Wristband-type tactile sensors based on bioelectrical impedance measurements

Tianyi Deng[1,2,a)] Shin Takahashi[2,b)]

Abstract: This study presents the development of a portable wristband-shaped touch sensor utilizing bioimpedance technology. The system integrates a microcontroller (STM32F4), an impedance measurement chip circuit (MAX30009), and a virtual keyboard interface implemented in PyQt. The impedance circuit generates a sinusoidal current at 66.944 kHz, measuring voltage responses for impedance calculations. The system detects impedance changes during hand contact, enabling flexible touch interaction on the hands.

1. Introduction

Bioimpedance measurement, which involves assessing the resistance of biological tissue to small electrical currents, offers a promising way for capturing physiological and biomechanical data. It can provide valuable information for touch detection [1–5].

We propose a wristband-shaped portable hand-touch sensor. It is a bioimpedance-based device that injects a small current at 66.944 kHz to measure the human impedance, which enables real-time detection of the change in impedance that occurs when hands touch each other. We also developed a simple touch-based virtual keyboard system to show the possible use of our wristband sensor.

2. Related Work

Regarding tactile sensors, there exists a considerable body of prior research. Das et al. [5] proposed a wearable sensor for bioelectric monitoring. The developed flexible conductive elastomer (CE) electrode can bend along the curvature of the body surface, allowing subjects to easily wear the system on their fingers for human-machine interaction. Chen et al. [6] has developed a large-area flexible tactile sensor based on Electrical Impedance Tomography (EIT) technology, achieving multi-touch and force detection. Liu et al. [7] presented a pressure-sensitive impedance-type touchscreen based on GPANI-PVB composite film and glass substrate. This touchscreen is capable of measuring changes in impedance and detecting touch positions as well as applied pressure. Corchia et al. [8] proposed two fully textile, chipless tags based on different frequency signal technologies as wearable touch sensors. Both proposed devices, when utilized as touch sensors, are capable of encoding four different configurations based on the distinct relative positions between the sensor and the hand. These studies have each offered unique approaches to touch detection, achieving high accuracy and diverse touch modes. However, they share a common drawback: the touch range is heavily dependent on a small area covered by the specifically designed electrodes. Our objective is to design a wristband-shaped portable hand-touch sensor based on bioimpedance technology, allowing operation at any position on both hands, such as situations where only one hand is available.

3. Implementation of Impedance Measurement Device.

The device comprises three main components: a microcontroller based on STM32F4, an impedance measurement circuit based on MAX30009, and a software interface based on PyQt.

3.1 Hardware

The main function of the microcontroller is to control the MAX30009 (a bioimpedance analog front-end integrated circuit developed by ADI) via SPI communication and read the measured impedance value in real time and then send it to a PC via Bluetooth at a baud rate of 115200.

The relevant circuit design for MAX30009 is illustrated in Fig. 1. Following references [9, 10], it is configured to output a sinusoidal current of 45.25 uA at 66.944 kHz in a four-electrode setup and measures the voltage response to calculate impedance.

We have also prepared a set of wrist-bands featuring copper dry electrodes, as illustrated in Fig. 2. This design enhances wearability, allowing users to easily put on the electrodes for seamless use.

[1] Hunan University
[2] University of Tsukuba
[a)] deng@iplab.cs.tsukuba.ac.jp
[b)] shin@iplab.cs.tsukuba.ac.jp

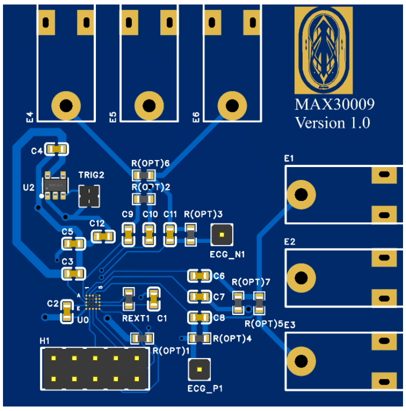

Fig. 1 Impedance measurement circuit board design

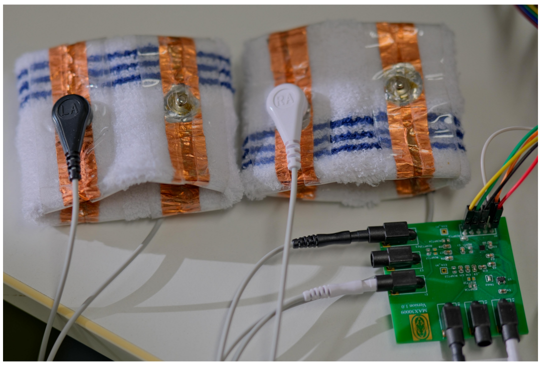

Fig. 2 Wristband-shaped electrodes and impedance measurement board

3.2 Software

To receive impedance information from the STM32F4, we developed a Python-based supervisory software. After calibration, the software repetitively processes the measured impedance information, and visualizes the results like an oscilloscope. For example, Fig. 3 shows the impedance change when the user puts on the wristband and stands still for some time and touches the lower arm area of the left hand with the right hand. The measured resistance and reactance are indicated by the blue and red lines, respectively. In the left half of the waveform, the current primarily flows through the hand, passes through the chest tissue, and reaches the opposite electrode. When the hand touches the other hand, an additional path for the current is created, resulting in a significant decrease in parallel resistance. In addition, due to the change in contact area and force of the touch, the impedance changes correspondingly. This property enables flexible sensing of the user's various touch interaction on the hands.

4. Touch-based Virtual Keyboard Interface

Fig. 4, shows the virtual keyboard interface. The interface consists of three parts, a text input box located at the top, a touch impedance prompt bar in the middle, and a current impedance prompt bar at the bottom.

When there is a rapid change in the slope of the resistance (indicating a quick contact between the hands), the system detects this change and records the post-change value. Subsequently, the current value is continuously compared with the recorded value and mapped to a progress bar for display. When there is a swift separation between the hands, the system determines the current selection, and associates it with one of seven different choices, corresponding to "asdfg[Cap]", "yuiop[Del]", "qwert[Num]", "[Null]", "hjkl;[]", "zxcvb[Space]", "nm,.?[Shift]". Upon the second touch-select-release sequence, the system outputs a specific character or command associated with the chosen option. For example, the first operation selects the corresponding "asdfg[Cap]" in the yellow block, and the second time again selects the corresponding character 'd' in the yellow block to complete the keying of a letter.

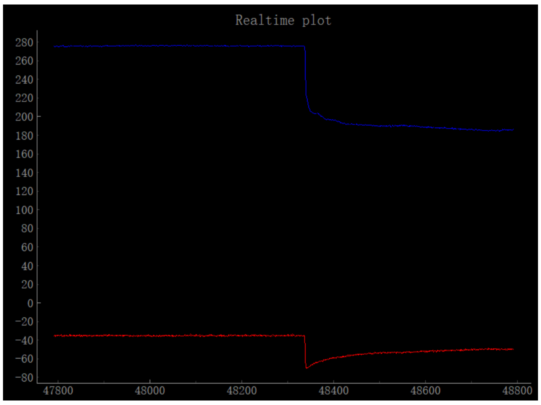

Fig. 3 The impedance changes when one hand touches the other hand

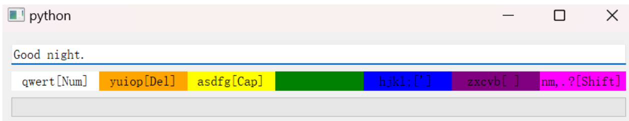

Fig. 4 Virtual Keyboard Interface

5. Summary

We have developed a portable wristband-shaped touch sensor based on bioimpedance technology.

The device includes a microcontroller (STM32F4), an impedance measurement chip circuit (MAX30009), and a graphical user interface (GUI) implemented in PyQt. We designed wristbands with copper dry electrodes for easy wear. The system detects impedance changes when hands touch, enabling flexible touch interaction on the hands.

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