

A unified nonlinear circuit combining piezoelectric and electromagnetic transducers

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Abstract. With the aim of using as much as electroactive parts as possible in the same electronic interface, the purpose of this work is to propose a hybrid nonlinear circuit combining piezoelectric and electromagnetic harvesting systems for significantly increasing the final output power while ensuring a relative independence to the load. The resulting technique, called Synchronous Electric Charge and Induced Current Extraction (SECICE) has been developed taking into consideration the Synchronous Electric Charge Extraction (SECE) and the Synchronous Magnetic Flux Extraction (SMFE) schemes, initially developed for the sole use with piezoelectric and electromagnetic transducers, respectively.

Introduction

Over the past decades, the development of wireless sensor networks has received a great interest, particularly in the framework of the Internet of Things. To supply such nodes, harvesting ambient energy appears to be a key technology for replacing conventional batteries normally used in this field, going towards the development of autonomous self-powered devices. Many sources of energy already present in the environment can be considered for this purpose. Among these, mechanical vibrations, featuring high power density and wide availability, can be typically exploited via electromagnetic or piezoelectric transductions, being particularly advantageous due to their relatively high power levels and no external source requirement [1]. In order to enhance their conversion abilities, nonlinear techniques have been developed for both of these systems. One well-known example for piezoelectric harvesting is the so-called Synchronous Electric Charge Extraction (SECE) [2], while the Synchronous Magnetic Flux Extraction (SMFE) [3] addressed electromagnetic devices. Both of these techniques have demonstrated a significant enhancement of the electromechanical conversion capabilities while addressing the issue of impedance matching. However, due to their intrinsic dual natures, combination of piezoelectric and electromagnetic devices at circuit level is far from being straightforward. The purpose of this work is to propose a nonlinear interface dedicated to hybrid piezoelectric/electromagnetic systems based on the combination of the SECE and SMFE interfaces. The resulting interface, named Synchronous Electric Charge and Induced Current Extraction (SECICE), allows a significant increase of the output power while overcoming in a simple way the typical complications of hybrid systems, such as different output current/voltage or different load values that maximise the power.

Results and discussion

The proposed SECICE interface is illustrated in Fig. 1 and its working principle can be summarized in three phases: default configuration phase (where the piezovoltage and electromagnetic current are varying with the displacement), the charge transfer phase, occurring at displacement extrema (where the piezoelectric energy is transferred to the electromagnetic transducer, boosting the electromagnetic current) and finally the energy extraction phase (where the boosted electromagnetic current is transferred to the storing capacitors). The resulting power of the hybrid scheme when considering a constant displacement analysis has been measured and compared with the power obtained when using the SMFE scheme, as shown in Fig. 2, allowing to reach a power gain of 4 compared to the maximal harvested power in the SMFE method. When conducting the analysis as a function of a constant excitation magnitude, Fig. 3 plots the harvested and extracted powers versus the piezoelectric coupling: the SECICE technique allows harvesting more energy than the SMFE interface, especially in the region of lightly coupled/highly damped structures.

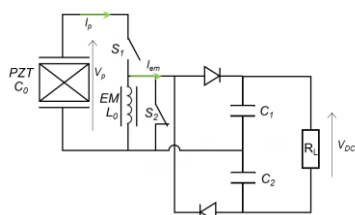


Fig. 1: circuit schematic

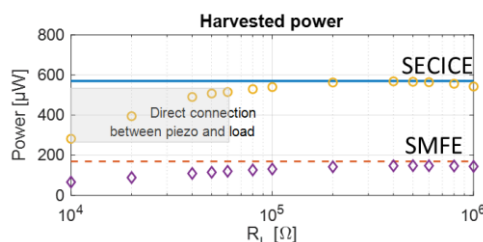


Fig. 2: Harvested powers (const. displacement)

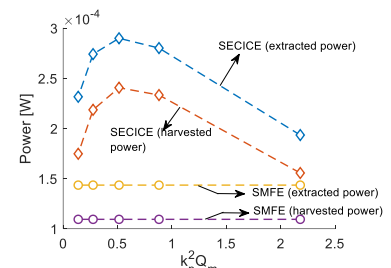


Fig. 3: Harvested powers (const. acceleration)

References

- [1] A. Badel, F. Formosa, and M. Lallart. (2015), Electromechanical transducers, *Micro Energy Harvesting*.
- [2] Lefeuvre, E., Badel, A., Richard, C., & Guyomar, D. (2005). Piezoelectric energy harvesting device optimization by synchronous electric charge extraction. *Journal of Intelligent Material Systems and Structures*, 16(10), 865-876.
- [3] Arroyo, E., & Badel, A. (2011). Electromagnetic vibration energy harvesting device optimization by synchronous energy extraction. *Sensors and Actuators A: Physical*, 171(2), 266-273.