Live Demonstration: Heartbeat-Powered Biosensing Harvester for Intracardiac Monitoring

Noora Almarri [1], Fawaz Nahab [2], Dai Jiang[1], Wenhui Song[2], Andreas Demosthenous[1]

[1]Department of Electronic and Electrical Engineering, University College London, Torrington Place, London WC1E 7JE, UK
[2]Department of Surgical Biotechnology, University College London, Royal Free Hospital, London, NW3 2PS UK
e-mail: uceenal@ucl.ac.uk, a.demosthenous@ucl.ac.uk

***Abstract*— A heartbeat-powered harvester for cardiac monitoring will be demonstrated. The device harnesses mechanical vibrations from heartbeats and converts them into electrical energy to power pressure sensors, enabling real-time monitoring of heart's health without an external powering source. The system integrates biocompatible piezoelectric flexible materials with sensors utilizing power electronics. Live demonstrations illustrate the system's feasibility for continuous intracardiac monitoring. Initial results suggest promising performance in terms of energy harvesting efficiency and bio-signal acquisition accuracy for various medical and wearable devices applications.**

Keywords—Biosensing, biocompatibility, intracardiac monitoring, medical devices, piezoelectric energy harvesting, real-time data acquisition, self-powered device.

I. Introduction

Traditional implantable devices are powered by batteries, leading to challenges in device longevity, surgical replacements, and increased patient risk [1]. To address these issues, self-powered devices that can operate continuously without external power is of interest. Piezoelectric materials, capable of converting mechanical energy into electrical energy, provide a promising solution for powering implantable biosensors [1]. These materials can harvest energy from the mechanical movements of the heart, such as the contraction and relaxation phases during heartbeats. The energy harvested can then be used to power biosensors that continuously monitor key physiological parameters, providing real-time intracardiac data without the need for battery replacement. In this demonstration, we present a self-powered piezoelectric biosensing harvester capturing critical parameters such as intracardiac pressure.

II. Demonstration Setup

Fig. 1 illustrates the energy harvesting system [2]. The demonstration includes a piezoelectric harvester integrated into an in vitro heart simulator and VR simulation set designed to mimic the mechanical behavior of a beating heart. The system has two key components:

1) The piezoelectric harvester is positioned inside the heart simulator, where it deforms in response to the simulated heartbeats. This mechanical deformation is converted into electrical energy by the harvester.
2) The biosensors measure critical parameters such as pressure distribution and volume changes within the heart. The collected data is then transmitted to a remote computer for real-time monitoring, providing continuous insights into the heart's behavior.

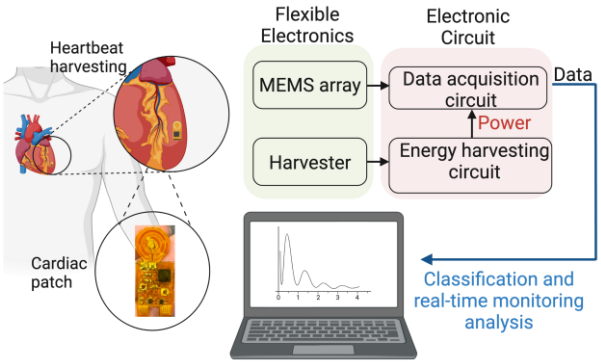

Fig. 1. Overview of heartbeat-powered monitoring patch.

III. Visitor Experience

Visitors will engage in an immersive virtual reality (VR) experience where they'll enter a virtual lab and control a harvester that collects energy from a simulated beating heart. By using hand gestures or VR controllers, visitors will move the harvester to different areas of the heart, optimizing energy harvesting based on the heart's mechanical activity.

1) Energy Harvesting: In the VR environment, visitors will take part in a "Heartbeat Power VR Challenge," where they balance energy harvesting and biosensor functionality under different heart conditions (e.g., tachycardia, arrhythmia). As they succeed, biosensors unlock, and real-time heart pressure are displayed.
2) Real-Time Biosensing: Powered by harvested energy, the biosensors will transmit real-time data from the heart simulator, highlighting abnormalities like arrhythmias. Visitors will see how the energy they collect powers these sensors in real time.
3) Live Broadcast and Haptic Feedback: The entire VR experience will be broadcast on a screen for onlookers, with real-time commentary explaining how the system works. Visitors will feel haptic feedback simulating the heartbeats.

This demonstration showcases the potential for continuous, health monitoring, merging educational content with an interactive VR game on Unity.

References

[1] N. Almarri, J. Chang, W. Song, D. Jiang, and A. Demosthenous, "Piezoelectric energy harvesting and ultra-low-power management circuits for medical devices," *Nano Energy*, vol. 110, p. 110196, Sep. 2024.

[2] N. Almarri, F. Nahab, J. Chang, D. Jiang, W. Song and A. Demosthenous, "Self-powered piezoelectric biosensing harvester for intracardiac monitoring," *2023 IEEE Biomedical Circuits and Systems Conference (BioCAS)*, Toronto, ON, Canada, 2023, pp. 1-4.