Self-charging Peripherals with inbuilt Power Harvesting System

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Abstract. Most of the computer peripherals around us require an active power source; they are either wired while some are wireless and are powered by DC batteries. The majority of these devices consume significantly less power when compared to the main device’s power consumption patterns. One may observe that we perform physical activities on the input devices in specific, and since these devices anyway just sip on power, we might as well consider harvesting some energy from the actions performed on the device to power the device itself. In this paper, we explore and discuss the mechanisms that could be potentially used in order to design and produce computer (input) peripherals that would practically last forever without the need to recharge, or swap batteries. We have designed and made prototypes of harvesting mechanisms based on electromagnetic induction, as well as the piezoelectric effect. The work presents a potentially exhaustive system for the next generation of self-powered devices over which any physical human input is expected, and not necessarily confined to the application discussed here.

Keywords: Computer Peripherals, Electromagnetic induction, Energy harvesting, Piezoelectric effect, Self-powered

1. Introduction

Devices that are used pretty much on a daily basis are expected to hold up and provide us with their intended service at all times. It may get annoying or frustrating if and when they die out on us. The majority of the wireless input peripherals that are available today do not have a well predictable lifespan, and neither do they indicate their expected battery life. The once that do, are priced out of reach for a huge majority of general consumers. When designing our solutions, we had to keep in mind that the solution has to be easy to produce and wouldn’t add significantly to the overall costs.

We have primarily based our designs on a pointing device, ie, a computer mouse. However, these mechanisms may also be used in other devices such as keyboards, etc. When we use the pointing device, we physically move it around on a flat platform. This movement of the device on a horizontal plane seems to allow us to harvests enough energy to power up a generic low-powered mouse with no fancy features (such as RGB lighting) that could require additional power resources. Another advancement in such energy harvesting processes can be the clicking action on a computer mouse, or the typing action on a keyboard. The keyboard strokes or mouse clicks can be used to convert force applied by the user into electrical energy using piezo-electric modules [1] and thus could potentially help achieve self-powered peripherals.
Most existing devices widely available in the market consist of direct wired power and data transfer systems, or a wireless data transfer system with a battery within the device to power it. Some experimental setups harvest from stray RF signals [2, 3], while some harvest from vibrations [4, 5] or other basic motions [6, 7] and are capable of giving output voltages in the range of hundreds of millivolts to even volts. Some have been specifically designed for applications such as vehicle suspensions [8] and hence can harvest relatively much larger amounts of energy. Linking this to bio-inspired approaches have also shown some scope [9]. Nano-generators [10] can be extremely helpful in healthcare applications such as Invasive Electronic Biosensor Circuits and Systems. Due to the unpredictable nature of some harvesting systems, innovative capacitors and super-capacitors have also been explored [11].

Accrediting to the advancements in low power VLSI designs, wireless sensor nodes could conjunct very well with such systems [12]. As for the industry, a setup similar to the second type of proposed system has been explored by Logitech® and Razer™, they have been discussed below.

2. Proposed System
We have proposed three interlinked systems that utilize similar electronic systems however, different electromechanical systems. Some of these systems suit only specific use cases however others may be used in other applications as well.

2.1. Type A: Embedded electromagnetic harvesting
In this system, the pointing device (a mouse) contains two tubular structures as depicted in Figure 1 which house two fixed magnets on either ends of the tubes and another floating magnet suspended between them. The tube is surrounded by a coil around it as has been depicted in
2.2. Type B: Multi-part electromagnetic harvesting

This type of system may be considered as a multi-part system as, unlike Type A proposal, the harvesting system is not embedded into and integrated into a single device but rather a multiplicity of devices. In this case, there are two parts, the pointing device, and the base plate. The pointing device may have a set of coils (copper windings) placed towards the bottom surface with minimal distance between the coil(s) and the base plate. The base plate (a mouse-pad) shall have thin permanent magnets just under its upper outer surface. Figure 2 depicts a mouse-pad with an integrated wrist-pad for added comfort, this mouse-pad contains permanent magnet plates with each adjacent unit of opposite polarity; the mouse contains copper windings towards its bottom surface as depicted. The interaction between the permanent magnets and the coils will equip the system to harvest energy from the electromagnetic flux. This system needs both the parts and its relative motion in order to function; this might limit its functionality to specific use cases where this condition may be met. Razer’s Hyperflux [13] and Logitech’s PowerPlay [14] use somewhat similar of a setup, however, they are based on the transfer of power using the wireless induction coils similar to the once used in smartphones; hence require an active supply for the base plate, through which the energy is transferred to the mouse and stored either in a battery or a capacitor. They are therefore, based on wireless transfer of energy.
2.3. Type C: Piezoelectric harvesting using pressure
In this type, a piezoelectric layer needs to be integrated into the system such that when the user presses any button on the device, the pressure applied over the button is either directly or indirectly transferred onto the piezoelectric layer causing deformation due to which electrical energy can be produced. The piezoelectric layer may be placed just underneath the outer plastic surface that bends upon clicking or pressing as depicted in Figure 3. When the user presses the button, the force is used to cause a small deformation in this layer, and only then is the button activated.

3. Prototype Design
We had worked on basic setups that would stand as proof of concepts for the proposed systems. In our prototype for the Type A system, we had a single tubular structure attached to the right side of a right-handed pointing device. The tubular structure consisted of two fixed (glued) neodymium magnets as described previously and depicted in Figure 4, along with a floating neodymium magnet array placed inside a plastic tube with ferrofluid [15] lubricant. The two fixed magnets ensure that the floating magnet array would not collide and be repelled towards the center from either end. Due to the strong force keeping the mass at the center, the external motion leads to a relatively high frequency of motion. It should be noted that the mass and vibration characteristics may be varied based on the filtering setup in place in the harvesting system; some harvesting setups would do better with high frequency and low
amplitude, while some would prefer otherwise. This setup generated around 0.06 mW peaks with casual mouse movement; however, with greater impact forces, (which could be more suited to other applications such as sports equipment, etc.) the setup could peak with over 0.15 mW.

As for the Type B system, to simulate the pointing device (a mouse) consisting of a two-
For the Type C system, since DIY style fabrication of the proposed system would have been difficult with available resources, we decided to settle for a more feasible alternative. We placed a piezoelectric layer (coin) between the outermost plastic layer of the pointing device and its electronic button as depicted in Figure 6. This way, when the user presses the button, (the direction of force depicted by a red-colored arrow) first the coin undergoes a small amount of deformation due to pressure from the outer surface pivoting around its point, and then the electronic switch is activated. One of the main advantages with such a system is, for many applications, it wouldn’t always be possible to attain high resonance frequency which in the case of electromagnetic systems, could be important. In piezoelectric systems, it’s easier to work around this limitation. In this system, we achieved a power output of around 0.005 mW per click. A custom PZT (lead zirconate titanate) layer would likely largely increase the power output.

We had first used a very basic circuitry setup consisting of a full-wave bridge rectifier, capacitor, and a DC-DC converter. The efficiency could possibly be largely improved by utilizing better circuitry and better electromagnetic configuration. Another set of test runs was done with a commercially available energy harvesting integrated circuit, namely, the LTC3588-1, along with external capacitors and inductors (Figure 7) to provide a continuous and stable stream of supply. The LTC3588-2 may also be used in case of higher input quiescent current requirements.
4. Conclusion
The work presented in this paper contributes towards attaining a hassle-free experience when it comes to input devices that we use on a daily basis and have ended up becoming a core product that is ubiquitously present in almost every household. Though the problems generally aren’t major as such, the short-lived annoyances could rightly be avoided. The mechanisms presented show great potential and could be designed to completely replace the need for internal batteries in many devices beyond computer peripherals. However, it should be noted that the results obtained were that of basic proof of concepts, there is significant scope for improvement, especially in the efficacy and efficiency of harvest, with improved circuitry and electromechanical/electromagnetic configurations. That may require application-specific empirical experimentation. Future work may be in the line of improving the mechanism to better fit the application and to hybridize different systems, in order to achieve more favorable outcomes. As from the scope of this work, the two-part electromagnetic harvesting system seems to be the better one for a computer mouse, while the switches with piezoelectric members seem to be the better one for a computer keyboard.

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