PhotoPlethysmography Device; Precursor to Noninvasive Glucotometer

Dhakshenan Pushparajan1, Kyle Butler[2], Joaquin Rodarte[3]
Venumadhav Korampally1

Elizabeth Gaillard

[1]Biomedical Engineering, [2]Electrical Engineering

NORTHERN ILLINOIS UNIVERSITY
College of Engineering and Engineering Technology

Abstract

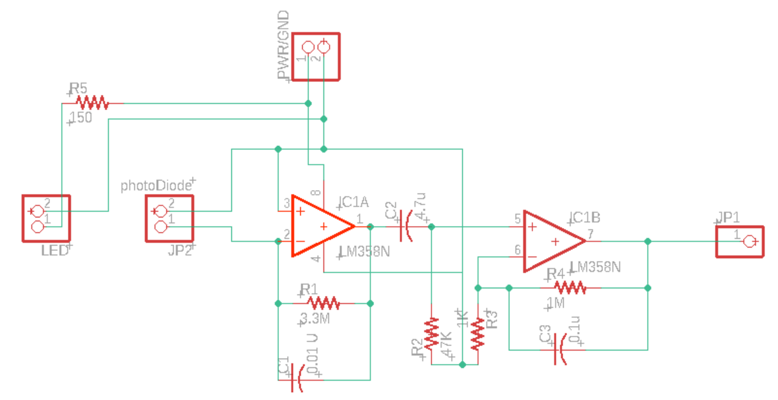
Currently the most accurate and easily accessible method to check the blood glucose levels is to prick the finger for blood samples. This method is painful and unpleasant as multiple finger pricks may be required for adequate blood supply for the detection unit. There is also a chance of infections occurring with the current method and the long-term costs are very high. This project is aimed to create a photoplethysmography (PPG) device to be further used for blood glucose monitoring that will mitigate the issues that arise due to the current methods. The primary objective is to create a non-invasive sensor that would ensure accurate monitoring of a PPG signal. The secondary objective was to relate the features of the PPG signals to estimate blood glucose levels however was not able to be done due to covid-19 restrictions at this time. Due to this the project involved generating a low-cost PPG sensor and to extract the features related to the signal that was acquired.

Introduction

The development of this instrument based on Photoplethysmography technology will revolutionize blood glucose detection. As current methods are expensive, messy, and generally unsanitary, this is not an ideal method for test for blood glucose levels. Currently, the most accurate and easily accessible method to check the blood glucose levels is to prick the finger for blood samples. This method is painful and might require the individual to prick their finger multiple times to ensure adequate blood is supplied to the device. Also, as the finger is being pricked, there is a chance for infections to occur if the needle is not sanitized. Infections can also occur at the prick site if the needles penetrate too deep in the skin and wound does not heal in a timely manner. Furthermore, an individual is required check his or her blood sugar levels multiple times a day to ensure proper steps can be taken which leads to a high quantity of needles and testing strips being required. Diabetes test strips cost on average of $50 a month and can cost up to $100 a month. Needles also need to be regularly replaced adding to that relatively high monthly cost. Due to this, the long-term monetary cost for the current method is very high. However, with the proposed non-invasive blood glucometer, users will have access to a cheaper and more sanitary method that can consistently deliver accurate results.

Methods and Materials

Designing the circuit that would be used to generate a PPG signal was researched intensely to determine what would provide the best results. The schematic of the circuit used is shown below.



This circuit is a combination of using a high pass filter and a low pass filter to provide frequencies above .48 Hz and below 4.98 Hz. The average heart beats between frequencies of 1-2 Hz. Using that we determined what would be the best cut off frequencies to use to filter out unwanted noise from the signal. The circuit is composed of:

- Five Resistors
  - One 150Ω
  - One 1KΩ
  - One 47KΩ
  - One 330KΩ
  - One 1MΩ
- Two .1µ Farad Capacitors
- One 4.7µ Farad Capacitor
- One LM358 Operational Amplifier
- One NONIN Finger Probe

The NONIN finger probe is composed of an LED light that emits wavelengths around 940 nm to probably pass through the finger to a photodiode installed within the probe. The casing that was used for this project was made in SolidWorks and 3d printed. The size of this casing is 150mm (length) x 80mm (width) x 80 mm (height).

Results

The raw data obtained from the PPG sensor is shown below. This comes directly from the circuit before being processed through the mat lab code. The signal that is shown in Figure 1, shows the diastolic arch coming before the systolic arch. Once the signal is processed through an Arduino UNO, the signal will be shown correctly through MATLAB. Once this data is digitally filtered, features will be extracted to develop patterns throughout that will analyze the PPG for future development of blood glucose concentrations.

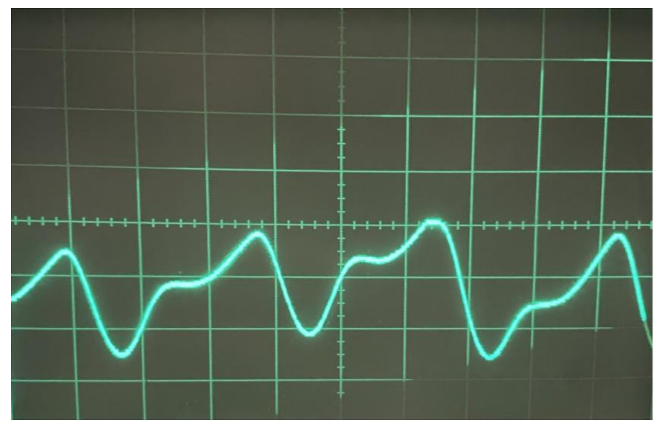


Figure 2: RAW PPG DATA> VOLTAGE VS. TIME

Discussion

The results show that with a relatively simple to implement circuitry along with ample digital signal processing a stable PPG signal can be attainted. The current design uses only one LED and wavelength of light to attain the signal. Future versions of the device can have multiple wavelengths that are highly absorbent by glucose, multiplexed together for a higher potential in accuracy when analyzing the features of the wave for glucose measurement.

Figure 3: PPG deivice in use

Conclusions

This project provides a cheap and accurate measurement of a PPG signal generated through the index finger. Unfortunately, due to Covid data collection of a large enough sample size of volunteers was not possible. The features extracted allow for future pattern recognition to develop measurements for blood glucose concentration that involve the use of machine learning to determine an algorithm that can find minute differences in the wave when glucose levels are normal and when they are elevated.

Acknowledgements

We would like to express gratitude to Dr. Venumadhav Korampally for guiding us in the right path throughout this project. We would like to express thanks to Dr. Elizabeth Gaillard for allowing us to use her lab and helping throughout the biology related components. We would also like to thank Instructor Edward Miguel for guiding us through the electrical components necessary for this device to work and for supplying us with additional parts that we could not obtain without his expertise.