Analytical modeling of electret-based microgenerators under sinusoidal vibrations

by

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Statement of originality

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Abstract

Recent advances in microfabrication technologies and electronics have led to a vast reduction in sizes and power consumption of electronic circuitry. This has revolutionized the field of wireless sensor networks, and in particular, Internet-of-Things, with a booming number of applications that enable the capabilities of autonomous sensing and monitoring. However, the implementation of such applications has been hindered by the slow development of scalable energy sources which provides power for operation. Batteries, which are the most common energy sources, have not kept pace with the demand of these developments. The challenge to provide power for microelectronic devices has, therefore, driven several innovations in vibration energy harvesting - a technology that has been flourished in recent years as a possible alternative to provide continuous energy for autonomous operation. During the last decade, a significant number of microscale vibratory energy harvesters has been fabricated using active materials (piezoelectric, ferroelectric and magnetoelectric) or exploiting the electromechanical coupling mechanisms (electromagnetic and electrostatic) to harvest energy from mechanical stimuli or ambient vibrations. Such transduction mechanisms have both benefits and limitations that vary depending on the employed technology and the targeted application. For miniaturization, electrostatic systems are favorable due to their compatibility with MEMS fabrication processes. In addition, electrostatic systems with pre-charged electrets can autonomously harvest energy to energize microelectronic devices such as wireless sensors and actuators. Hence, this transduction mechanism is selected as the topic of this research.

The main focus of this research is the analytical modeling approach that provides insights into the operating mechanism and trade-off involved when designing an electret-based microgenerator. Sinusoidal excitations which resemble ambient vibration stimuli were considered in this research. The modeling process was, firstly,

undertaken for a simple case when the vibration amplitude is small, and then extended and generalized for an arbitrary sinusoidal vibration. Under these conditions, an electret-based can be modeled as a sawtooth voltage source in series with an equivalent internal resistance, or a current source. These models were validated using a simulation-based method presented in the literature and showed good agreements. A performance optimization was also carried out by employing the proposed analytical model combined with voltage breakdown phenomenon and the limitation of material properties. However, a fully functional micro power generator driven by vibrations has yet to be demonstrated.

In summary, the research has expanded the capability of analytical modeling and understanding of electret-based microgenerators. These can be used in further studies and optimizations to achieve the ultimate goal of autonomous operation.

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Publications

Journal articles

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