire coil l is attached to the mass and moves through the field of a permanent magnet B as the mass vibrates. The moving coil cuts a varying amount of magnetic flux, which in turns induces a voltage on the coil in accordance with Faraday's Law of induction. This voltage is the electrical output of the generator.

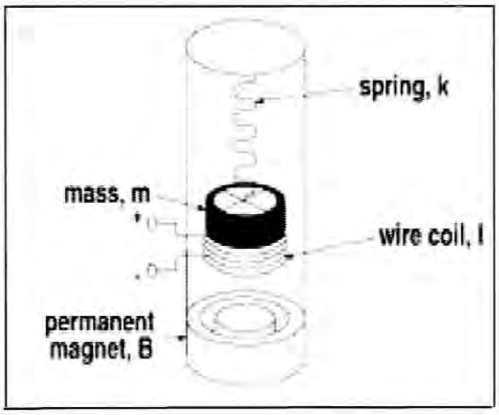

Figure 1: Generator mechanical schematic

1.3.1 Faraday's Law

Any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil. No matter how the change is produced, the voltage will be generated. The change could be produced by changing the magnetic field strength, moving a magnet toward or away from the coil, moving the coil into or out of the magnetic field, rotating the coil relative to the magnet, etc.

Faraday's law of induction gives the relation between the rate of change of the magnetic flux through the surface *S* enclosed by a contour *C* and the electric field along the contour:

$$\int_c \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \int_s \mathbf{B} \cdot d\mathbf{A} \tag{1.1}$$

where **E** is the electric field, **dl** is an infinitesimal element of the contour *C* and **B** is the magnetic flux density. The directions of the contour *C* and of dA are assumed to be related by the right-hand rule. Equivalently, the differential form of Faraday's law is

$$-\mathbf{V} \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{1.2}$$

which is one of the Maxwell equations. In the case of an inductor coil where the electric wire makes N turns, the formula becomes:

$$V = -N\frac{d\Phi}{dt} \tag{1.3}$$

where V is the induced electromotive force and dΦ/dt is the time-rate of change of magnetic flux Φ. The direction of the electromotive force (the negative sign in the above formula) was first given by Lenz's law. Faraday's law of induction is based on Michael Faraday's experiments in 1831.

1.4 Problem Statement

Portable systems that depend on energy that is stored explicitly, for example, in a battery have limited operating lives and can failed at inconvenient times, while a system powered by ambient sources has a potentially infinite lifetime. When using a system powered by ambient sources, the output voltage from this energy varies rapidly with time, in contrast to the slowly drooping battery voltages of conventional system.

Besides that, maintenance and replacement of batteries is also a hassle especially in long-lived system. For example, in a smart structure where the detectors are embedded in a bulk material, access to the electronics is greatly reduced. Modern electronic components are becoming smaller and smaller, thus the scaling down of traditional batteries also faces technological restrictions as well as a loss in storage density.

CHAPTER 2

LITERATURE REVIEW

2.1 Vibration

Vibration is generally defined as any oscillatory motion induced in a structure or mechanical device as a direct result of some type of input excitation or one would say a movement first in one direction and then back again in the opposite direction. It is exhibited, for example, by a swinging pendulum, by the prongs of a tuning fork that has been struck, or by the string of a musical instrument that has been plucked. Random vibrations are exhibited by the molecules in matter. Any simple vibration is described by three factors: its amplitude, or size; its frequency, or rate of oscillation; and the phase, or timing of the oscillations relative to some fixed time [1].

For most practical applications, mechanical or structural vibrations are phenomena to be avoided since they are generally unwanted and, according to their magnitude, can produce physical discomfort, misalignment of equipment, and loosening of mechanical fasteners. In the case where the excitation is of sufficient magnitude (such as in an earthquake), severe structural damage can occur.

Vibrations are commonly measured using a device known as an accelerometer. This device consists of a small piezoelectric crystal shaped to produce an electrical charge when it is vibrated. Decibels may also be used to describe vibration levels. The symbol VdB is used to differentiate vibration levels from noise levels. Like the decibel measure used for noise levels, the vibration decibel is used to express a large range of levels over a logarithmic scale. Take note that although decibels are used to describe both noise and vibration, the values are not comparable.

Various references provide different values for the threshold of human perception. A vibration of more than 100 VdB may cause structural damage to a house.

2.2 Vibration Generator

2.2.1 Electromagnetic Generator

For electromagnetic generators as written by Sterken T., Baert K., Van Hoof C., Puers R., Borghs G., and Fiorini P [3] in their journal, an electromotive force (e.m.f.) is induced across a coil if the magnetic flux coupled to the inductor changes as a function of time. The relationship between this e.m.f. and the displacement *z* of the mass depends on the design of the system.

Referring to the two examples of electromagnetic generators given in Figure 2.1, the relationship of *z* to the induced e.m.f. for both cases are represented by

$$\text{e.m. f.} = Kz. \qquad (2.1)$$

A similar relationship exists between the force on the coil and the current through the coil: $F = Ki$. For conservation of energy, the factor K in both the expressions needs to be identical. It represents the change in coupled flux per unit displacement. Linearization of the model results in a constant transformation factor K. applying a resistive load R_{load} gives the following relation between the current through the load and the induced e.m.f.:

$$\text{e.m.f} + R_{load} + \frac{Ldi}{dt} = 0 \qquad (2.2)$$

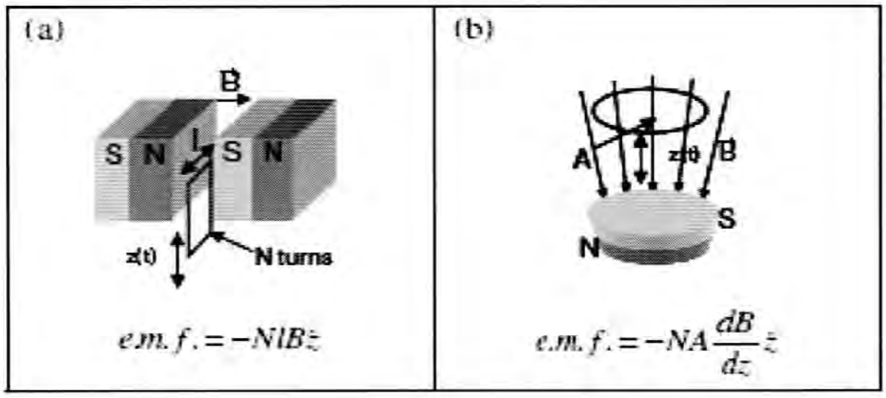

Figure 2.1: Electromagnetic generators (a,b)

2.2.2 Electrostatic Generator

Two common configuration of the electrostatic generator are shown in Figure 2.2 are taken from the journal by Sterken T., Baert K., Van Hoof C., Puers R., Borghs G., and Fiorini P [3]. The electrostatic generator consists of a capacitor whose values changes as a function of *z*. If the electrodes of the capacitor are connected to a load resistor R_{load} a current will flow given by:

$$I = \frac{dQ}{dt} = \frac{d\,(C(z)V)}{dt} = V\,\frac{dC(z)}{dz}\,z' + C(z)\,\frac{dV}{dt} \qquad (2.3)$$

where V represents the voltage across he capacitor charged with Q. The first term in the right side of the equation represents the electromechanical coupling, while the electrical behaviour of the capacitance is described in the second term. When the capacitor is biased with a voltage V_0, the electromechanical coupling of the generator is enhanced.

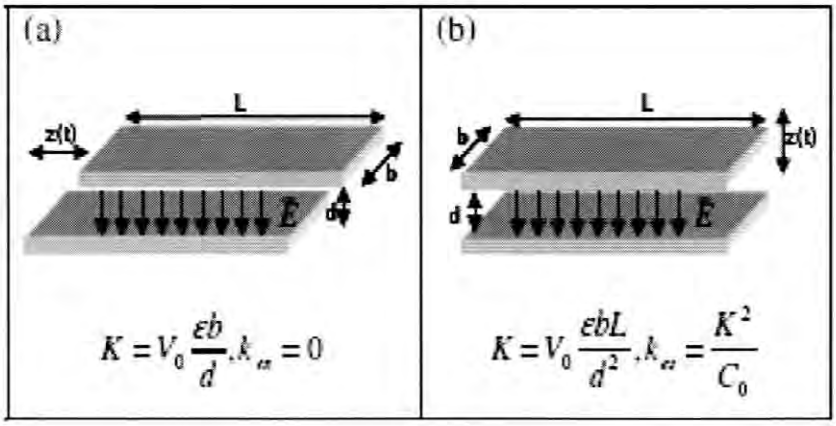

Figure 2.2: Electrostatic generators (a, b)

2.2.3 Piezoelectric Generator

The piezoelectric generator uses a piezoelectric material within a capacitor as a generator as written by Sterken T., Baert K., Van Hoof C., Puers R., Borghs G., and Fiorini P [3] in their journal. A voltage appears across the capacitor and a current will flow through the load resistor when a mechanical force deforms the material. It is not possible to connect piezoelectric materials directly between the mass and the packaging of the generator as this would result in a very high resonance frequency because piezoelectric materials are stiff materials.

As a solution to this problem, the generator is often mounted on a long thin beam that transforms a large movement z into a smaller elongation x by bending the piezoelectric layer. The bending beam behaves as transformer that down scales the displacement while scaling up the force on the piezoelectric layer. Figure 2.3 below shows the configuration of a piezoelectric generator.

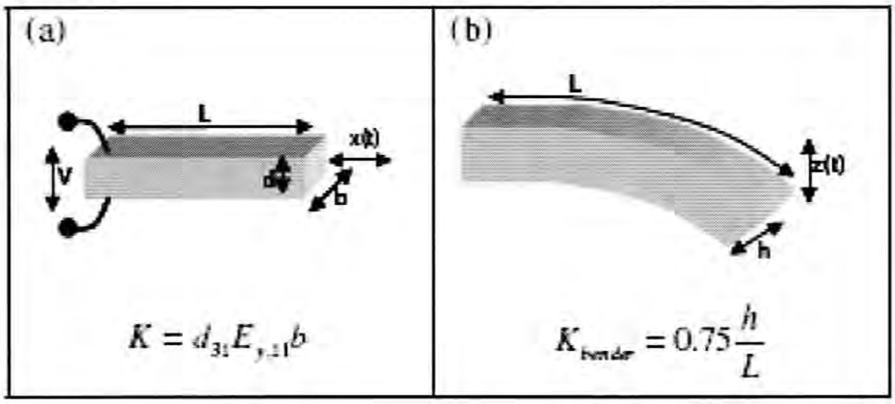

Figure 2.3: A Piezoelectric generator (a), a bender (b)

2.2.4 Electromagnetic Micro-Generator

The design of two prototypes of miniature generators capable of converting ambient vibration energy into electrical energy are describes in the journal written by P. Glynne-Jones, M.J. Tudor, S.P. Beeby, N.M. White [3] in November 2002.

The first prototype (prototype A) is a two magnet generator coupled to a coil attached to a beam. A typical magnet-coil generator consists of a spring-mass combination attached to a magnet or coil in such a manner that when the system vibrates, a coil cuts through the flux formed by magnetic core. The beam can either be connected to the magnetic core, with the coil fixed relative to the enclosure, or vice-versa.

The second prototype (prototype B) is designed to create a magnetic field through a greater proportion of the length of each coil winding when compared to double or single magnet design. The coil is characterized by the proportion of the coil that passes through the magnetic field, the number of turns in the coil, and its series resistance. Second-order effects such as the coil inductance can often be ignore due to the low frequency of many applications.

It is important in this case to choose a type of magnet that will produce a strong flux density in order to improve the degree of coupling. For this application,