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Abstract

Energy-Harvesting Smart Tiles for Human–Machine Interface Applications †

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Abstract: In this work, a human–machine interface with energy harvesting capabilities was developed and a modular floor made of tiles equipped with piezoelectric elements was produced. The developed platform was tested as a position-tracking system for a human user, allowing the tracking of the lower body in a virtual reality environment. Moreover, the energy collected by the device was evaluated.

Keywords: energy harvesting; smart tile; piezoelectric; human–machine interface

1. Introduction

Given the growing interest in renewable energies and the continuous research aiming to reduce the energy consumption of electronic devices, the purpose of this work is the development of a human–machine interface capable of recovering energy from the user; specifically, a modular floor made of tiles equipped with piezoelectric elements was produced. In the literature, sensorized mats are often used as a tool for data acquisition [1,2]; the system developed in this work can be used to track the position of a user in a structured environment. In order to show the versatility of the developed device, it was tested as a position-tracking system for a human user moving on a series of tiles, allowing the tracking of the lower body in a virtual reality environment. Moreover, the energy collected by the device was evaluated.

2. Materials and Methods

Each tile is divided into four sections equipped with six stacks in parallel made of three piezoelectric elements each in order to maximize the performances [3]. Signals produced by the piezoelectric stacks are applied to an EH (energy harvesting) circuit and to a voltage booster. The developed system is described in the block diagram in Figure 1.

To realize the EH block, several circuit configurations proposed in Covaci et al. (2020) [4] were simulated, such as the SSHI (synchronized switch harvesting on inductor) technique or two-stage circuits with an AD/DC stage and a DC/DC stage. These configurations did not show the performance required by the specific application. Thus, an alternative approach was used, exploiting the capabilities of the LTC3588 Energy Harvester IC [5] combined with an LTC4070 Charger IC [6], both produced by Analog Devices. The Voltage Booster block consists of a rectification and squaring stage that allows the signal to

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reach the logical levels of a microcontroller, specifically represented by an ESP-32; when a tile is trampled, the master µC receives a signal from a slave µC through Bluetooth low-energy communication and transmits a specific message to a PC, corresponding to a keyboard input. Moreover, the smart tiles can communicate between each other and perform an autonomous assignment of an identification address using a master–slave finite state machine model. A virtual environment was created using Unity; it contains a scene with a floor, a humanoid avatar, and a system of 16 tiles. When the user reaches a position on the real-world tile section, the avatar in the VR environment moves from its initial position to the corresponding tile.

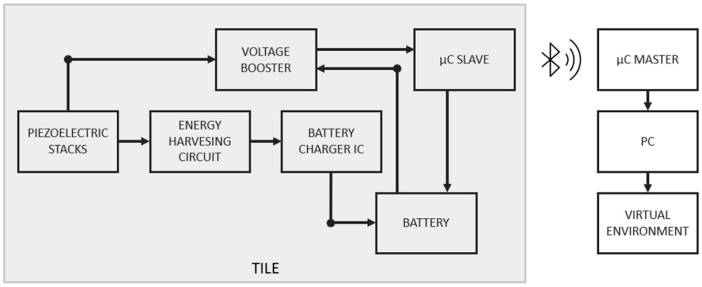

Figure 1. Block diagram of the overall system.

3. Discussion

In order to test the actual operation of the platform, four tiles of size 65 × 65 cm were produced and tested. To quantify the energy collected by the device, voltage waveforms generated by real footsteps on a single section were recorded; a full step generates 4 mC of charge. The time required for the µC to activate, send a message, and return to deep sleep mode is approximately 2.5 s resulting in 245 mC of charge. Approximately 62 charging steps will therefore be required to completely compensate one transmission. Thus, the platform developed in this work achieves a good balance between cost, efficiency and energy harvesting/saving. However, the developed platform, being open to multiple applications, is not optimized for a specific task. The device is not superior in terms of capacity compared to other devices already on the market, but it excels in its flexibility of use.

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