Design of Portable Galvanic Skin Response Sensor for Pain Sensor

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***Abstract*— This paper describes the design of a portable galvanic skin response (GSR) sensor for pain sensors. GSR sensors can measure electricity change in the skin. The signal results obtained are used to collect autonomic nerve responses as a function parameter of sweat ties. This response can increase the electrical conductance or increase the resistance in the palm. GSR is a psychological change in the skin resulting from the changes in sweat gland activity; at the time, the sweat glands will be active when the body is in a state of pain. This prototype was made to measure the conductivity of the skin, and the activity based on light blows to the arms. This prototype was made to measure the conductivity of the skin, and the activity based on light blows to the arms. Measurement was delayed by 1 minute to let the body rest before receiving physical impulse. The total time taken for the measurement is 4 minutes. This prototype uses an Arduino Uno microcontroller as an analog to digital signal processor, and the results will be sent to a PC using Bluetooth HC-05 via a serial plotter for display. The purpose of this research is to develop a prototype portable GSR sensor for pain sensors in the human body. The additional value of this research is to use Bluetooth as a data transfer to make it easier to use. The results of this study succeeded in developing a prototype portable galvanic skin response with good sensor sensitivity by verifying the data using a commercial galvanic sensor module.**

Keywords—Galvanic Skin Response, Electrodermal Activity, Arduino Uno, Bluetooth

I. INTRODUCTION

Physiological Sensor Analysis is a developing field of research [1],[2]. Recent research developments have shown better accessibility to wearable devices. The emergence of this technology has made it possible to measure pain in humans by using sensors. Galvanic skin response (GSR) is a simple, useful, and reproducible method for capturing autonomic nerve responses as parameters of sweat gland function [3]. Based on the physical, GSR is a change in the electrical properties of the skin in response to various types of stimuli. Galvanic Skin Response (GSR), known as electro-dermal activity (EDA), psychogalvanic reflexes, or skin conductance responses.[4]. GSR signals show electrical changes measured on the surface of human skin that vary with changes in skin moisture levels (sweating) and reflect differences in their sympathetic nervous system [5]. GSR signals are formed by changes in body resistance due to changes in body conductivity caused by responses to secretions in the sweat glands [6]. The main glands are the eccrine and apocrine glands [7]. Eccrine sweat glands are mainly involved in emotional responses, and they are integrated with sympathetic nerves that accompany various psychological impulses and allow the gland to respond accordingly based on nerves [8],[9]. In its development, the GSR sensor measures the response of skin conductance because of a spontaneous reaction that cannot be controlled by the user. Also, this is considered to be one of the most active signals that can be used for the detection of physical stimulation [10], [11].

The prototype galvanic skin response previously still used a USB cable to transfer data to a PC. Data transfer using a USB cable has a weakness in terms of measurement distance. This research aims to develop a prototype galvanic skin response using Bluetooth so that it can be more easily used, and measurements can be used remotely. The developed system must also provide a reliable Bluetooth Low Energy (BLE) connection. Such a system requires relatively low power consumption [12]. Therefore, components must minimize power consumption. Sensor sensitivity results are compared with the commercial GSR module as a reference. During the measurement process, physical impulses are introduced and measured.

This paper explains and assesses the performance of devices based on electrodermal activity that can be used to detect pain or distress. Section 2 introduces the method and hardware used. Section 3 presents the results and discussion of experiments that have been designed to assess the validity of the device being worn. Then, section 4 covers the outermost conclusions regarding this work.

II. MATERIALS AND METHODS

To measure electrical resistance, a constant voltage needs to be applied and skin conductance can be calculated with the help of Ohm's Law by measuring current flow [13]. Conductance is the ability of a material to conduct electricity, conductance is the opposite of resistance so that the formula can be used :

$$G = \frac{1}{R} \tag{1}$$

Where G is Conductance (µsiemens), and R is Resistance (Ω).

Two different methodologies can be used to measure electrodermal activity (EDA) signals. The first method is the endosomatic methodology, this method does not use external currents to obtain EDA signals and this endosomatic method is difficult to interpret the recorded signal [14]. The second method is the exosomatic method, this method uses direct current called DC-Exosomatic, or alternating current, AC-Exosomatic. Exosomatic DC has been widely performed in EDA studies because the empirical superiority of the AC-Exosomatic variant has not been demonstrated [14]. So this is the main reason why exosomatic methodology is more widely used to measure EDA signals. Then, this literature uses the DC-Exosomatik methodology, with a simple series, as shown in Fig.1.

Fig.1 indicates that the signal resistor (Rs) is connected in parallel to the SC, where both units are connected in series with battery life (*Re*). SC consists of two parts of human skin, each end connected to a conductive electrode. The resulting signal is then amplified by specific amplification factors depending on the subject being measured.

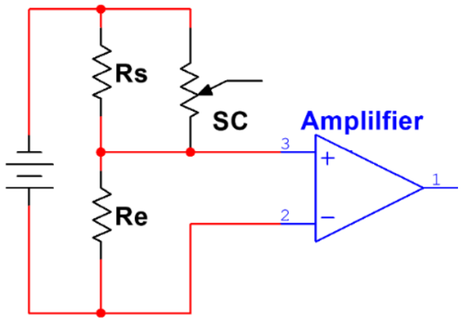

Fig. 1. A simple circuit to measure skin conductance by exosomatic method, adapted from [15].

The electronic system circuit is shown in Fig.2. This series is divided into three stages. Each stage has its function. Each stage has an output voltage, each represented by probe V_1 (ADC0), V_2 (ADC1), and V_0 (ADC2). The advantage of this configuration is that it only requires one voltage source. The source voltage can be changed as desired. In this literature, 5 volts are used because 5 volts is the standard voltage used on USB ports [16], so this device can be supplied with a USB-based power source.

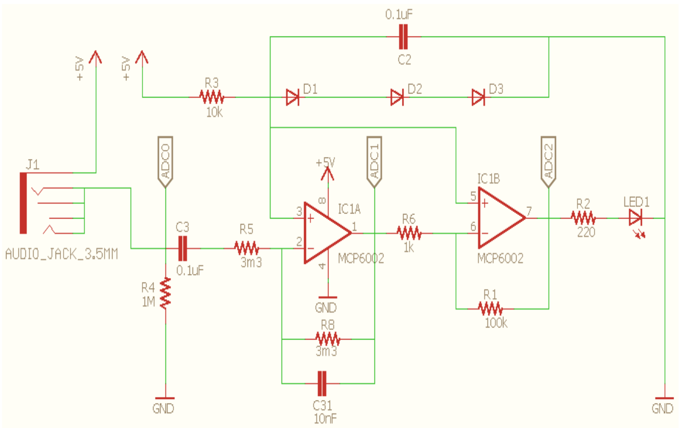

Fig. 2. Schematic circuit of the prototype galvanic skin response

The prototype galvanic skin response design, referring to the EDA described earlier, exosomatic DC electrodermal activity was measured using an EDA sensor through two disposable Ag / AgCl electrodes with a contact diameter of 10 mm. Fig.3 (a). shows the position of the electrodes attached to the medial phalanx on the side of the palm of the index and middle fingers. The stratum corneum below the electrode is flowed by a small DC. The current that passes through must be limited to 10μA / cm2 to avoid damage to the sweat gland ducts [17].

The prototype galvanic skin response block diagram can be divided into 7 parts, namely: finger sensor, power supply, voltage divider, bandpass filter, amplifier, microcontroller, Bluetooth and PC, as shown in Fig.3 (b). The main function of this prototype circuit is to measure changes in skin conductance. We use a voltage divider circuit consisting of leather, functioning as an RS resistance connected to a voltage source of 5 volts on one side and 1 MΩ resistance connected to the other side. Furthermore, using an op-amp (MCP6002) for voltage amplifier. Op-amps are also used to form bandpass filters to eliminate noise. The bandpass filter circuit consists of a passive highpass filter connected to an active lowpass filter. This filter aims to eliminate noise caused by skin barriers that are not consistent in one measurement condition. The circuit output is connected directly to the microcontroller.

In this study, we use the Arduino Uno microcontroller for data acquisition. This microcontroller is based on ATmega328 (8-bit microcontroller) with a 10-bit ADC that functions to convert analog measurements into digital. The Arduino Uno Board is programmed using Arduino IDE software. Inter-communication between the Arduino microcontroller and the laptop is made via a Bluetooth connection and then submitted to the laptop for further data processing.

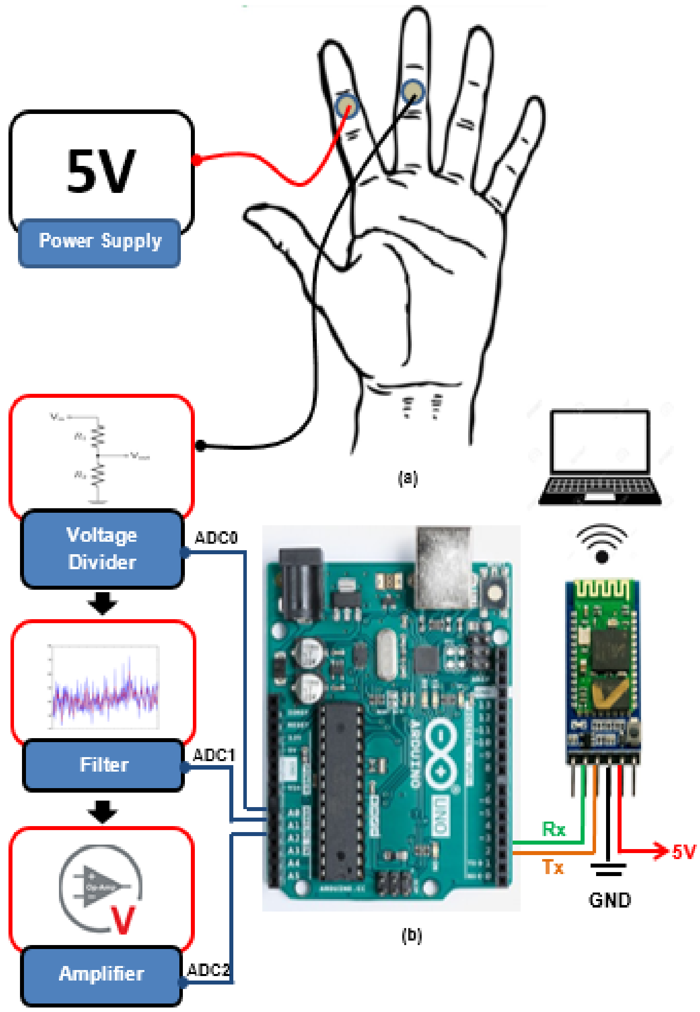

Fig. 3. (a) Electrode placement on palm; (b) Block diagram of the prototype galvanic skin response

One development of the prototype galvanic skin response is to use a Bluetooth module. Bluetooth HC-05 module is one of the commercial Bluetooth at a relatively low price. The Bluetooth HC-05 module consists of 6 connector pins [18], each connector pin has a different function, as added in Fig.4. The 3.3V supply voltage on the Arduino Uno board is connected to pin 12 of the Bluetooth module on the HC-05 module for use as a VCC. The transmitter function on the Bluetooth module is located at pin 1 (TX) then the receiver function on Bluetooth is placed at pin 2 (RX).

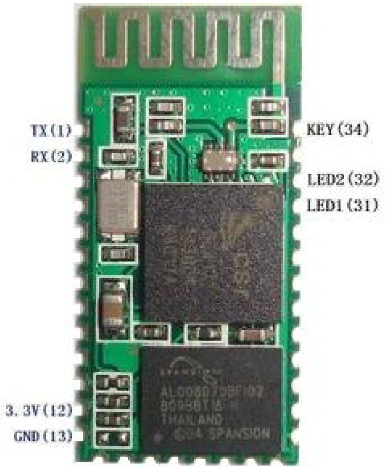

Fig. 4. Bluetooth module HC-05 [19]

Description of Bluetooth Module used [21] :

- Low supply voltage of 3.3 V.
- Baudrate can be set according to user needs. The default Baudrate is 9600.
- The frequency is 2.4 GHz
- Currents during pairing conditions are 20-30 mA

III. Results and Discussion

A. Validation of Prototype Galvanic Skin Response Results

The results of this study are the prototype galvanic skin response portable by measuring sensor sensitivity data verification using a commercially available galvanic skin response module and the prototype galvanic skin response portable using Bluetooth. Hardware as a data source and software is a hardware and data processing interface.

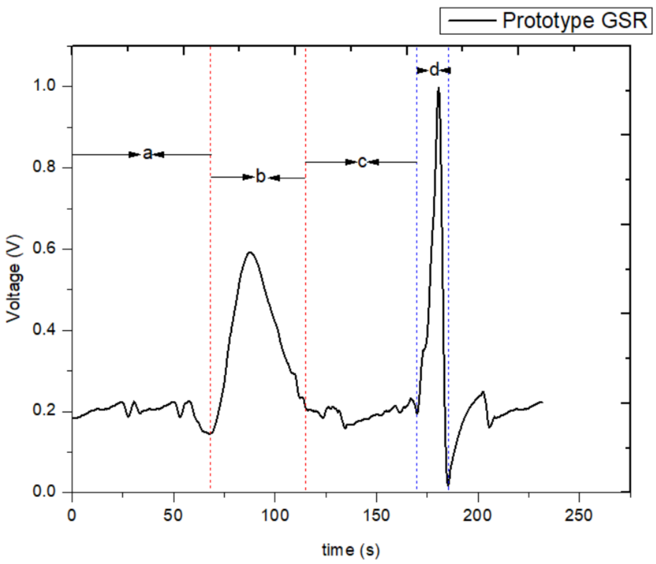

Fig. 5. Data of the prototype galvanic skin response sensor. (a) Initial condition; (b) represents the period of the first bump; (c) state of recovery before the second blow; (d) represents the second bump.

The galvanic prototype skin response was successfully built and worked well as recommended shown in Fig.5. To approve the prototype galvanic sensor response based on the galvanic response module measurement results, GrooveTM as shown in Fig.6. Verification provides a different punch stimulus to determine the effect of each value on the device reading. Graph of verification results between the galvanic skin response prototype and the galvanic skin response module, as shown in Fig.7.

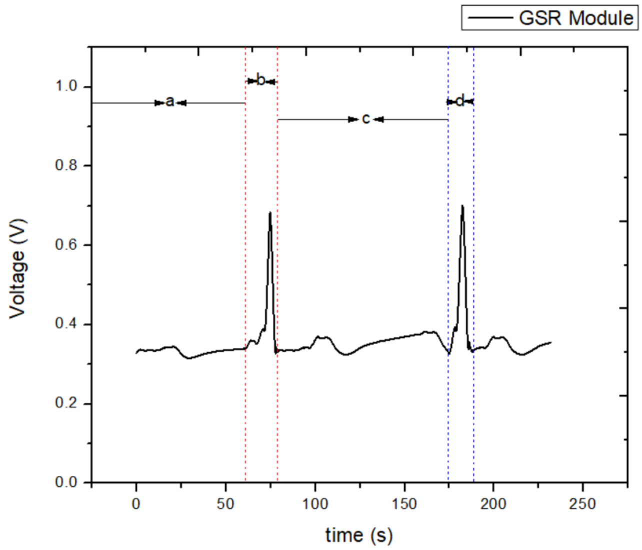

Fig. 6. Data of the module galvanic skin response commercial. (a) Initial condition; (b) represents the period of the first bump; (c) state of recovery before the second blow; (d) represents the second bump.

The sensor shows good results regarding its sensitivity. The measurement is delayed by 1 minute to let the body rest before receiving the first physical impulse, and after 1 minute 30 seconds, the second physical impulse is introduced. The total time taken for measurement is 4 minutes. The difference in voltage between the peak voltage and the voltage in the time frame before the peak is calculated. For the prototype galvanic skin response, the calculation results at 0.4 volts. For the GSR module, this calculation produces 0.33 volts. There is also a delay that can be observed between physical impulses and climbing response, as shown in Fig. 7, which has a 5 second and 8-second interval on the galvanic skin response prototype and the GSR module on the first physical response.

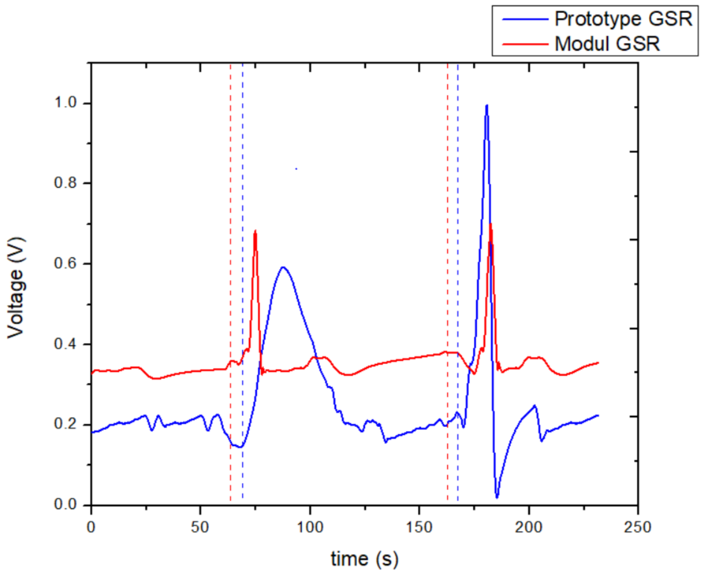

Fig. 7. Data comparison of the designed galvanic skin response sensor and commercial galvanic skin response module.

There is also a delay in the second physical response, which has a 10 second and 12-second interval on each device. For the calculation results of the galvanic prototype skin response at 1 volt, for the commercial galvanic skin response module, the calculation result is at 0.73 volts. Based on the calculation of the voltage change above, it can be concluded that the galvanic skin response prototype that has been designed results is not much different from the results of the commercial GSR module and when receiving physical impulses, the galvanic skin response sensor prototype is more sensitive than the commercial galvanic skin response module.

B. Realization of Galvanic Skin Response using Bluetooth

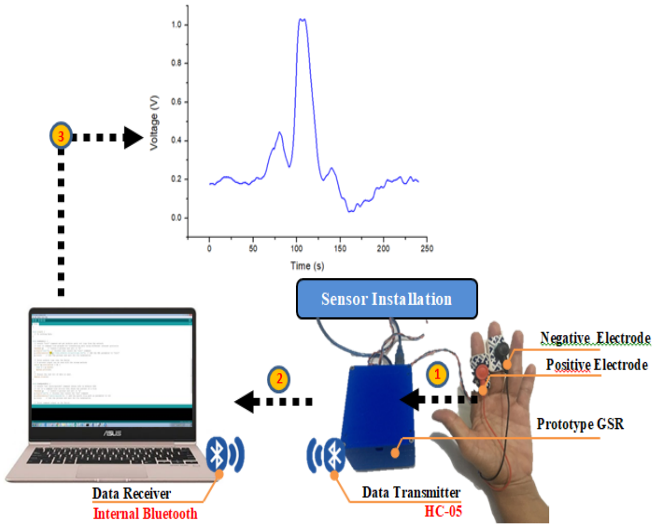

Fig. 8. Configuration of the Prototype Galvanic Skin Response

Fig.8 shows the testing configuration of the Prototype Galvanic Skin Response sensor using Bluetooth. This prototype uses 5 volt supply voltage and uses 2 electrodes, namely positive electrode and negative electrode. Measured data from the GSR prototype will be sent to the Laptop to display the results using the Bluetooth HC-05 wireless network. On a laptop, the Arduino IDE display will monitor and plot changes to any data changes recorded in real-time. Tests have been carried out by recording for 4 minutes; for the first 1 minute, no impulses are introduced then physical impulses are given in the form of blows to the arm after the first 1 minute so the bulge at the output voltage on the graph shows that the sensor response to the impulse is functioning properly. Data transfer speeds using Bluetooth reach 1Mbps in synchronous mode.

C. Bluetooth Distance Measurements

Bluetooth communication distance testing, to find out how far the HC-05 Bluetooth module connection range to send galvanic skin response sensor data to Bluetooth laptop. The testing process is carried out by sending galvanic skin response (GSR) sensor data at rest and when receiving a physical impulse. The test is carried out 10 times for each distance that has been determined.

The purpose of this test is to determine the success rate of the GSR sensor to receive and make the move so that it can be used for pain sensors from any data sent. The test results are shown in Table.1.

TABLE I. THE RESULTS OF THE EXPERIMENT TO SEND DATA USING BLUETOOTH WITHOUT HINDRANCE

No	Distance (cm)	Data	
		Send	***No Send***
1	100	✓	
2	200	✓	
3	300	✓	
4	400	✓	
5	500	✓	
6	600	✓	
7	700	✓	
8	800	✓	
9	900		✓
10	1000		✓

IV. CONCLUSIONS

In short, we have built a prototype portable galvanic skin response that is equipped with Bluetooth so that it can be more easily used and can be used for remote measurements. The distance of the Galvanic Skin Response prototype communication range with the laptop as far as 8 meters without a hitch. This project still uses the Arduino IDE display for the results. For further research, it is hoped that an application that will provide a Graphical User Interface (GUI) will be created to make it easier for users to see measurement results.

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