ENGR 113 - Spring 2025
First-Year Engineering Design

"Transcutaneous Vital Signs Monitoring Device"
Final Report

Date Submitted: May 28, 2025

Submitted to: **Bruce Eisenstein,** eisens@drexel.edu

Group Members:
Ashley Benjamin, abb97@drexel.edu
Earli Ismaili, ei77@drexel.edu
Hakan Alex Kucukhuseyin, hk862@drexel.edu
Esila Özdemir, eo425@drexel.edu
Darti Lila, dl3292@drexel.edu

Abstract:

The motivation behind our team's Transcutaneous Monitoring Device lies in the fact that some individuals might find it difficult to always access such medical devices and some of them are not comfortable with the way that such readings are obtained (e.g. blood glucose levels are measured and monitored invasively). Taking that into account, what we aim to accomplish through our project is to provide a transcutaneous monitoring device that is going to monitor the heart rate, oxygen and glucose levels in the body using the 880 nm near infrared signal and signal processing methods, which allows these individuals to noninvasively always access such parameters of their body. Our goals for this project consist of our team having a working final prototype by the end of the term that we can use for testing and from which we can receive persistent readings.

1 Introduction

Diabetes mellitus is a chronic and increasingly common disease, now known to afflict over half a billion people worldwide and projected to rise to 783 million by 2045 [2]. It is crucial to monitor blood glucose in order to prevent severe complications such as cardiovascular disease, neuropathy, and renal failure. The most common method, however—finger-pricking—is painful, inconvenient, and invasive, and this deters individuals from frequent use.

1.1 Problem Overview

A study at MIT states that "more than half of patients don't test often enough, in part because of the pain and inconvenience of the needle prick" [1]. This highlights a significant deficiency in diabetes management: the necessity for a trustworthy, noninvasive glucose monitoring technique that improves patient compliance and overall quality of life.

1.2 Existing Solutions and Marketability

Recent developments in biomedical sensing technologies provide encouraging alternatives. One of these techniques is near-infrared (NIR) spectroscopy, which enables glucose concentration to be determined through the measurement of the absorption and reflection of infrared radiation that has passed through the skin. In the opinion of Ali et al., "NIR Spectroscopy, which operates in the 750–2500 nm wavelength region, offers deep skin penetration and has been identified as an inexpensive approach to glucose monitoring" [2]. Furthermore, signals obtained by photoplethysmography (PPG), through optical sensors like the MAX30102, have been found to "offer valuable information on heart rate, blood flow, and oxygen saturation, which indirectly correlate with glucose levels" [2]. The integration of these technologies enables the creation of systems that can estimate blood glucose levels in a non-invasive manner, thereby providing real-time, continuous, and comfortable monitoring.

1.3 Project Objectives and Deliverables

The goal of our project was to design a device that will noninvasively monitor the heart rate, oxygen, and glucose levels in the body using the near-infrared signal. To achieve the expected results, we decided to use two MAX30102 biosensors.

This system allows for a more efficient and accurate data collection process compared to conventional single-sensor technologies.

The processing of the sensor data and communication with peripheral components is handled by the ESP32 microcontroller. The microcontroller communicates with the two MAX30102 sensors and processes the raw signals that it is going to receive from both, as well as the OLED display that shows the data once the signals have been processed.

Additionally, when designing our device, we had to make sure that the required electrical components would be easily accessible and affordable from an electronic components' distributor. We also had to make sure that the components would be compatible with one another and had to ensure seamless integration between each of them.

This device presents an opportunity to disrupt the healthcare monitoring market, particularly for diabetic individuals and those with chronic cardiovascular diseases. This device eliminates the need for frequent needle-based glucose testing, making it more comfortable and accessible.

Since the device is easy to use and maintain, it will only require them to change the batteries occasionally, to ensure accurate performance. It is also important to emphasize that most of the components required to build this device are low – power consumption, it is going to help reduce the environmental strain.

2 Technical Activities

The sections below describe the steps that were taken each week to produce our final prototype.

2.1 Weekly Progress

Week 1: We all met to discuss potential project ideas that we wanted to complete as our prototype for this 10-week project

Week 2: We all did a lot of research finding similar projects that have been completed to find some inspiration and what parts are needed to bring our idea to life. Also, Hakan Alex Kucukhuseyin started designing our web server that we later connected to the microcontroller programming to display the data that was processed

Week 3: We all continued to do some research on our project and Alex continued to work on creating the web server. From our research, we were able to pick out the electronics that we wanted to use, so we ordered our parts, and Darti Lila, Earli Ismaili, and Esila Özdemir started on our first circuit design

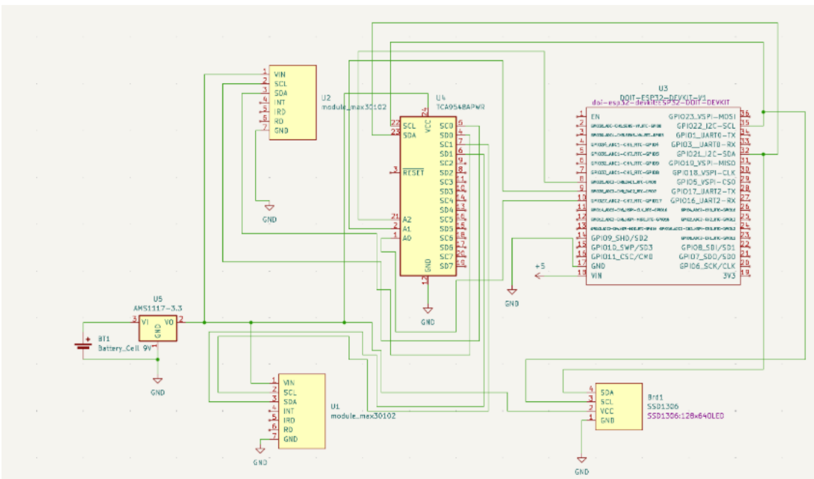


Image 1. Preliminary circuit schematic

Week 4: Alex added some finishing touches to our web server and had to wait until the ESP32 was finished being programmed before he could make big adjustments to the web server code. Darti, Earli, and Esila moved on to designing a PCB to use for our circuit rather than just a breadboard and wires with our components. The parts we ordered came in, so Ashley Benjamin was able to start programming the microcontroller.

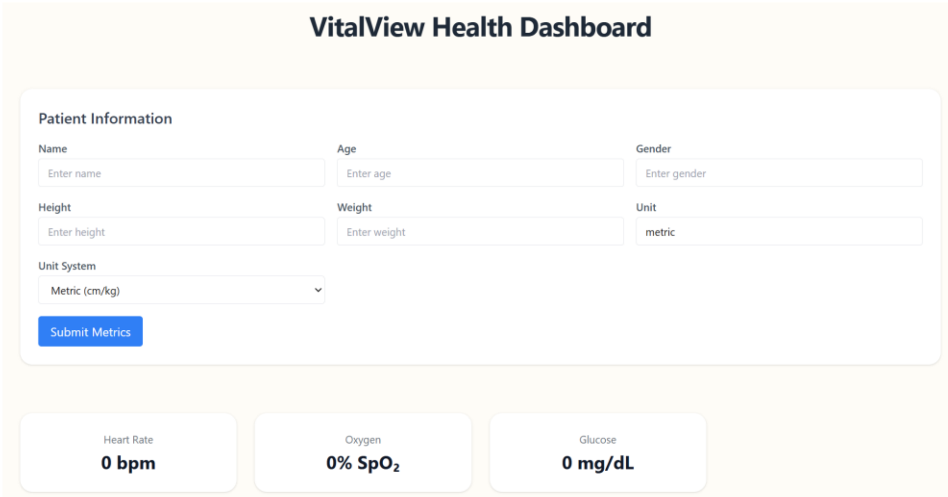


Image 2. First display of VitalView web server

Week 5: Darti, Earli, and Esila continued working on designing the PCB. Ashley continued programming the ESP32 and got the first sign of a working heart rate monitor.

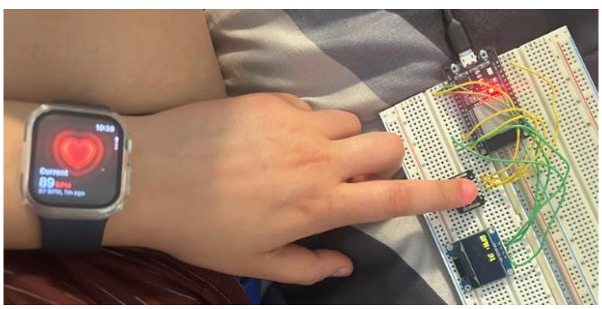


Image 3. Picture of working heart rate monitor being displayed

Week 6: Darti, Earli, and Esila kept working on improving the PCB design. Ashley moved on to programming the ESP32 to accurately measuring blood oxygen levels.

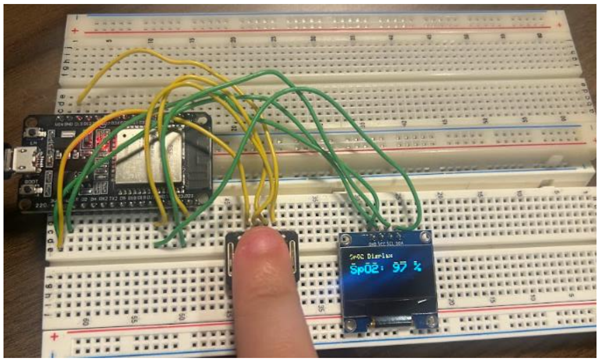


Image 4. Picture of accurate blood oxygen level being displayed

Week 7: Ashley now had to connect the two programs to detect and display heart rate and blood oxygen level at the same time. This brought about an issue of getting accurate results, so the code and circuit had to be changed slightly. Darti, Earli, and Esila continued working on designing the PCB, but had to incorporate the change of circuitry design.

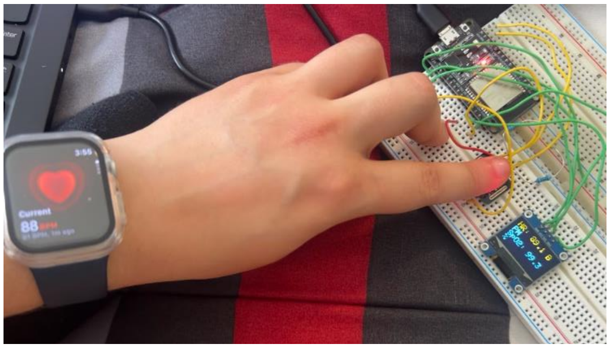


Image 5. Picture of accurate blood oxygen level and heart rate being displayed

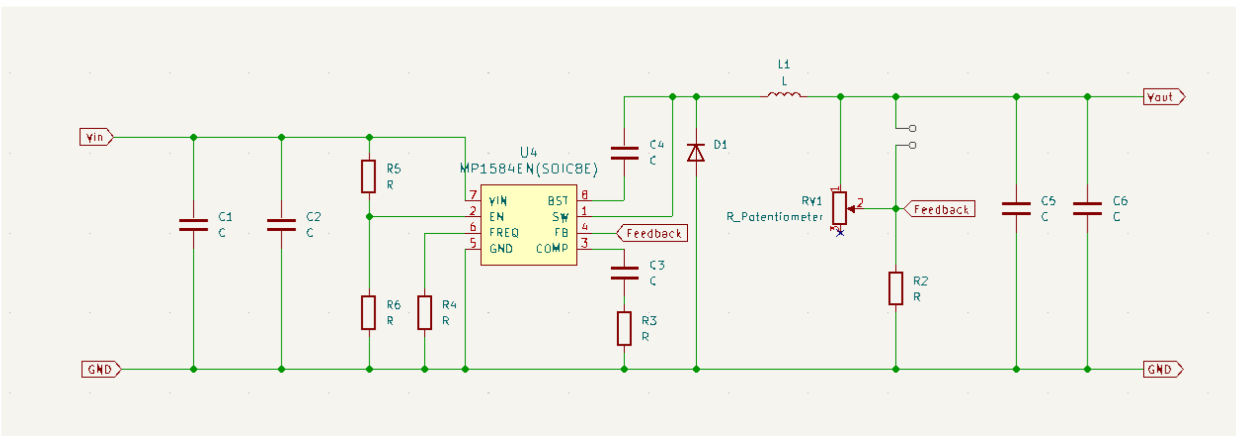


Image 6. Schematic of buck converter circuitry

Week 8: Due to the changes made in week 7, Darti, Earli, and Esila continued to change the PCB design to match the new circuit that the code was based off. Now that the microcontroller code was working, Ashley and Alex worked together to connect the back-end code to the front end. Ashley and Alex successfully connected their codes, and we had accurate heart rate and blood oxygen levels displayed on the server and the OLED display.

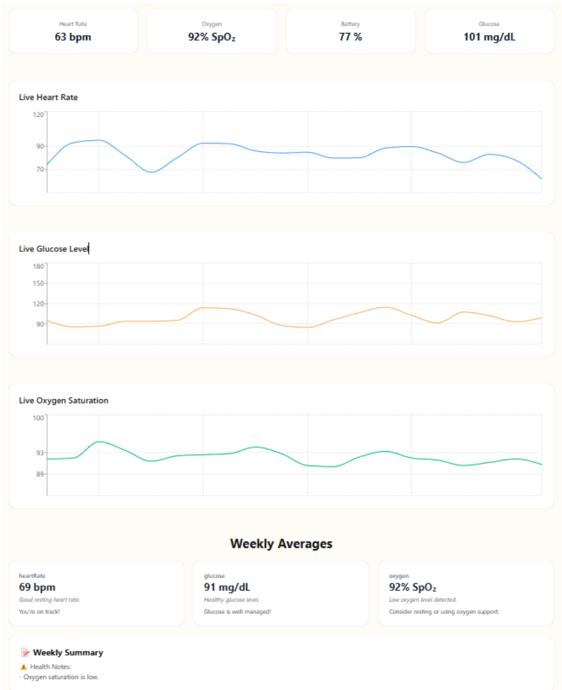


Image 7. Picture of vital signs data displayed on the website after the ESP32 code was connected to the web server code

Week 9: Darti, Earli, and Esila finalized the PCB and ordered it. Darti started working on the glucose monitor code. Ashley and Alex continued to look at improving their connected codes and making updates as needed.

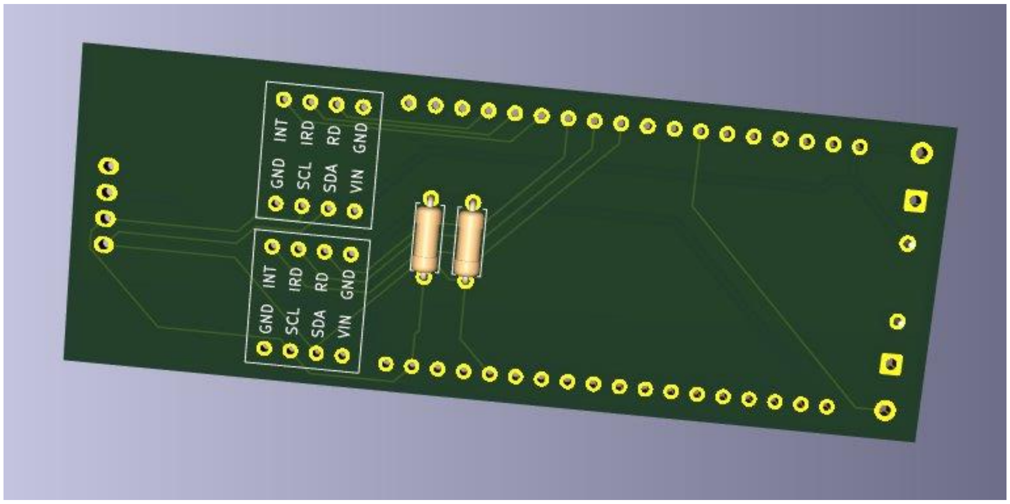
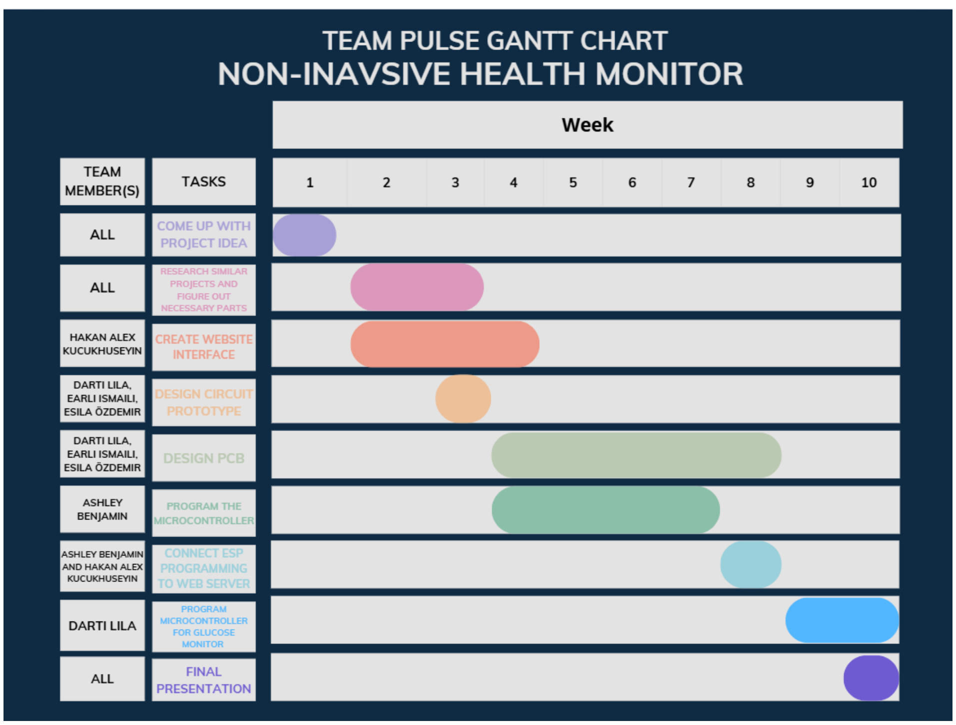


Image 8. Picture of finalized PCB design

Week 10: Darti finished programming the glucose monitor. We received the PCB and set up the circuit on that rather than the breadboard. We completed a lot of testing on our prototype.

2.2 Project Timeline

Table 1. Timeline to set individual deadlines and follow throughout the process of creating a transcutaneous health monitor prototype.



2.3 Project Budget (how much did it cost to create the prototype)

Table 2. Budget of the Project

Part	Quantity/Package	Cost	Total
ESP32 Microcontroller	1	$ 16	
MAX30102 Sensor	1	$ 8	
OLED Display	2	$ 7	
Battery pack	2	$ 9	
Battery holder	1	$ 6	
MP1584 Adjustable Buck Converter	6	$ 13	$ 59

Industrial Budget Table

Table 3. Industrial Budget of the Project

Number of emplyees	Salary/Hour	Total Duration [Hours]	Total
5	$50	200	$50,000
Components	**Total price / Component**		
ESP32 Microcontroller	$16		
MAX30102 Sensor	$8		
OLED Display	$7		
Battery pack	$7		
Battery holder	$6		
MP1584 Adjustable Buck Converter	$13		
Total	$59		
Fringe [30%]	$15,000		
Overhead [100%]	$65,059		
Total project cost	$130,118		

3 Results

We have successfully developed a transcutaneous vital signs monitoring device, which monitors the heart rate, oxygen saturation, and glucose levels of the patient/ user using the near – infrared signals that we had initially considered in the preliminary stages of our project. As a team we were able to enhance data collection accuracy through the integration of the two MAX30102 biosensors with the ESP32 microcontroller. This method appears to be more beneficial compared to conventional single-sensor systems. The microcontroller efficiently processes signals from both sensors and displays results on an OLED screen, ensuring real-time monitoring. We are also able to display the data on the website that our team has been working on. This built – in system with real-time feedback based on the users' readings and input information offers valuable insights that can help them manage their health more effectively. If our transcutaneous monitoring device were to be put on the shelf for the others to purchase, our final revision of this device would be compact, durable, and user-friendly. It would most likely consist of either a medical-grade plastic or aluminum for durability and comfort.

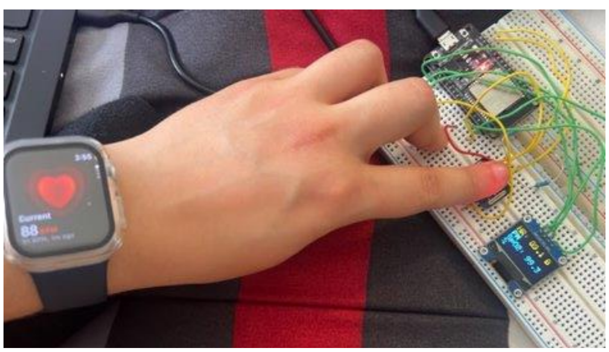


Image 9. Most recent revision of the Transcutaneous Vital Signs Monitoring Signs

4 Discussion

Our prototype successfully addresses the original problem by providing a non-invasive, real-time monitoring solution for vital signs. Considering that there is an increasing demand for telemedicine solutions, as well as non-invasive methods, our transcutaneous vital signs monitoring device appears to be a promising innovation regarding its marketability. However, there are several that need to be taken to bring the device to the market. This will include improving the design from a prototype to a manufacturable model, as well as obtaining regulatory approvals such as FDA certification in the U.S. or CE marking in Europe. The abovementioned steps will allow the device to meet industry standards and gain reliability among users.

5 Impact Statement

The primary beneficiaries of this device will be diabetic patients, as well as individuals who require constant monitoring of these parameters, such as the sick and the elderly. Healthcare providers could also benefit, as the device enables regular updates of patient information on the website, allowing physicians to monitor their assigned patients effectively [3].

Maintenance of this device could be managed either by healthcare institutions or individual users, given its affordability and ease of handling. Additionally, during the design phase, it was crucial to ensure that the necessary electrical components would be both accessible and reasonably priced through an electronic component's distributor [4]. Since many of these components are low-power consumption, the device is expected to minimize the environmental impact associated with mass production [3].

However, the availability of these materials could be influenced by climate or geopolitical conditions, posing challenges for suppliers in providing the necessary components if large-scale production were undertaken [4].

6 References

[1] A. Trafton, "Researchers hope to make needle pricks for diabetics a thing of the past," *MIT News*, Jan. 24, 2020. [Online]. Available: https://news.mit.edu/2020/raman-spectroscopy-needle-pricks-diabetics-0124.

[2] S. Ali *et al.*, "Development and Evaluation of a Sensor-Based Non-Invasive Blood Glucose Monitoring System Using Near-Infrared Spectroscopy," in *Eng. Proc.*, vol. 82, p. 19, 2024. doi: 10.3390/ecsa-11-20395.

[3] KJ Manjunatheshwara & S Vinodh (2021) Sustainable electronics product design and manufacturing: State of art review, International Journal of Sustainable Engineering, 14:4, 541-551, DOI: 10.1080/19397038.2021.1900448

[4] Abdelbasir, S.M., Hassan, S.S.M., Kamel, A.H. et al. Status of electronic waste recycling techniques: a review. Environ Sci Pollut Res 25, 16533–16547 (2018). https://doi.org/10.1007/s11356-018-2136-6