Extraction of a Pulse Wave Using a Piezoelectric Element Toward Energy Harvesting

1st Isao Nakanishi
Faculty of Engineering
Tottori University, Japan

2nd Hiroyuki Nakamura
School of Engineering
Tottori University, Japan

***Abstract*—Pulse waves are expected to be used as a power source for wearable devices. In this study, we examine whether a pulse wave can actually be extracted from a human body using commercially available piezoelectric elements. By improving the contact condition between the skin and the piezoelectric element, we confirmed that pulse waves could be extracted.**

***Index Terms*—energy harvesting, pulse wave, piezoelectric element, wearable, biologging**

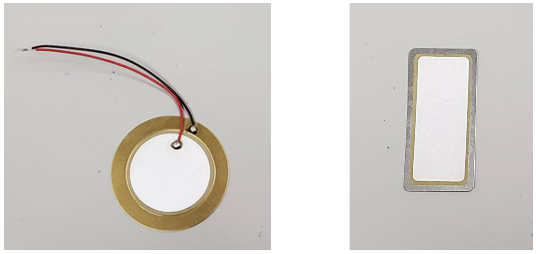
I. Introduction

In recent years, Internet of Things (IoT), in which all electric devices are connected to the internet, has attracted considerable attention. However, it has certain problems, including increased energy consumption. IoT devices consume a large amount of electric energy for working and communicating. Securing a power supply is also an issue. IoT devices require many power-supply cables or frequent battery replacement. Thus, energy-harvesting technologies that collect unused energy around us and generate a new power source are being investigated. In this study, we focus on a pulse wave, which is generated as long as humans or animals are alive. If the electric signal is extracted from the pulse wave, it can be used as a power source for wearable watches and computers as well as biologging devices for investigating animal behavior.

II. Energy Harvesting

Energy-harvesting technology is used to collect unused energy around us and generate a new power source [1]. In particular, we focus on micro power generation on the order of μW to mW. Energy sources can include electromagnetic waves, mechanical vibration, temperature difference, bioenergy, etc. Bioelectric power generation, which utilizes bioenergy, is considered to be suitable as a power source for wearable devices.

There are two methods for bioelectric power generation: one that uses the chemical reaction of a living body and another that uses the piezoelectric effect. In this study, we focus on the method using the piezoelectric effect. Many studies have converted the mechanical vibration due to an organ or body movement to an electric signal by using a piezoelectric element (sensor) [2]. However, surgery is required to extract the vibration of an organ. In the case of using body movements, electric power is never generated when a body is not moving. Thus, we extract organ movements from outside the body. The pulse movement (pulsation) is extracted as an electric signal using a piezoelectric element on the body surface and then converted to electric power.



(a) (b)

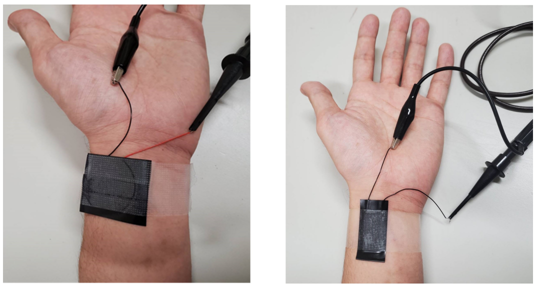
Fig. 1. Piezoelectric elements used.

III. Extraction of Pulse Wave Using Piezoelectric Element

A pulse wave is measured as the time-variation in arterial volume or pressure caused by the blood pushed out of the heart; therefore, it is generated as long as the human or animal is alive. It can be extracted and converted to an electrical signal using a piezoelectric element. Such a method of extracting the pulse wave using a piezoelectric element has been used for a long time [3]. Moreover, an energy-harvesting device based on this extraction method has been also developed [4]. However, the focus has been on the fabrication of such a device. Thus far, only verification using artificial pressure has been performed, and verification using an actual human body has not been conducted.

In this study, we aimed to verify whether a pulse wave can actually be extracted using commercially available piezoelectric elements shown in Fig. 1, where (a) is generally used as a piezoelectric speaker and (b) is produced for a piezoelectric energy harvester. In particular, element (b) can be used flexibly so that a high contact ability can be expected even on uneven skin. The output of the elements was measured by a digital oscilloscope.

In general, we examined the pulse by touching the skin near the thumb of the wrist. The reason we examined this part is because the radial artery runs there. In this part, the layer of subcutaneous fat is thin and blood vessels are in the shallow part of the subcutaneous fat. In addition, this part is



(a) (b)

Fig. 2. Measuring scenes.

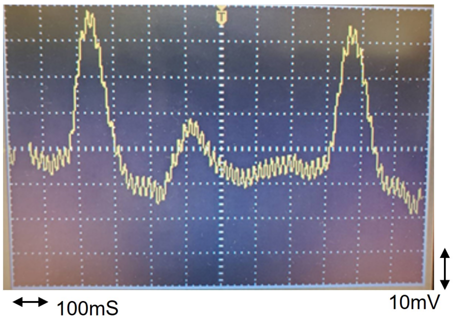


Fig. 3. Measured waveform.

rarely covered with clothes; therefore, this skin can be easily accessed.

Thus, we attached the piezoelectric element with an adhesive tape to the wrist near the thumb as shown in Fig. 2 and measured the output of the element. To prevent the lead wires from being cut from the piezoelectric element, its entire surface was covered with an insulating tape.

As a result, when using element (b), a waveform was measured as shown in Fig. 3. The period of the extracted waveform was approximately 0.7 s, corresponding to 86 cycles per minute. Because the number of cycles of the adult pulse wave is 70 to 80, the measured waveform can be estimated as being a part of the pulse wave. This result confirms a pulse wave can be extracted from an actual human body using a piezoelectric element.

However, when using element (a), the waveform could not be measured. Even when using element (b), the amplitude of the measured waveform was approximately 40 mV. We considered that this was because the skin vibration due to the pulsation was not transmitted well to the piezoelectric element.

In general, we can clearly examine and feel a pulse by increasing the pressure applied by the fingers on the wrist. In order to reproduce such a condition, we placed a protruding object between the skin and the piezoelectric element as shown in Fig. 4(a). In this study, we used the metal part of a disposal electrode for electrocardiography as depicted in Fig. 4(b). This was fixed on the skin of wrist using an adhesive tape as shown in Fig. 4(c), and the piezoelectric element was attached on it.

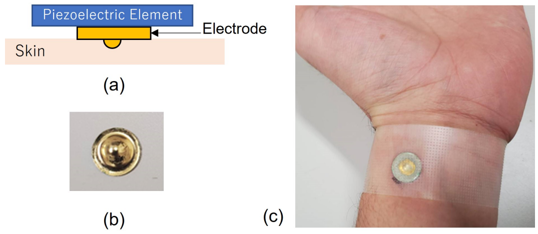
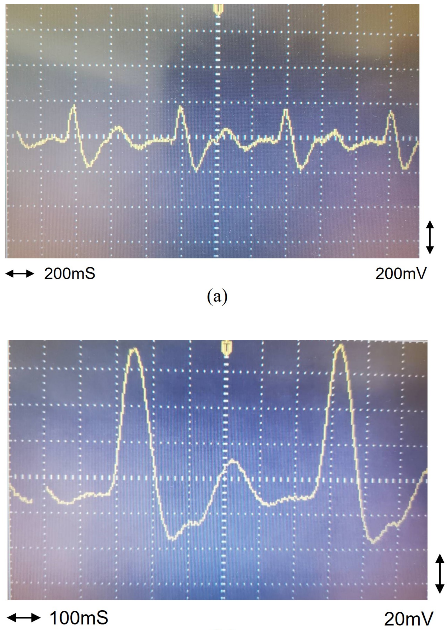


Fig. 4. Improved extraction of pulse wave.



(b)

Fig. 5. Measured Waveform (2).

Waveforms extracted from two piezoelectric elements are shown in 5. Even when using element (a), we could extract the waveform estimated as a pulse wave. In addition, the amplitude of the waveform also increased to 70–200 mV. We conclude that by placing the protruding object between the skin and the piezoelectric element, an effect similar to increasing the finger force of pressing the wrist when examining the pulse can be reproduced, and the skin vibration due to the pulsation can be transmitted well to the piezoelectric element.

IV. Conclusions

Expecting to use pulse waves as bioenergy, we verified whether a pulse wave can be extracted from an actual human body by using commercially available piezoelectric elements. As a result, we confirmed that this was possible by improving the contact condition between the skin and a piezoelectric element.

Further increasing the amplitude of an extracted signal is an urgent issue that must be addressed in the future. To utilize the extracted signal as electric energy, it is necessary to convert it to a direct current using a rectifier circuit and then store it in a capacitor. Since the amount of power obtained by the piezoelectric element is small, it is not used directly as a power source for the device but is temporarily stored in a capacitor for use.

If the entire circuit can be realized only using passive electric elements that require no power supply, the proposed method can be used to establish a self-supplied semi-permanent energy source by introducing it to a device that can be driven by weak energy.

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