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Energy Harvesting for Micro-Electro-Mechanical Systems (MEMS)

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ABSTRACT

"Energy harvesting" is a technology that converts the excess energy available in an environment into usable energy for low power electronics. Many ambient energy sources have been considered for this purpose such as incident light, vibration, electromagnetism, radio frequency (RF), human body functions, temperature gradient etc. However, each of these energy sources has its own drawbacks. For example, although the solar cells offer excellent power supply in direct sun light, they are inadequate in dim office lighting. On the other hand, the circuit design for transmitting the power harvested from low level vibrations is another challenging problem.

Keywords: radio frequency (RF), human body functions, temperature gradient.

INTRODUCTION

Energy harvesting, also known as "Energy Scavenging", "Parasitic Energy", or "Micro Generators" in the literature, is a process performed by a conversion mechanism for generating electric power from available ambient energy sources. Incident light, thermal gradients, machine vibrations and human body functions are the well known examples of ambient energy sources receiving the attention of many researchers. Since energy harvesting systems offer maintenance-free, long-lasting, green power supply for many portable, low-powered electronic devices, they are likely to become an essential part of power management systems. In this paper the growing interest in the field of energy harvesting systems is also due to great developments in related technologies such as micro-electromechanical-system (MEMS) technology, wireless sensor network (WSN) technology. In figure (1), components of a vibration energy harvesting system are depicted. This flow chart can be generalized for all energy harvesting systems in which an energy source, a conversion device, a conditioning circuit and an electric load are the main components of the general energy harvesting system.

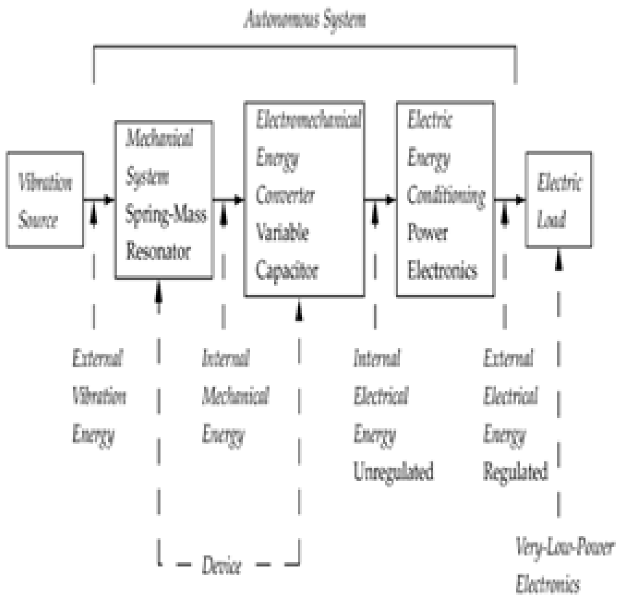

Figure 1: Vibration Energy Harvesting System Components

In this paper the general system basically aims to accomplish five consecutive tasks:

- Collecting the maximum energy from the energy source
- Converting the ambient energy into electric energy efficiently
- Rectifying and storing the maximum amount of electric energy
- Regulating the output voltage level depending on the application
- Transmitting the electric energy to the load when it is required.

Availability of the ambient sources, the power densities of the converters, the duty cycles and the power needs of the electric loads, however, are the primary limitations of the energy harvesting systems. For example, solar cells can generate excellent power densities in direct sun light; but they need to be optimized for conditions of dim light or no light at all. Thermoelectric energy converters need large energy gradients to generate substantial power. Power delivery and user comfort are critical while generating power by means of body functions such as breathing, blood pressure, walking etc.

LITERATURE REVIEW

Energy harvesting from a vibration source for low power electronic devices and sensors is an appealing idea, since there are various kinds of vibration sources around ranging from the wind and sea waves to human body motion and vibrating machinery in the industry. Vibration sources are usually preferable to incident light or thermal gradient energy sources requiring an appropriate operating time and running condition. In this paper therefore many research programs focusing specifically on "vibration to electric energy converters" have been conducted for various medical, industrial and military applications for more than a decade. Despite the large variety of prototypes designed for this purpose so far, the technology behind these conversion mechanisms is mainly based on three well-known effects in physics, namely the electrostatic, electromagnetic and piezoelectric effects. In brief, electrostatic, electromagnetic and piezoelectric designs require a variable capacitor, a magnet and piezoelectric material respectively inducing a voltage on plates, in a coil and between the electrodes as they oscillate. However, the design of an energy converter, especially in microscale, becomes a little more sophisticated and therefore attractive for the researchers, when the system emerges as a vibration energy dissipation problem needing to be examined for various aspects to achieve a maximum power density and efficiency. While some of the reported generators have already been fabricated using MEMS techniques, others have been made on a mesoscale with the intention of later miniaturizing the devices using MEMS [2].

Williams et al. (1995) [1] introduced a generic model for estimating the power that can be generated in a microscale device. In this model, any electric component in which the energy conversion takes place is considered as an energy dissipation element (other than the inherent mechanical dissipation element) of the mechanical system.The vibration source here is assumed to be infinitely large with respect to the system so that it is not affected by the motion of the conversion system.

Mitcheson et al. (2004) [2], classified the vibration-driven micro-generators reported in the literature so far based on three fundamental architectures, namely the velocitydamped resonant generators (VDRG), coulomb-damped resonant generators (CDRG), and coulomb-force parametric generator, for establishing a unified analytical framework for such devices and providing a methodology for designing optimized generators for particular applications. First of all, they adapted the deflection limit of the proof mass, a key constrained in a MEMS application, to the general formulation.

Roundy et al. [2] analyze the design parameters of electrostatic and piezoelectric converters, and then fabricate and test their prototypes shown in figure (2).

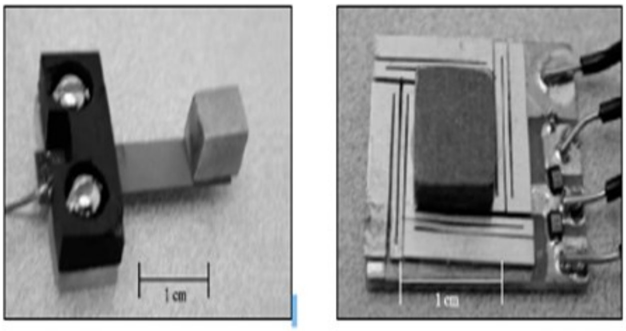

Figure (2) Piezoelectric (on the left) and Capacitive (on the right) Converter Prototypes

The mathematical model introduced by Williams et al. is modified for each mechanism by substituting the system specific design parameters. The estimated powers of the optimized converters are given in table (3) where a vibration source with a fundamental frequency of 100Hz and an acceleration magnitude of 2.25m/s2 is employed. On the experimental side, the piezoelectric prototype without an optimum design is reported to generate an average power of 60 µW, however no comparable output power is stated for the electrostatic converter prototype.

PIEZOELECTRIC ENERGY HARVESTER MODEL

A unimorph consists of a single layer of piezoelectric material on the substrate. A proof mass is attached to the free end of the cantilever beam.

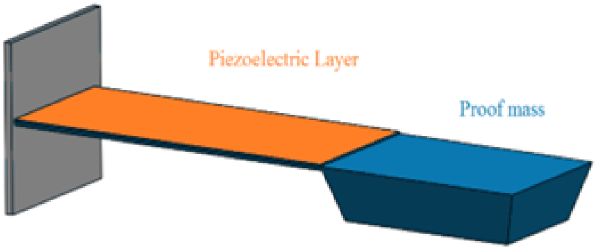

Fig 3. Perspective view of a typical piezoelectric energy harvesting cantilever

In this paper in the piezoelectric energy harvesters, the strain energy of vibrations is converted by the piezoelectric material into electrical energy.The harvester is in the form of a piezoelectric cantilever beam with an end-mass as shown in Fig. 3. The piezoelectric layer on the substrate gets stretched and compressed longitudinally during vibrations. The alternating strain in the layer results in alternating charge separation across the thickness of the piezoelectric material. It is assumed that electrodes cover the piezoelectric material completely. Hence, the two parallel electrodes act as equipotential surfaces along the beam length. In order to determine the amount of energy generated by the harvester, a load resistance is connected to the two equipotential surfaces of the harvester. Modelling of such harvesters can be carried out using either Newtonian or Lagrangian approach. Following these approaches, several researchers have proposed piezoelectric energy harvester models[5][6]. An extension of the model to multilayer and multistep harvesters following Lagrangian approach[7]. The equations of motion governing the harvester dynamics.

POWER DEVELOPED BY A HARVESTER

In this paper the power developed by a piezoelectric harvester depends on excitation, equivalent mass, frequency and power factor. As these are in convoluted form, the dependence is delineated based on size, material, composition and inertia.

The power developed by a harvester is determined by noting the amplitude of the alternating voltage across the load resistance Rl. If the voltage drop across R_l is V_0, the power developed is given by

$$P = \frac{V_o^2}{2R_l} \qquad (1)$$

where V_0 is given by the complex quantity.

CONCLUSION

In this paper the conversion mechanism is described by a linear model consisting of a damped spring mass system coupled with an oscillating platform. The proof mass creates a relative motion with respect to the vibrating platform, while the spring stores and discharges potential energy in the vibrating system. Since energy conversion can be considered as a way of dissipating energy, the electrical component where energy conversion phenomenon takes place can be modeled as a damper other than the inherent damping element of the vibrating system. Design of piezoelectric energy harvesters for higher power generation involves selecting the right geometry and piezoelectric material for a given size of the harvester. We have discussed a method to analyze the power generated by a unimorph that can also be extended to bimorphs or multilayer harvesters. The proposed method introduces the fewest possible variables that govern the power developed by a harvester. The power expression obtained from the previous analysis contains the fundamental design parameters including proof mass, electrically induced and total viscous damping factors, amplitude of the source acceleration and the excitation frequency. With the appropriate selection of these parameters maximum energy transformation efficiency should be achieved.

Conflicts of interest: The authors stated that no conflicts of interest.

REFERENCES

1. Williams CB, Yates RB, "Analysis of a Micro-Electric Generator for MicroSystems", Proceedings of the Transducers 95/Eurosensors IX (1995) 341-344
2. Roundy S, Wright PK, Rabaey J, "A study of low level vibrations as a power source for wireless sensor nodes", Computer Communications,2003, v 26, n 11, Jul 1, p 1131-1144
3. Umeda M, Nakamura K, Ueha S, "Analysis of the Transformation of Mechanical Impact Energy to electric Energy Using Piezoelectric Vibrator", Japanese Journal of Applied Physics, Part 1: Regular Papers & Short Notes & Review Papers,1996, v 35, n 5B, May, p 3267-3273
4. Umeda M, Nakamura K, Ueha S, "Energy storage characteristics of a piezo generator using impact induced vibration", Japanese Journal of Applied Physics, Part 1: Regular Papers & Short Notes & Review Papers,1997, v 36, n 5B, p 3146-3151
5. Sriramdas R, Chiplunkar S, Cuduvally RM, and R. Pratap, "Performance enhancement of piezoelectric energy harvesters using multilayer and multistep beam configurations," IEEE Sensors J., Jun. 2015, vol. 15, no. 6, pp. 3338–3348.
6. Roundy SJ, "Energy scavenging for wireless sensor nodes with a focus on vibration to electricity conversion," Ph.D. dissertation, Dept. Eng.-Mech. Eng., Univ. California, Berkeley, CA, USA, Jun. 2003.
7. A. Erturk, "Electromechanical modeling of piezoelectric energy harvesters," Ph.D. dissertation, Dept. Eng. Mech., Virginia Polytechnic Inst. State Univ., Blacksburg, VA, USA, Nov. 2009.