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Original

A rotary electromagnetic microgenerator for energy harvesting from human motions

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Abstract

In this paper, a rotary electromagnetic microgenerator is analyzed, designed and built. This microgenerator can convert human motions to electrical energy. The small size and use of a pendulum mechanism without gear are two main characteristics of the designed microgenerator. The generator can detect small vibrations and produce electrical energy. The performance of this microgenerator is evaluated by being installed peak-to-peak during normal walking. Also, the maximum harvested electrical energy during normal walking is around 416.6 μW. This power is sufficient for many applications.

Keywords: Energy harvesting; Rotary microgenerator; Human motions; Electromagnetic induction; Kinetic energy

1. Introduction

Computer technology has progressed quickly over the last two decades as shown in Figure 1; however, it is also clear that battery technology has not kept the same speed. Batteries, although the capacity of batteries has increased over these years, development of portable electronics seems to have slow down to reach a wider adoption. For example, the cost of a battery replacement prohibits a wider use of wireless sensor networks. As a result, other energy sources are needed to cover the demands of new electronic applications. Energy harvesting is an option to solve this problem.

Figure 1 shows the increase in the performance for different technologies compared to those available in 1990. For example, disk capacity has increased by a factor of 10,000 between 1990 and 2010, whereas battery energy density has increased only 5× (Collado & Georgiadis, 2013; Starner & Paradiso, 2004; Vaisband, Saadat, & Murmann, 2015).

Moreover, energy sources other than batteries exist with even higher power densities, but most of them are designed for large systems and/or require some kind of fuel to operate. The human body is also an alternative energy source that can provide power densities around 1 W/kg. Because of the decrease in the power consumption of electronic devices, the available power density levels of 1 W/kg are an interesting option for low-power devices. Since power is generated by body motions, the devices that can directly be beneficial for this approach are biomedical and electronic devices (wearable or surgically implantable). Figure 2 highlights the power budget for some electronic applications within the generation range of the human body. For example, using the previous reference of 1 W/kg, only a few miniature low-power devices (such as hearing aids, pacemakers, watches, and some consumer devices) can directly use the human energy harvesting approach. Nevertheless, larger generators can produce higher power outputs. Regarding the reference of 1 W/kg, small generators with a volume of 10 cm^3 could produce up to 10 mW. According to Figure 2, 10 mW can be used to power some communication devices and remote controls. Taking as a reference the shoe-powered generator presented by Leonov (2013) with a power generation over 0.2 W, power for some cell phones and radios can be supplied by human energy harvesting.

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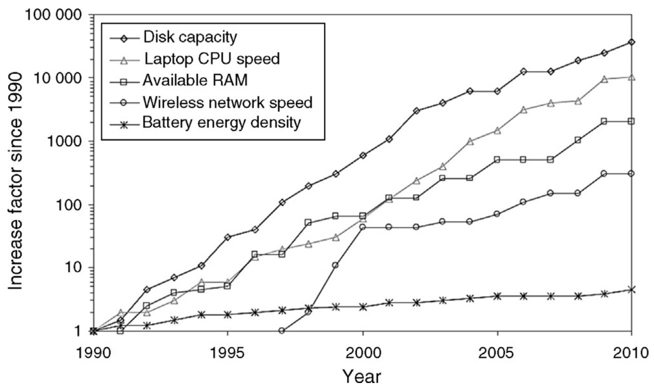

Figure 1. Improvements in portable computing from 1990 to 2010. Wireless connectivity only considers the IEEE 802.11 standard released in 1997. Partial data from specialized computer magazines (Starner & Paradiso, 2004).

Figure 2 shows the power consumptions of different electronic devices ranging from medical devices to consumer applications (power consumption from around one microwatt up to several watts). This figure also presents the power output of an energy harvester (a shoe-powered generator) and some human-operated generators for comparison purposes. Even supposing that human microgenerators do not have a power output high enough for some electronic devices (such as laptops), they can produce a lower power output, for low-power electronic applications, including some medical devices. Thus, it is clear that human energy harvesting is suitable for biomedical applications and other low-power devices (Chen & Fan, 2015; Peng, Tang, Yang, & Heo, 2014).

Based on the above discussion, the design of a rotary microgenerator is described in this paper. This microgenerator can convert human motions to electrical energy. The small size and use of a pendulum mechanism without gear are the two main characteristics of the designed microgenerator. The generator can detect small vibrations and produce electrical energy.

This paper is organized as follows. Section 2 presents a background of the harvesting energy and its purposes. In Section 3, the mechanism of energy harvesting from body motions and its relations are described. The design process of the microgenerator and its relations are presented in Section 4. In Section 5, the implementation process of the microgenerator and several experimental results related to the microgenerator are explained. Finally, in the last section, a conclusion of the design process and the experimental tests are presented.

2. Energy harvesting background

Energy harvesting is a research subject that is gaining relevance for powering electronic devices because of an almost infinite life-time potential (Levron, Shmilovitz, & Martinez-Salamero, 2011; Ylli et al., 2015). Energy harvesting from motion, temperature changes, and solar light has proven to be a confident alternative to batteries for commercial applications, such as flash lights, hand-cranking radios, thermal-powered

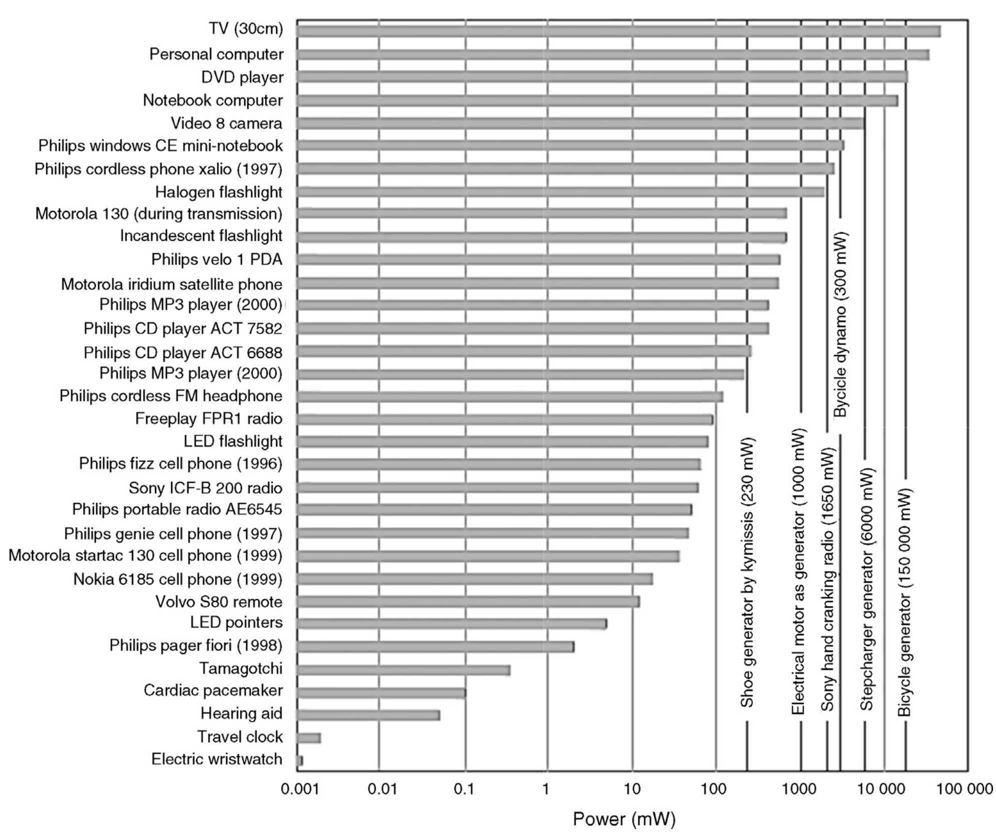

Figure 2. Comparison of power consumption against power generation for some electronic devices. Chart adapted from Vaisband et al. (2015).