Design of energy harvesting systems for harnessing vibrational motion from human and vehicular motion

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ABSTRACT

In much of the vibration-based energy harvesting literature, devices are modeled, designed, and tested for dissipating energy across a resistive load at a single base excitation frequency. This paper presents several practical scenarios germane to tracking, sensing, and wireless communication on humans and land vehicles. Measured vibrational data from these platforms are used to provide a time-varying, broadband input to the energy harvesting system. Optimal power considerations are given for several circuit topologies, including a passive rectifier circuit and active, switching methods. Under various size and mass constraints, the optimal design is presented for two scenarios: walking and idling a car. The frequency response functions are given alongside time histories of the power harvested using the experimental base accelerations recorded. The issues involved in designing an energy harvester for practical (i.e. time-varying, non-sinusoidal) applications are discussed.

Keywords: power harvesting, piezoelectric

1. INTRODUCTION

Energy harvesting – the ability to harness, store, and distribute energy from the local surroundings of an electronic device – has generated significant research over the past decade. By tapping into nearby sources of energy in the surroundings of a device, this ability has the potential to reduce the frequency of battery replacement or altogether eliminate the need. The field of vibration-based energy harvesting has received particular attention due to the ubiquity of untapped vibrational energy available in or around most manmade systems [1]. This great potential has spurred research into several methods of electromechanical transduction, including electromagnetic induction (e.g. [2]), electrostatic varactance (e.g. [3]), and the piezoelectric effect, the latter being the focus of this study.

In many practical scenarios, the vibrational energy existing in the environment is stochastic, time-varying, and insufficient to power wireless devices continuously. Thus, a power management scheme that utilizes energy conversion and storage is usually required. Many studies have been focused on optimizing the interfacing circuit to maximize the power output of a piezoelectric transducer on specific resistive loads. For example, a DC-DC step-down converter circuit has been implemented to increase the energy harvesting efficiency at high excitation levels [4-5]. Techniques such as SSHI/SSHC (Synchronized Switching Harvesting on an Inductor/Synchronized Switching Harvesting on a Capacitor) are also capable of increasing the piezoelectric transducer power output when electromechanical coupling is low by inverting the electric field every half cycle and, consequently, increasing its amplitude [6-7]. Furthermore, synchronous charge extraction methods similar to the SSD (Synchronized Switching Damping) technique used in structural damping [8] have been shown to increase the power output to 400% the power output across a matched resistive load under ideal circumstances. This performance has been demonstrated to be independent of the load resistance; however, the power consumption of the switching circuit is not considered [9]. Recently, a self-powered

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