Energy Management of Multi-component Power Harvesting Systems

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ABSTRACT

Recent efforts in power harvesting systems have concentrated primarily on the optimization of isolated energy conversion techniques, such as piezoelectric, electromagnetic, solar, or thermal generators, but have focused less on combining different energy transducer types and have placed less emphasis on storing the converted energy for use by other devices. The purpose of this work is to analyze and present an integrated piezoelectric and electromagnetic power harvesting system utilizing existing technology for energy management and storage. Primary emphasis is on the analysis of the combination of existing, or readily obtainable, energy conversion techniques, operating as a single system, and the energy conversion efficiency of the alternating to direct current management, or storage, circuit.

Keywords: Power harvesting, energy harvesting, piezoelectric, electromagnetic induction, management circuitry, AC-DC efficiency, energy storage, full-wave rectification

1. INTRODUCTION

Research publications on power harvesting devices have seen a sharp increase within the last ten years due to the advancements in low-power electronics, specifically wireless technologies, and the corresponding limited performance growth in standard batteries. With these new embedded power source technologies, researchers have turned their focus on renewable power systems for electrical energy storage, which is the impetus for development of ambient energy transducers, also known as energy harvesters, power harvesters, or simply, generators. Researchers such as Sodano et al. [1], Glynne-Jones et al. [2], Fleurial et al. [3], and Raghunathan et al. [4] have therefore been driven to explore the available energy present for their power harvesters to utilize, where options range in the form of vibration energy, thermal-gradient energy, solar energy, amongst others. With many of these devices being ultimately integrated into printed circuit board designs, investigators such as Roundy et al. [5] and Mateu and Moll [6] have also studied scaling issues with regard to dimensions available for the power harvesting device, its mass constraints, and the minimum power generation required for it to be useful. Typically, results have shown that with limited efficiencies, as shown by Goldfarb and Jones [7] and Reissman et al. [8], for these energy transducers and the coupling of the small amounts of energy available for conversion, shown by Pereyma [9], integrated power harvesting devices are appropriate for providing low power. This has caused researchers to shift focus from the power harvester to optimizing the power transfer to the energy storage device, be it a capacitor or rechargeable battery. Approaches by researchers such as Guyomar et al. [10], Ottman et al. [11], and Shu et al. [12] have primarily concerned themselves with only piezoelectric power harvesting devices, which convert vibration energy into electrical energy. The reason that the majority of energy management circuitry is based on piezoelectric sources is that there exist a multitude of ways in which conditioning of the electrical signal generated can be performed, using characteristics such as large output voltages, high energy densities, etc. In circumstances where tuning of the piezoelectric is necessary in order to lower its resonance frequency to that of the driving frequency, many designers choose to simply add a tip mass to the cantilever's free end, see Roundy and Wright [13]. This mass is effectively a dead mass in the system, which is not practical in systems with mass limitations. An example of such a mass-limiting system would be tracking devices attached to migratory birds. With too much payload, the birds are unable to fly. Thus, a piezoelectric system can only add mass within the limits defined by the system.

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