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Abstract

In-Ear Energy Harvesting: Harvester Design and Validation (Part II) †

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Abstract: The mechanical deformation of the ear canal induced by the temporomandibular joint movement constitutes a promising source of energy to power in-ear devices (hearing aids, communication earpieces, etc.). The large morphological variability of the human ear canal and its intrinsic dynamic characteristics—with displacement frequencies below 1.5 Hz with an average volume variation of 60 mm^3—motivate the development of non-conventional dedicated energy harvesting methods. This paper demonstrates the concept and design of a modular hydraulic–piezoelectric self-actuated frequency up-conversion micromachine for energy harvesting. The mechanical energy is conveyed using a liquid-filled custom fitted earplug, which can be considered as a hydraulic pump. A hydraulic circuit composed of a pressure amplifier, two driven valves and two check valves allows to drive two micro-pistons. These micro-pistons actuate a bistable oscillator associated to a piezoelectric transducer allowing the low frequency mechanical excitation to be efficiently converted into electric energy through frequency-up conversion. The two integrated passively driven valves are based on tube buckling and allow the pistons to act alternatively on the oscillator to generate a backward and forward run for two jaw movements. A complete theoretical multiphysics model of the machine has been established for the design and evaluation of the potential of the proposed approach. Global analytical and refined FEM approaches have been combined to integrate the fluid and mechanical behaviors. Based on simulation and preliminary experimental data, the harvested energy is expected to be 8 μJ for one jaw closing, with a theoretical 40% end-to-end conversion efficiency.

Keywords: ear; energy harvesting; generators; frequency up-conversion; bistable oscillator; hydraulic transmission; passive hydraulic valves.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data supporting reported results can be found in CRITIAS:DB open database repository and can be requested from https://critias.etsmtl.ca/CRITIAS-DB.