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ENERGY SCAVENGING USING PIEZOELECTRIC MATERIALS

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Abstract

In recent years, wireless devices have been developing rapidly for various uses that run on batteries. However, when the devices are made smaller and the networks increase in number, it is not practical to replace the depleted batteries, such as in areas difficult to access. Alternative method is to scavenge power available in the environment where the wireless device is placed.

This thesis is focused on scavenging power via vibrations as a power source. According to the literature piezoelectric material is the best choice to convert mechanical forces into electric field. Piezoelectric generator devices have been modelled and analyzed.

A case study of power generator for use in traffic monitoring sensors is assumed. The thesis describes such a piezoelectric power generator, developed based on a cantilever beam and using modelling techniques available in literature. The design is optimized by Sequential Quadratic Programming method. A prototype of the generator is built and tested extensively. The generated power is stored in a specially built circuit.

The experiments show that the prototype piezoelectric power generator can provide 0.09J in a simulated traffic scenario. Also the generated energy can be stored in the electric circuit which gives a stable 5 V DC output. It is noted that piezoelectric material is very brittle and was cracked during the experiment. As a consequence, the most of the experiment were conducted with a slightly modified generator.

In conclusion, this thesis research has developed successfully both mathematical and a physical model of the piezoelectric power generator for wireless traffic monitoring sensors. Further work will still be in order in improving the current design.

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1. Introduction

With the recent advances in wireless and Micro-electro-mechanical-systems (MEMS) technology, the requirement for portable wireless sensors and electronics is growing rapidly. A significant engineering problem that needs to deal with is the supply power for the applications such as medical implants and structural monitoring. The power supply of the applications makes use of the conventional batteries in most cases, however, problems can happen because of their finite lifespan. In some cases, replacing the battery of portable electronics is problematic because the electronics could die at any time. For the wireless sensors application, the sensors can be placed in very remote locations such as structural sensors on a bridge or global positioning system (GPS) tracking devices on animals in the wild. When the battery of all its power goes flat, the sensor must be got back and the battery be replaced. Because these devices are placed in remote locations, only acquiring the sensors and replacing the batteries can become a very expensive task or even impossible. For some civil infrastructure applications the sensors are often expected to be embedded, replacing battery is unfeasible. As an alternative, scavenging energy from the surrounding medium seems very attractive, and then it could be used to replace or charge the battery. One method is to use piezoelectric materials to convert mechanical forces into an electric energy in response to the application of mechanical stresses. This scavenged energy could be used to extend the life of the power supply or in the ideal case provide endless energy for electronic devices lifespan.

The aim of this thesis research was to use piezoelectric material to design and build such a power supply device based on the principle of piezoelectric converter, as proposed by Roundy et al [1]. Then the model of piezoelectric generator was optimized for a wireless magnetic sensor node assumed as the power consumer. This work was carried out with the following objectives:

- *Modelling and analysis of piezoelectric generator.* A general model is formulated for the conversion of the kinetic energy of a vibrating mass to electrical power.
- *Design optimization for wireless sensor node.* A case study of energy scavenging for traffic surveillance is performed and a prototype is

designed and optimized for the wireless traffic sensor node.

- *Circuit design for power storage.* Once the piezoelectric device generated electric power by vibration the circuit is then designed as an energy buffer between the input from the piezoelectric generator and the output to the sensor node.
- *Experimentation of the optimized prototype generator.* A prototype converter is designed and built based on the optimizations. The test results would be presented.

The rest of the thesis is organized as follows. In Chapter Two, literature review is detailed. It focuses on the wireless medical sensor systems and enumerates available power sources for wireless sensor network. In Chapter Three, a brief review of the modelling piezoelectric generator is given first. Then based on the research deduction of Roundy et al [1] a piezoelectric generator is modelled mathematically and simulated for analysis. In Chapter Four, a case study of a wireless magnetic sensor powered by piezoelectric generator is analyzed and the design is optimized in Matlab. In Chapter Five, a circuit for power storage is designed. It is a classical AC-DC converter. In Chapter Six, according to the designed and optimized converter in previous chapter, experiments are conducted and the results analyzed. In Chapter Seven, the conclusions and recommendation are given.