Demo Abstract: A Battery-free Wireless Keyboard

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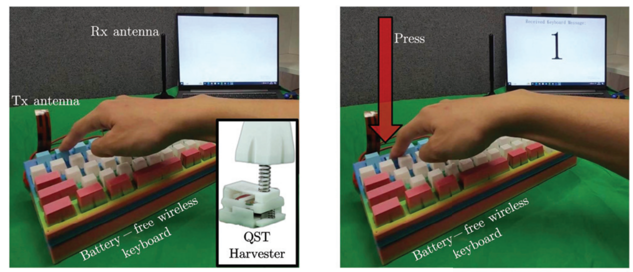
ABSTRACT

This demonstration showcases a battery-free wireless keyboard that utilizes the kinetic energy generated from key presses to generate electrical power. Each key incorporates a Quasi-Static Toggling harvester, which employs potential energy pre-charging to ensure a consistently reliable energy output. Extensive practical testing has confirmed that this keyboard exhibits responsiveness and low latency comparable to traditional wireless keyboards. This study represents a significant improvement over previous battery-free IoT applications that often compromised service quality, as it offers a stable energy-harvesting mechanism and provides a dependable framework for designing battery-free devices.

KEYWORDS

Battery-free IoT, human-computer interaction, motion energy harvesting



(a) (b)

Figure 1: User interaction with the battery-free wireless keyboard. (a) Positioning over key '1'. (b) Actuation of key '1' and resultant display.

1 INTRODUCTION

This demonstration showcases a kinetic energy harvesting-based wireless keyboard that operates without the need for batteries. In contrast to previous battery-free IoT devices[1] relying on environmental energy sources like solar, vibration, radio-frequency, or thermal, which are susceptible to fluctuations in external stimuli resulting in reduced Quality of Service (QoS) compared to their battery-inclusive counterparts, the proposed battery-free keyboard efficiently harvests consistent amounts of energy regardless of gender, age, or individual finger pressure dynamics.

In contrast to previous kinetic-powered wireless keyboards[2] that required continuous and forceful pressing for a simple signal output, this demonstration only requires a momentary press to enable text input, thereby aligning with the customary tactile experience of battery-powered counterparts. As shown in Fig. 1, each key of the keyboard is equipped with a Quasi-Static Toggling (QST) harvester [3, 4]. By conducting structural dynamics analysis and electromechanical coupling analysis, every key is capable of delivering precise metrics for kinetic energy harvesting output. Through efficient conversion of the kinetic energy generated by user keystrokes into reliable electrical output, the keyboard successfully fulfills the stringent response time requirements of Human-Computer Interaction devices.

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2 IMPLEMENT

QST Harvester: Fig. 2 illustrates the operational principle of the QST harvester, which converts kinetic energy obtained from key actuation into electrical power through a magnetic polarity toggling mechanism. In the presence of a magnetic field, the harvester demonstrates two stable states, and Fig. 2(a) to 2(d) illustrates the sequential transition from initial stable position #1 to position #4. The trajectory of mechanical potential energy within the harvester, resulting from the interplay between magnetic and elastic forces, is concurrently depicted in Fig. 2(e) to 2(h), with the trends of potential energy indicated by red circles. From position #1 to position #2, there is a gradual increase in potential energy with the external pressure. At position #3, reaching its critical point - referred to as the magnetic threshold where the magnet undergoes a transition from the South (S) to North (N) pole. Subsequently, under the influence of magnetic field, this potential energy rapidly converts into kinetic and electric energies before eventually stabilizing at position #4. As indicated in Fig. 3, the system overcomes a magnetic-field-induced potential barrier, journeying from the initial stable position #1 to position #4. The magnitude of this barrier determines the minimum threshold for energy capture of the harvester, representing the lowest amount of energy that can be reliably generated by the device. Consequently, by strategically redesigning the mechanical aspects of this potential barrier, it becomes feasible to customize and optimize the energy yield for diverse applications.

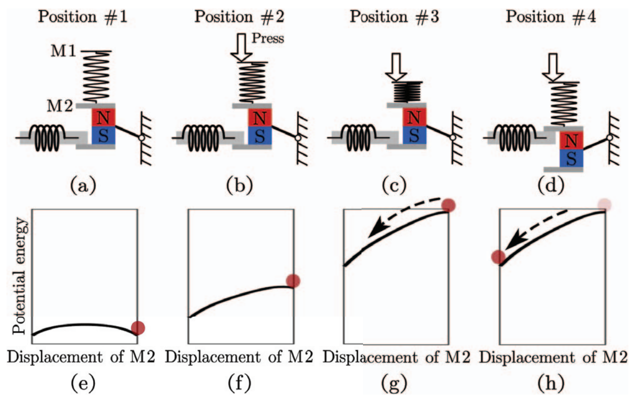

Figure 2: Schematic illustration of a QST harvester [(a)-(d)] and its potential energy evolution process [(e)-(h)].

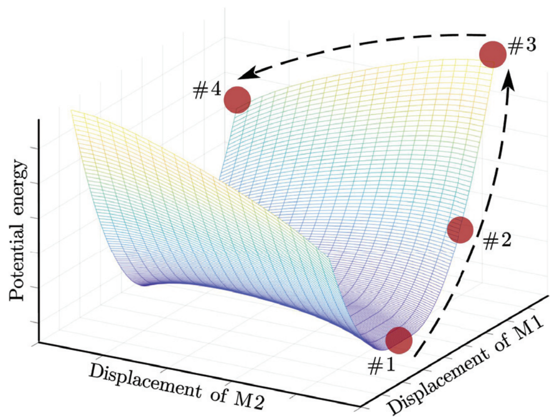

Figure 3: Process of a QST harvester overcoming the potential energy barrier. Position #1 to #3: accumulation phase; Position #3 to #4: release phase.

Keyboard Architecture: The keyboard architecture encompasses a complex assembly comprising a QST harvester, an energy management circuit, a Bluetooth communication unit, and indispensable mechanical components. The QST harvester, upon actuation by a keypress, utilizes its inherent mechanism to generate a quantifiable amount of power. This generated energy is subsequently captured by the energy management circuit, which is responsible for both storing the energy in an energy storage capacitor and regulating the voltage of the capacitor to align with the operational demands of the communication unit. Upon detection of a keypress, the communication module triggers the transmission of a signal to the computer, facilitating the accurate representation of the corresponding characters on the display. The harmonious integration of these components ensures the effective conversion of mechanical keystrokes into digital inputs, highlighting the keyboard's innovative design and functional efficiency.

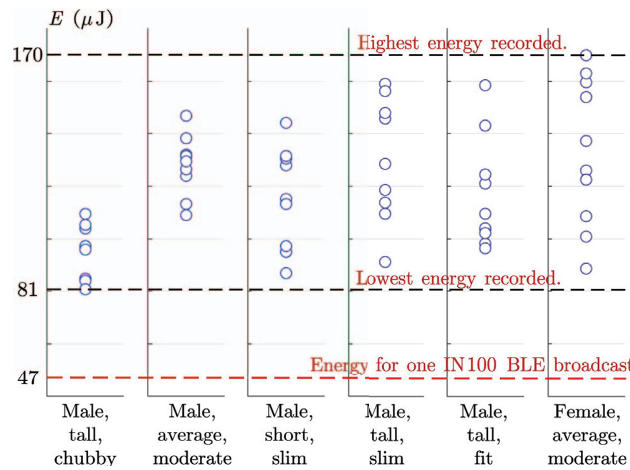

Figure 4: Practical outcomes of energy harvesting from a single keypress.

3 EVALUATION

As shown in Fig. 4, the robustness of the keyboard and its superiority over battery-powered alternatives were assessed and verified. A total of 60 keystrokes were performed by five different users, with the setup connected to a 10 μF capacitor through a diode rectifier bridge for data collection purposes. The findings reveal an average energy output of 120 μJ per keystroke, with a minimum energy level observed at 81 μJ, thus emphasizing the consistent energy conversion efficiency of the system. Furthermore, these results substantiate that each keystroke generates sufficient energy to power the Bluetooth unit for stable wireless communication, thereby reinforcing both durability and operational effectiveness of the keyboard.

4 DEMONSTRATION

The battery-free wireless keyboard employs battery-free technology in human-computer interaction. As shown in Fig. 1, the keyboard is placed on a table for user engagement. Interaction with the keys results in the immediate display of character output, capturing each keystroke in real time. The setup confirms the keyboard's capability to respond promptly, as well as its reliability and low latency, which are comparable to those of conventional wireless keyboards, indicating its suitability for real-world use.

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