Team Assignment 2: EK 210: Section A8

Pulse Oximeter Engineering Report

Spring 2021

Due: 04/21/2021

Team members: Yury Luzhkov, Melissa Sierra,

Josh Barton, Alexander Mackanic

Introduction

A pulse oximeter is a device that measures the amount of oxygenated hemoglobin in the blood, as well as the heart rate of an individual. For our final project, we were tasked with building a pulse oximeter using our knowledge of circuits and the tools given to us in the kits for the class. Our group aimed to create a device to safely measure heart rate and oxygen levels in patients for a hospital. Using LEDs and a photodiode we can measure the blood oxygen level, by obtaining differences between the absorption of IR and Red light through an appendage. The LED's will shine intermittently and the photodiode will capture how much the light that passes through. This information is used to calculate the level of Hb and HbO_2 in the blood that can be used to calculate the oxygen content in the blood. The information needed to find a patients SaO_2% can also be used to find the patient's heart rate as the level of admittance of light will pulse as the patients capillaries expand due to their heart rate. This information then can be displayed on an LCD for the patient to obtain the information calculated.

Problem Statement

Create a device that acrautalty, safely, and quickly measures heart rate and oxygen levels in patients for a hospital.

Possible Design Alternatives

As with many engineering projects, our first design for the pulse oximeter is not the one we eventually ended up with. Through trial and error the design of our pulse ox change. We started with our conceptual brainstorming of possible ideas to accomplish the needed functions to have a working pulse ox. The major functions as well as possible means for each are shown in figure1. From these possible means to complete these designs we chose to use a photodiode, an IR and red LED's, an arduino to complete the programming process and calibrated the device manually with another heart rate and SaO_2 reading device. We decided to have information be displayed both on a built in LCD as well as creating a hole in the case to create an auxiliary connection to a computer. To maximize use of the device the hole for one's finger to be placed in is the shape of an oval as fingers are generally wider than they are tall. This allows for many fingers to fit and minimizes light from the surroundings being detected by the photodiode. The LCD screen on the device is recessed in to minimize damage to the screen. The top of the pulse ox is hinged to allow for easy access to the inside of the prototype to fix components if needed. Lastly, the design of the final prototype allows for auxiliary power as well as a separate location for a battery power source to be used if greater portability is desired. This seperate location of the battery protects all circuit components if the battery ever happens to corrode.

	Functions					
	Light Detection	**Measure Heart Rate**	**Measure Blood Oxygen Level**	**Calibration of Readings**	**Display Information**	**Sequencing of Electronics**
Means 1	photo-resistors picks up light that is being	Measures amount of light such as red or infrared that will transmit through the tissue	Measures absorption of infrared light with infrared LED	Use another pulse oximeter to calibrate oxygen levels	Print out on LCD display	Program intermittent voltage at given time intervals
Means 2	photodiode picks up light that is being transmitted	Uses optical LED to sense light passing through your finger, changes with blood moving through your body	Measures absorption of red light with red LED	Use a computer to calibrate pulse oximeter	Print onto sheet of paper	Always have LED's on
Means 3	Use of photo-transistors	Use of a radio receiver that detects the radio signal given off by heart beat	Measure with HD camera	Automatic Zero calibration based upon theoretical SpO2 /*R* research data	Send information electronically to computer	

Figure 1: Chart of functions and possible means for a pulse oximeter to create design space.

Evaluation of Results

After assembling the prototype for the pulse oximeter, we tested it and found that it successfully measured the heart rate and blood oxygen level of a person. The average heart rate using the data plotted in figure 2 was found to be 65.29BPM and the standard deviation was 14.2BPM. This is a relatively large standard deviation and means that our values have a much wider range than our objective of +/- 3 BPM. Figure 3 shows the plot of the SaO2 % and the average SaO2 of this data is 95 with a standard deviation of 0.0636 when all nan values are thrown out. This shows that we meet our desired results for accuracy of oxygen level of a patient in +/-2%. While obtaining this data the heart rate of the test subject was found to be 63BPM and SaO2 % of 96% with an apple watch. The mode value of the SaO2 data was 96BPM and was obtained with an alpha value of 1.2. We also meet our response wait time of no more than 30 seconds as it takes 5 seconds to originally start reporting values and the longest stretch of nan values of SaO2 from the data set reported was 15 seconds. We did not achieve all of our objectives and did not meet all parts of our problem statement but we were able to make a device that can accurately find SaO2% and on the average find a close heart rate +/-3BPM to the actual values.

During our building of the final prototype some alterations were needed. The shelf that the LEDs sat on had to be lowered to obtain more precise information with regards to intensity of light passing through the finger for the calculations to be more accurate. In order for the hinge to fit flush on the top a cavity for the hinge needed to be filed into the bottom face of the cover. For future iterations of the prototype the switch turning the power of the device on and off will be between the power source and the arduino and not between the arduino and the circuitry.(See figure 6) The arduino itself is a large power draw and to become a more efficient device the arduino should also turn off. Another recommendation is to use a clamp or some sort of device to make sure the finger is really held in place and so the results can be more accurate. This is the believed cause as to why the standard deviation of heart rates found is so great but the average is within an acceptable range of the actual value. This too would create even faster response times as there would be much fewer nan values calculated for SaO2. Lastly, the size of the device could be condensed as there is wasted space inside the pulse ox. With all wires neatly soldered and glued to the walls the arduino could be stacked above the LED's on another shelf making the pulse ox shorter.

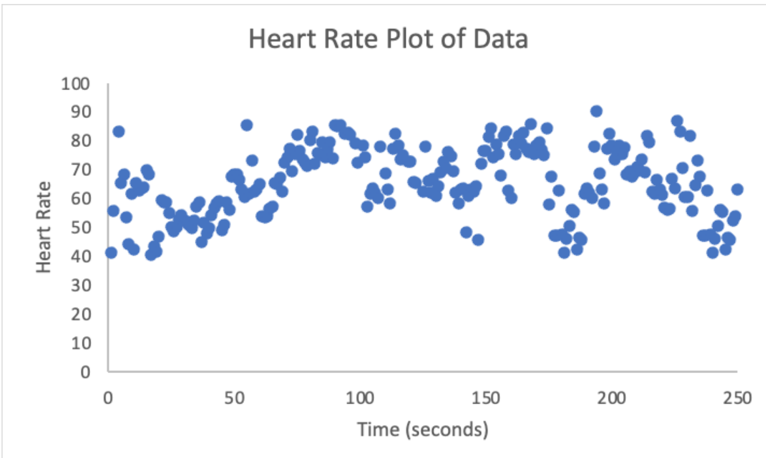


Figure 2:A plot of time versus heart rate of data obtained from pulse oximeter prototype.

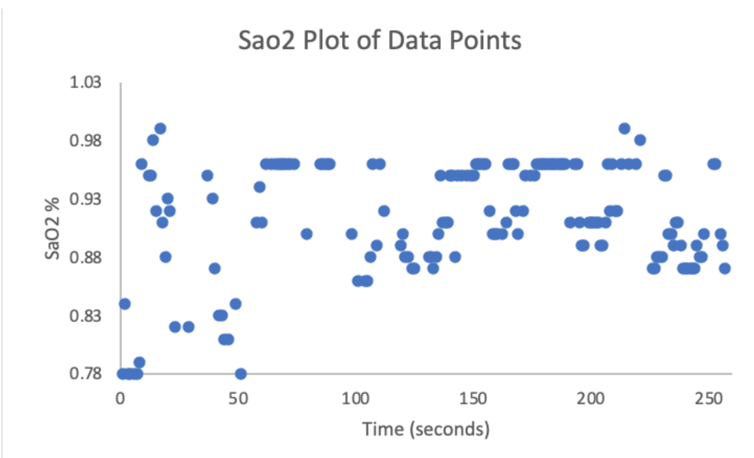


Figure 3:A plot of time versus SaO2 % of data obtained from pulse oximeter prototype.

Supporting Materials

1. CAD Model of Pulse Oximeter

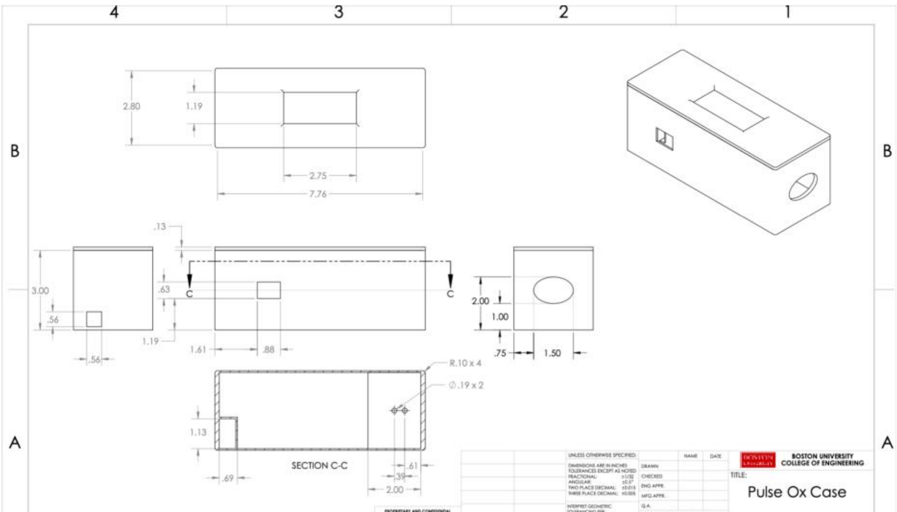


Figure 4: CAD drawing of final prototype of pulse oximeter.

2. Functional Analysis

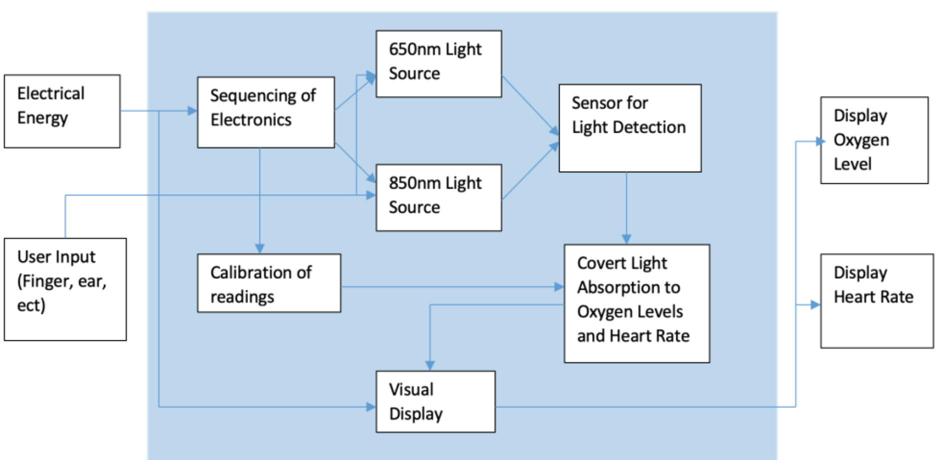


Figure 5: Glass box diagram showing the process of pulse oximeter.

3. Circuit Drawing

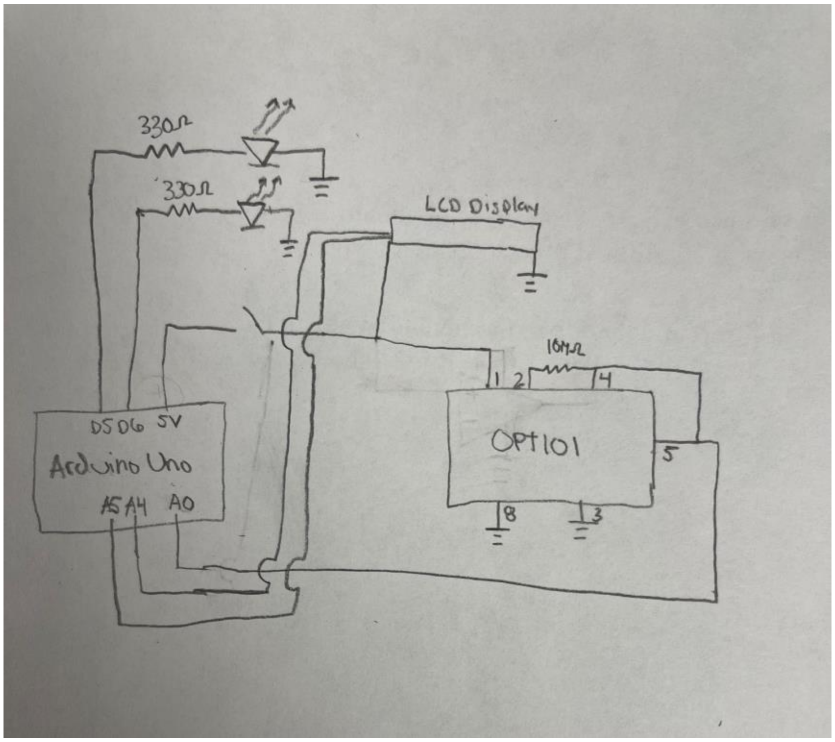


Figure 6: Diagram showing circuit drawing for operation of pulse oximeter.

4. Absorbance Equation

$$I(x) = I_0 e^{-\epsilon c x} \quad (1)$$

5. Calculating SpO2 Equation

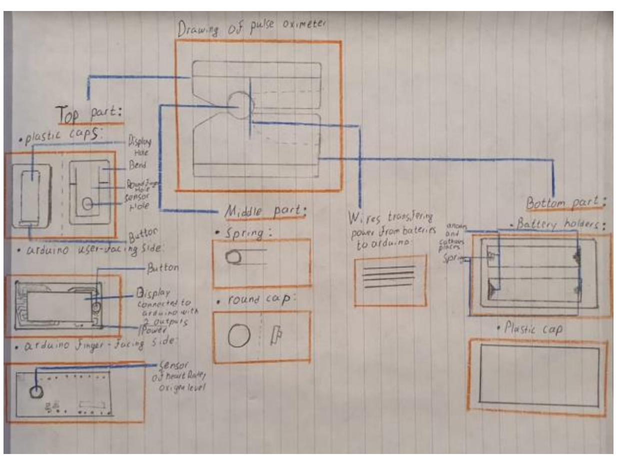
$$R = \frac{\log_{10}(\frac{I_{in1}}{I_1})}{\log_{10}(\frac{I_{in2}}{I_2})} \quad (2)$$

$$SpO_2 = \frac{C_o}{C_o + C_r} = \frac{\epsilon_{r1} - R\epsilon_{r2}}{(\epsilon_{r1} - R\epsilon_{o2}) - R(\epsilon_{r2} - R\epsilon_{o2})} \quad (3)$$

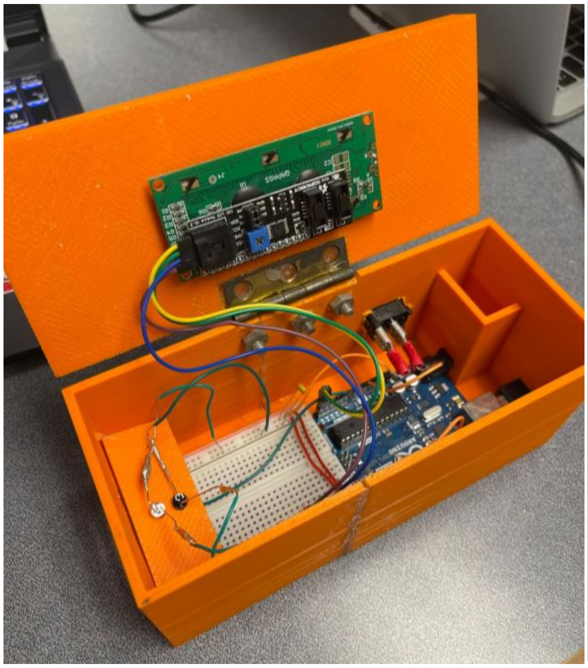
6. Table of objectives and metrics

Objectives:	The initial plan for Metrics:	Completion:
Accuracy of oxygen reader	+/-2%	Yes
Accuracy of heart rate	+/-3bpm	No
Durability	Sustains 5 drops	Yes
Response time	Less than 30 seconds	Yes
Lightweight and portable	Less than a pound	Yes-14.25oz
Easy to operate	10 minutes of training required	Yes
Cost-efficient	Under $50 per unit	Yes-~$40
UV light proof	Can withstand UV light to sterilize the device	No

7. The initial design of the pulse oximeter picture and intermediate prototype



8. The final product



References

1. False, *Guidelines for SpO2 Measurement Using the - Maxim Integrated*. [Online]. Available:

https://www.maximintegrated.com/en/design/technical-documents/app-notes/6/6845.html. [Accessed: 21-Apr-2021].

2. O. Yossef Hay, M. Cohen, I. Nitzan, Y. Kasirer, S. Shahroor-karni, Y. Yitzhaky, S. Engelberg, and M. Nitzan, “Pulse Oximetry with Two Infrared Wavelengths without Calibration in Extracted Arterial Blood,” *Sensors*, vol. 18, no. 10, p. 3457, 2018.