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Abstract

Misconceptions in Piezoelectric Energy-Harvesting System Development †

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Abstract: Energy harvesting from wasted or unused power has been a topic of discussion for a long time. We developed 'damper devices' for precision machinery and automobile engine mats in the 1980s. However, in the 1990s we realized that electric energy dissipation on its own was useless, and started to accumulate the converted electric energy into a rechargeable battery. Historically, this was the starting point of 'piezoelectric energy harvesting devices'.

Keywords: energy harvesting; piezoelectricity

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As one of the pioneers in piezoelectric energy harvesting, Uchino feels frustration about many of the recent research papers for the following reasons:

(1) Although the electromechanical coupling factor k is the smallest among various piezo-device configurations, the majority of researchers primarily use the 'unimorph' design. Why?
(2) Although the typical noise vibration is in a much lower frequency range, the researchers measure the amplified resonance response (even at a frequency much higher than 1 kHz) and report these 'unrealistically' harvested electric energy values. Why?
(3) Although the harvested energy is much lower than 1 mW, which is lower than the required electric energy to operate a typical energy-harvesting electric circuit with a direct current/direct current (DC/DC) converter (typically around 2–3 mW), researchers report the result as an energy 'harvesting' system. Does this situation mean actually energy 'losing'? Why?
(4) Few papers have reported successive energy flow or exact efficiency from the input mechanical energy to the final electric energy in a rechargeable battery via the piezoelectric transducer step by step. Why?

Interestingly, the unanimous answer from these researchers to my question 'why' is "because the previous researchers did so!"

This paper focuses on how to rectify the above common "misconceptions" in the piezoelectric energy harvesting system. We will consider comprehensively three major phases/steps associated with piezoelectric energy harvesting: (i) mechanical–mechanical energy transfer, including mechanical stability of the piezoelectric transducer under large stresses, and mechanical impedance matching; (ii) mechanical–electrical energy transduction, relating to the electromechanical coupling factor in the composite transducer structure; and (iii) electrical–electrical energy transfer, including electrical impedance matching, such as a DC/DC converter to accumulate the energy into a rechargeable battery. In order to provide comprehensive strategies on how to improve the efficiency of the harvesting system, the author conducted detailed energy flow analysis in piezoelectric energy-harvesting systems with stiff "Cymbals" (~100 mW) and flexible piezoelectric transducers (~1 mW) under cyclic mechanical load, to improve the efficiency of the harvesting system. Energy transfer rates were practically evaluated for all three steps above. The former "Cymbal" was to be applied to the automobile engine vibration, while the latter flexible transducer was for the human-wearable energy-harvesting system.

We should also point out that the commercially-successful piezo-energy harvesting devices are for signal transfer applications, where a pulse input load is applied to generate instantaneous electric energy for transmitting signals for a short period (100 ms~10 s) without accumulating the electricity in a rechargeable battery. Present products include the "Lightning Switch" from Face International and the 25 mm caliber "Programmable Ammunition" from Micromechatronics Inc., State College, PA, USA.

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