Impact of Placement of Facial PPG Sensor on Pulse-Rate Monitoring Accuracy

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***Abstract*—The facial placement of a PPG sensor can affect pulse-rate monitoring accuracy. In situations where more commonly used sites for pulse monitoring are not available, PPG signals from the face can be taken, and the accuracy of the pulse rate may be affected based upon the PPG sensors facial placement. Using the pulse sensor PPG manufactured by World Famous Electronics LLC., and modifying the raw pulse signal through a series of instrumentation amplifier stages, PPG signals have been both detected and amplified for recording accuracy. Using human clinical trials, this modified pulse sensor will be used to study the impact of different facial placements on the accuracy of the pulse-rate being measured. The results of this research study could prove to aid in the future development of facial PPG sensors as well as their potential applications in wearable devices. The ability to accurately and consistently monitor pulse-rate from different parts of the body such as the face advances the possibilities for numerous applications in the realm of wearable biotechnology.**

I. Introduction

Photoplethysmogram (PPG) sensors are non-invasive electronic sensors used in hospitals, homes, and in many wearable electronic devices to optically obtain a volumetric measurement of an organ. The most common application for using a PPG is with a pulse oximeter, which uses infrared light emitting diodes (LED) to illuminate the skin and measure changes in blood volume through light absorption. The changes detected in blood flow volume are then used to calculate the heart rate or pulse of an individual. In recent years, advances in optical technology have enabled the use of high-intensity green LEDs for PPG sensors. The simplicity, low cost, and reliability of these sensors has led to the increased adoption of this measurement technique [1].

The design concept for the custom facial PPG sensor includes using part of the Pulse Sensor PPG designed by World Famous Electronics LLC. Specifically, the raw pulse output signal obtained through the light reflectance of the high-intensity green LED by the ambient light photodetector is what is needed from the Pulse Sensor PPG [2]. The pulse signal is then amplified and filtered using a custom-built circuit with a series of operational amplifiers.

This modified pulse sensor was used on key locations picked based on the vascular density in relation to human facial anatomy. Testing was conducted in human trials to determine the impact of the placement of facial PPG sensors on pulse-rate.

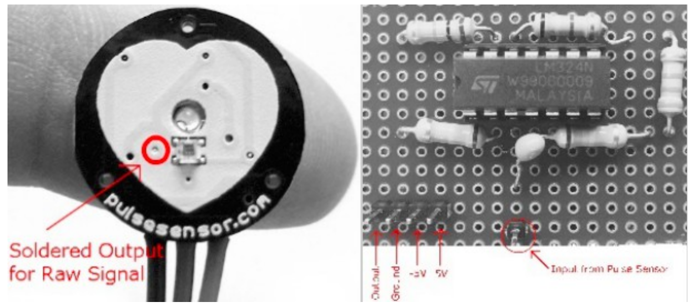

Figure 1: Output Pin (Left), Green Board Gain Stage (Right).

II. Methods

A. Hardware

The PPG sensor being used in this study illuminates the skin using a high-intensity green LED and measures changes in light absorption through the reflected light being bounced back to the ADPS ambient light photo sensor. The light sent through and reflected from the subject measures the blood within the tissue and generates a current in the sensors photodiode. During diastole, the volume of blood in the tissue increases and that amount of change can be measured through light reflectance. The resulting current from reflected light creates a voltage that can be used to calculate the wearer's pulse or heart rate (HR).

The pulse sensor PPG was modified by soldering a wire right at the output from the ADPS ambient light photo sensor to utilize only the raw unfiltered and unamplified pulse signal. However, this signal is weak (has a very low voltage), and so is difficult to be received and analyzed by anything used to process this signal. Therefore, before any filtering or analysis can occur in this research study, the raw pulse signal needs to be amplified.

The amplification of the pulse signal occurs through a series of operational amplifiers (op-amps). Since it is such a small signal (~2mV), it needs to be first AC coupled with a small capacitor in series to be properly read by DC components. The signal is then amplified using multiple stages on a LM324N quad op-amp. The first gain stage increases the signal by 5 times its original amplitude and is soldered onto a green board that is connected directly to the pulse sensor to provide a preliminary "set" gain stage. This amplified signal is then amplified again with another op-amp built on a breadboard that has an adjustable gain between zero and 11 using a potentiometer. The gain is set to increase the signal as much as it can to still be on a 0-5V range. The signal from this amplifier is sent to the PIC microprocessor which is what is used to both record the data during the study and send it to an LED display to provide feedback during recording.

B. Human Clinical Trials

Small scale human clinical trials, supported by an IRB, were used to evaluate the best placement for facial application of the wearable PPG sensor. Based on the vascularity of human facial anatomy, five locations were studied using the sensor. These locations were the left and right ear lobe, the left and right temple, and the forehead. Each location was measured using the sensor attached with a spring-loaded clip or an adjustable strap depending on the location with a contact force of approximately 0.4 N for ideal measurements [3].

The trials studied the effects of the sensor on 20 participants, one participant at a time. Each study took approximately 30 minutes from start to finish. Before the start of the testing, participants were asked to record their height, weight, age, sex, and self-described physical activity level on the questionnaire supplied to them by the researchers. After filling out the questionnaire, participants sat down in the upright position on a chair. The facial PPG sensor was attached using a spring-loaded clip to the thumb to record a baseline PPG signal (for reference). Using three minute intervals, the sensor was placed on the five predetermined locations on the face, one at a time. After each location was successfully measured for the allotted time, the experiment was concluded and the participant was asked to leave the study. The signals were processed using a PIC microchip that is programmed to record the PPG signal, and process it to be shown on an LCD display as a feedback mechanism. Once the data was collected from the clinical trials, the data was transferred to a secure computer where they were furthered analyzed.

III. Results

A. Strength of Signal and Visual Display

The signal was amplified to the ideal voltage with a maximum amplitude between 0 and 5 volts with the ability to adjust some amplification to avoid clipping or overloading the PIC microprocessor using the 2^{nd} gain stage potentiometer. When the signal stayed in the necessary voltage range, the PIC microprocessor successfully recorded the data. From this data, the effect of the facial placements for the PPG sensor for pulse-rate monitoring was successfully studied and analyzed.

The serial data recorded on the PIC microprocessor during the human clinical trials was sent to a file on a secure computer where it was analyzed using MATLAB. All studies were analyzed to determine the most reliable facial placement for accurate and consistent pulse-rates.

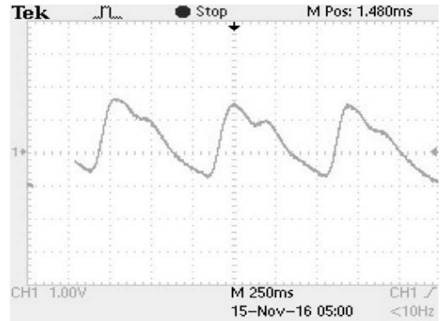

Figure 2: Ideal PPG signal Measured on Oscilloscope.

B. Facial Placement Impact

The expected results from this study are that the earlobes will produce the most consistent and accurate pulse-rate signal as there is already publications with data proving that clean PPG signals are attainable from them. However, it may be noted that this may not be the most ideal spot in all scenarios. To have something pinching and dangling off their ear while they are in constant motion trying to combat situations of distress may be uncomfortable and possibly annoying to the point that they may not wear them. The fact that it is on the peripherals of one face could introduce a lot of noise when even slightly moving one's head, to the point where the signal would be difficult to be read without the proper filtering. There would probably need to be a lot more factors included to provide proper stabilization and accurate readings of the PPG signal in contextual situations as above.

The next best facial placement that would be expected would be the forehead. Although it is not one of the higher vascular density areas of the face, the area between the bone and skin is very thin, and since this study is using reflected PPG measurements, it should still give strong readings because there is less area for the light to be absorbed versus reflected back to the ADPS ambient light photo sensor.

IV. Discussion

A useful platform has been developed for studying technologies using the PPG. The results pertain to the placement of facial PPG sensors should be applicable to wearable devices [4].

References

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