Ryerson University
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AT05: Pulse Oximeter

by

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Introduction

A pulse oximeter is a non-invasive medical device to measure the amount of oxygen of the blood continuously in critical care settings such as operating rooms, intensive care units and hospitals [1]. Clinicians monitor the blood oxygen saturation to identify the presence of hypoxemia for early treatment [2]. The measurement of the oxygen levels in the blood is done by monitoring changes in the light absorption of the blood [2]. Two light beams with different wavelengths are used such as Red light and Infrared light with wavelengths of 660 nm and 940 nm respectively. These wavelengths correspond to the flow of oxygenated and deoxygenated blood [2]. Red and Infrared lights are generated by the diodes, from which the generated light is emitted to a vascular tissue and it would pass through the tissue, and as a result a portion of the emitted light is absorbed by the tissue and the rest would penetrate through the tissue, reaching the photodetector and allowing for calculation of the light absorption [2]. The purpose of using two lights with different wavelengths is that the oxygenated and deoxygenated hemoglobin behave differently when exposed to different wavelengths. For example, deoxygenated hemoglobin absorbs a greater amount of red light compared to the oxygenated hemoglobin and oxygenated hemoglobin absorbs a greater amount of infrared light compared to the deoxygenated hemoglobin [2].

Acknowledgements

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Certification of Authorship

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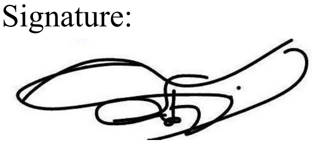

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Abstract

This paper will examine the design of a portable, wearable and easy-to-build pulse oximeter. Pulse oximetry is the use of light to non-invasively read changes in the user's pulsatile blood and extract features such as blood oxygenation levels and heart rate. Pulse oximetry devices have been widely used for medical and clinical applications. A wearable oximeter can significantly expand its applicability as it would increase accessibility. The goal of this capstone design project was to design and build a wearable pulse oximeter, by using biomedical instrumentation and software development theories. The system consists of four parts: 1) the sensor and light source placement within a ring, 2) the electrical circuit, 3) the microcontroller and bluetooth module, and 4) a mobile application. Together, the device can send the data from the user's finger to their phone via an application, which will make it easy for reading their heart-rate and oxygen saturation information in real time at any time. The results of the pulse oximetry device were displayed on a user interface. The values obtained for the heart rate and oxygen saturation level were compared with a Samsung application using an independent T test, which resulted in scores of 3.15 and 0.87 for heart rate and oxygen saturation respectively. These scores indicated the amount of differences between the proposed device and a working device. Discrepancies in the oximetry results were assumed to have stemmed from sudden changes in the read signals. In conclusion, the goal of the project to design a portable and accessible pulse oximeter while maintaining comfortability for the user and simultaneously enable use during everyday life was viable.

Keywords: Pulse Oximeter, IR LED, Red LED, Photodetector, PCB, CAD

Objectives

The purpose of this engineering design project is to design a portable pulse oximetry device which measures the heart rate and blood oxygenation level of a user in real time for at least 2 hours. The pulse oximetry device is designed in such a way that can be used by all individuals regardless of their age and physical conditions, while maintaining comfortability and safety.

Background

Pulse oximetry is the measure of blood oxygen saturation levels in a tissue using the concept of light absorption [1]. After entering the lungs, oxygen attaches to the hemoglobin molecules within the blood and the oxygenated blood is carried throughout the body. After deposition of the oxygen molecules, the blood is considered to be deoxygenated. Oxygenated and deoxygenated blood best absorb light at different wavelengths: 660 nm (Red) for deoxygenated blood and 940 nm (Infrared) for oxygenated blood [1]. The ratio between the light absorption levels of oxygenated and deoxygenated blood results in the oxygen saturation ratio, which can be used to categorize the subject as oxygen-deprived or healthy [1]. If the ratio falls below 90%, the subject is considered to have hypoxemic levels of oxygen in their blood [2]. The light is emitted into the target tissue by different light sources, and the remaining light, either reflected or attenuated, is to be picked up by a photodetector. The detected light signal can then be amplified, filtered and processed to calculate the oxygen saturation ratio, as well as additional features such as the subject's heart rate. This has been done through implementing various designs for the pulse oximetry to be obtained. Some of the common Pulse Oximeter designs are a finger clip design and an earlobe design. A new method has been introduced in this project.

Theory and Design

Currently, pulse oximeters come in various designs and depend on being positioned near the peripheral parts of the subject, such as the tip of the finger, earlobe, tongue and toes. Although the finger clip design's positioning allows for accurate reading, it has flaws during many daily tasks such as using a touch screen interface, long-term comfortability as well as during sleep. The most commonly used pulse oximeters come in a finger-clip design, which relies on the rich blood vessel layout around the fingertips allowing for a higher perfusion, as seen in the figure below:

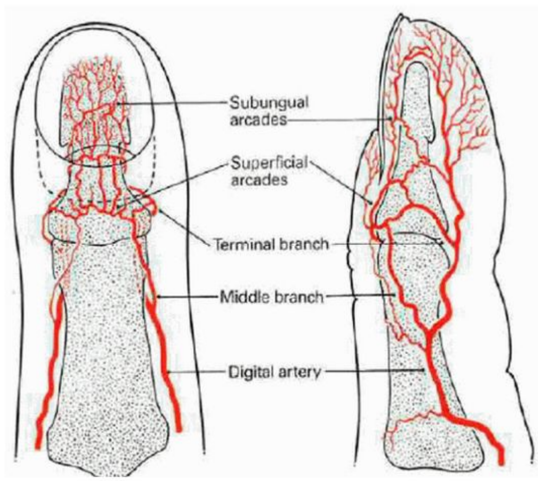

Figure 8.1: Layout of capillaries and blood vessels in fingertips [3].

As observed from figure 1 above, since the lower segments of a finger have less and less blood vessels spread out over an area, the detection of perfusion should be much lower which would make the proposed ring sensor design less effective than a typical finger-slip sensor design. It is estimated that the capillarisation around the phalanx is less than half of that around the fingertip [3]. However, according to a study conducted using 50 samples from a subject (as seen in Figure 2), the mean perfusion index at the fingertip was 0.8% while the mean perfusion index around the phalanx was 0.3%, which is not as significant a decrease considering one site has half the capillarisation of the other. This encouraged us to go forward with the proposed positioning of the sensor system.

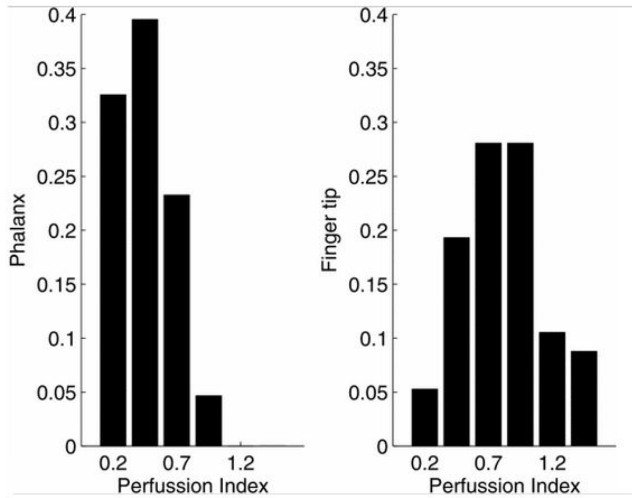

Figure 8.2: Mean Perfusion index of the fingertip vs the lower segments of the digit [3].

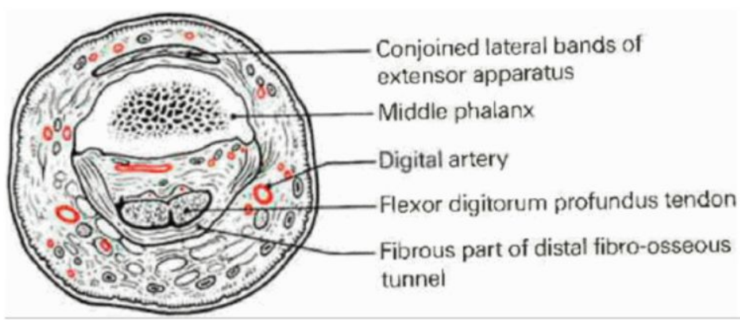

Figure 8.3: Cross section of the middle phalanx [3].

The figure 3 above is a cross section of middle phalanx, which will be used to configure the layout and build of the proposed sensor-housing ring design; we would not want to place the light sources near the bone portion of the finger as the scattered light would attenuate. The previously mentioned study gave us enough reasoning that allowed us to go forward with the proposed positioning of the sensor system. Since there are inadequate amounts of theory and literature related to the optimal positioning for the light sources and the sensors to be located for the most accurate readings, we opted to have multiple sets of LED-sensors to be placed around the meatus of the finger (underside), and continuously tested different combinations and positions to determine the most optimal location that results in the best readings.

An issue with using this proposed sensor housing design was the inadequate size and space needed for the housing of the other hardware components such as the microcontroller, battery, bluetooth module, and accompanying circuitry. One solution that greatly benefited our design was to place the aforementioned components on a printed/modelled base over the dorsal side of the palm, which would give adequate spacing for all hardware components to be physically integrated with each other. The following section will go more into detail on the layout and fit of the mentioned designs.

Hardware Design and Layout

This section contains images that display the layout of the hardware components for the proposed device. The ring design was made while keeping adjustability in mind, and the dimensions were made to be within the median of all ring sizes [4]. The image below illustrates the placement of the IR (Infrared) and Red LEDs as well as the photodetector inside the ring.

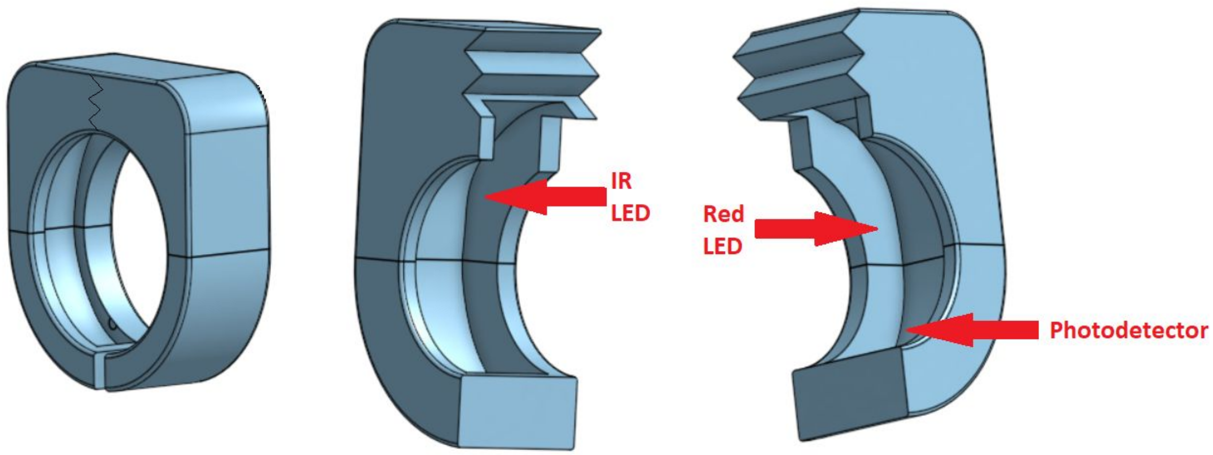

Figure 8.4: Ring model with the placement of LEDs and the sensor.

The 3D printed result of the figure above is shown below:

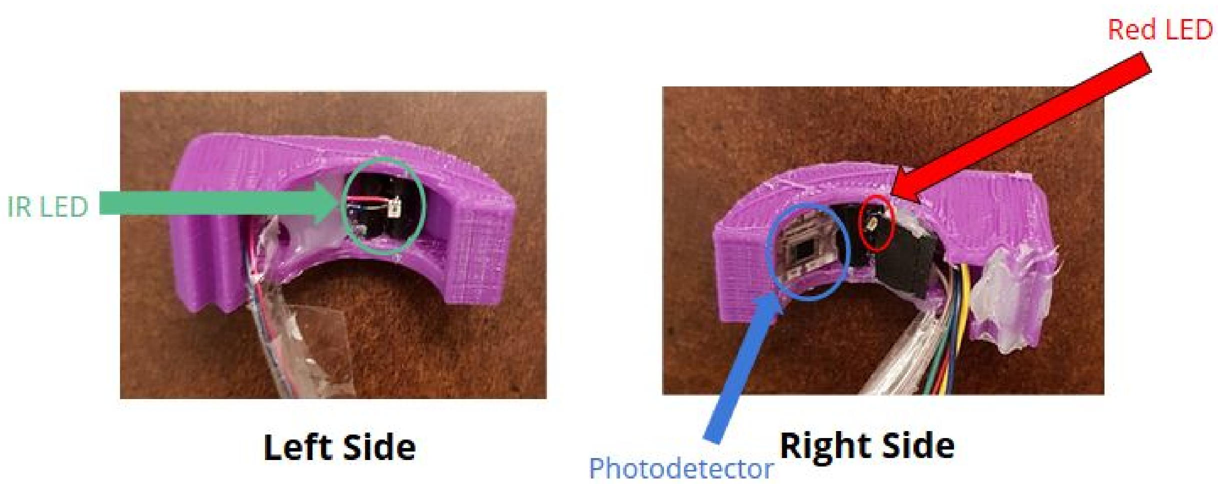

Figure 8.5: The 3D printed ring.

The dimensions for the ring casing changed due to fragility issues during the 3D printing process. The final dimensions have accounted for the structural integrity of the ring casing and the strength was tested after 3D printing it. The dimensions for the ring casing being split in two halves, are as following: (all dimensions are in mm)

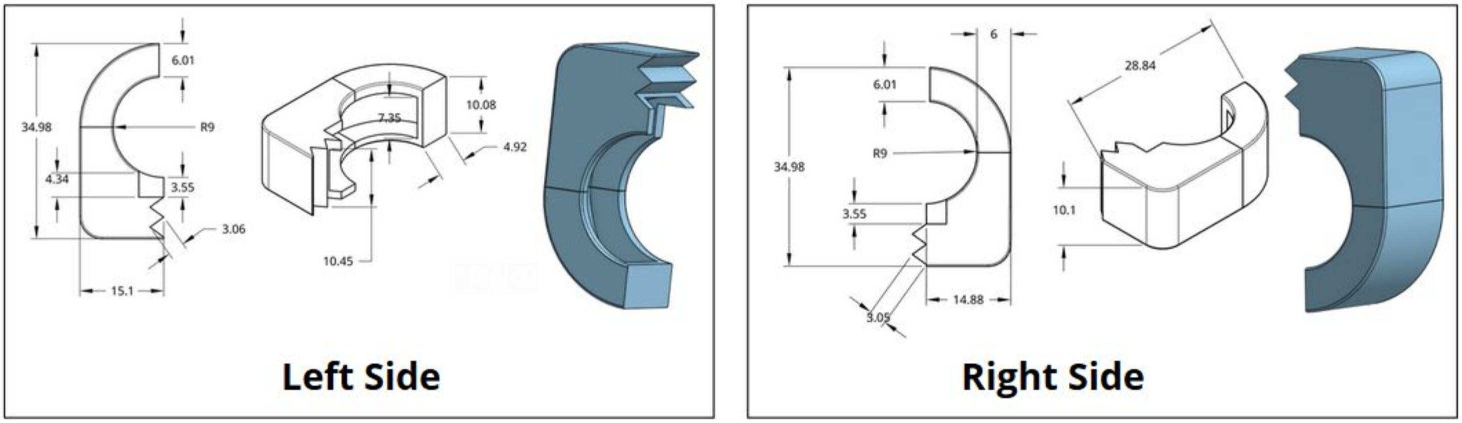

Figure 8.6: Ring Casing drawing.

The circuit and the hardware components of this project including the microcontroller, bluetooth and the battery are placed inside a wristband container that is 3D printed. This 3D printed container is placed on top of the wrist of the user, therefore, it is worn like a "wristband". The wristband CAD model is shown below along with its dimensions:

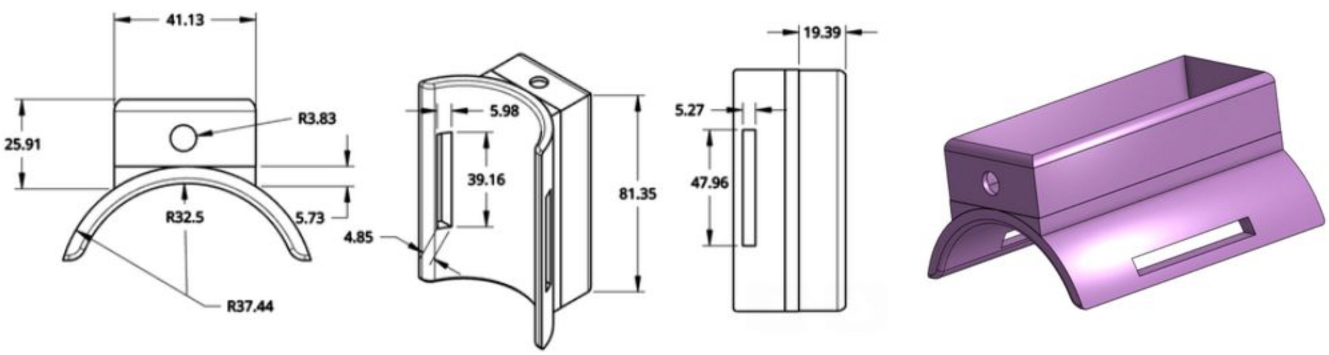

Figure 8.7: 3D model of the Wristband.

The 3D printed result of the figure above is shown below:

Figure 8.8: The 3D printed result of the wristband container.

The model shown in the figure 7 and 8 above, is connected through wires to the ring as shown below:

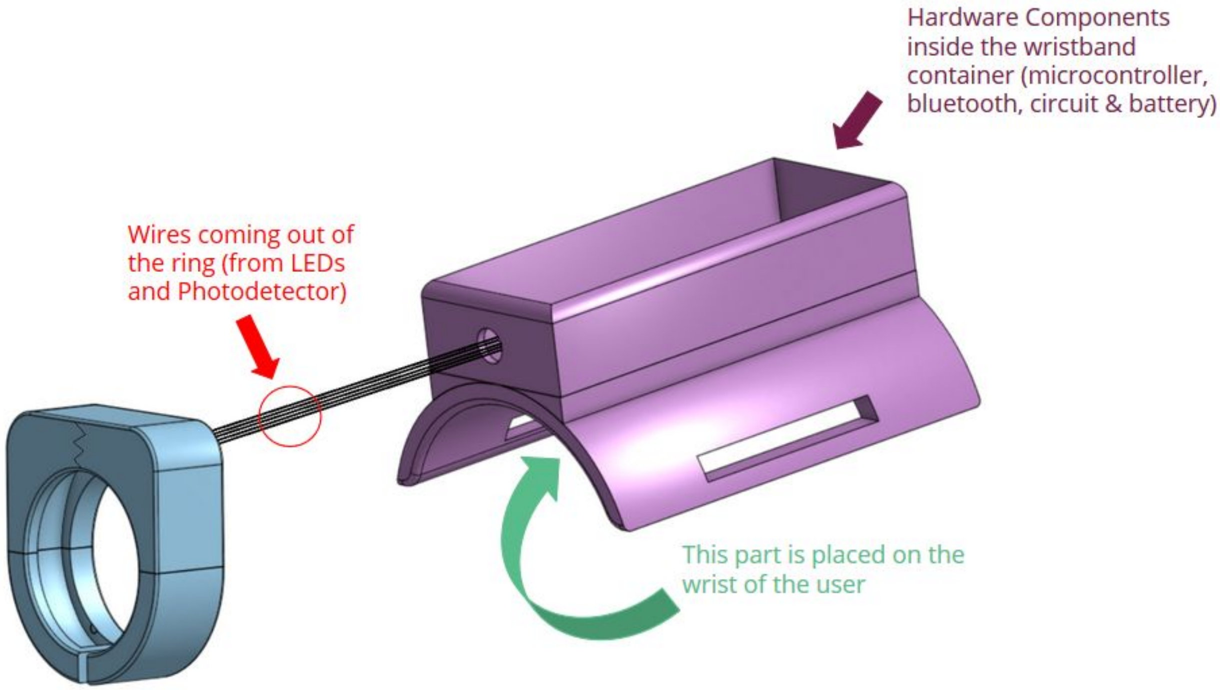

Figure 8.9: 3D model of wristband with the ring.

A wristband design was chosen for the user to be able to wear it for a prolonged period of time and the circuit components will not be in direct contact with the patient/user's skin.

In addition to CAD models, 3D printing materials were also looked at. The sections of the model that will be 3D printed are the ring and the wristband container for the hardware components to be placed inside. Some of the materials used for 3D printing that are available to the team have been looked into. The summary of these materials are explained as below along with their pros and cons:

Table 8.1: Available materials to be used for printing hardware structures [5] [6].

Material	Pros	Cons
Plastic	● Most commonly used for 3D printing ● Polyastic acid (PLA) ● Firm and Flexible ● Smooth surface ● Affordable ● very eco-friendly ● Biodegradable ● Available in soft and hard forms	● Potential allergic reaction ● Prints degrade over time ● Rough texture ● $20 to $50 per Kg

Circuitry Schematics and Layouts

This section of the paper consists of the circuit components that were necessary to design the novel pulse oximetry device. The designed circuit provided the following features for the system:

1. Acquire data related to oxygen concentration
2. Preprocess the signal and send it to the microcontroller
3. Provide power for the whole system
4. Control the LEDs with the microcontroller

While considering these requirements, and reviewing literature related to this topic, the following flow diagram, presented in Figure 10, of the overall circuitry and other components of both hardware and software, was designed. The diagram shows the overall process and flow of data and power into and out of each component in the proposed system. The purpose of each hardware component, and their roles in flow diagram will be explained in the upcoming sections.

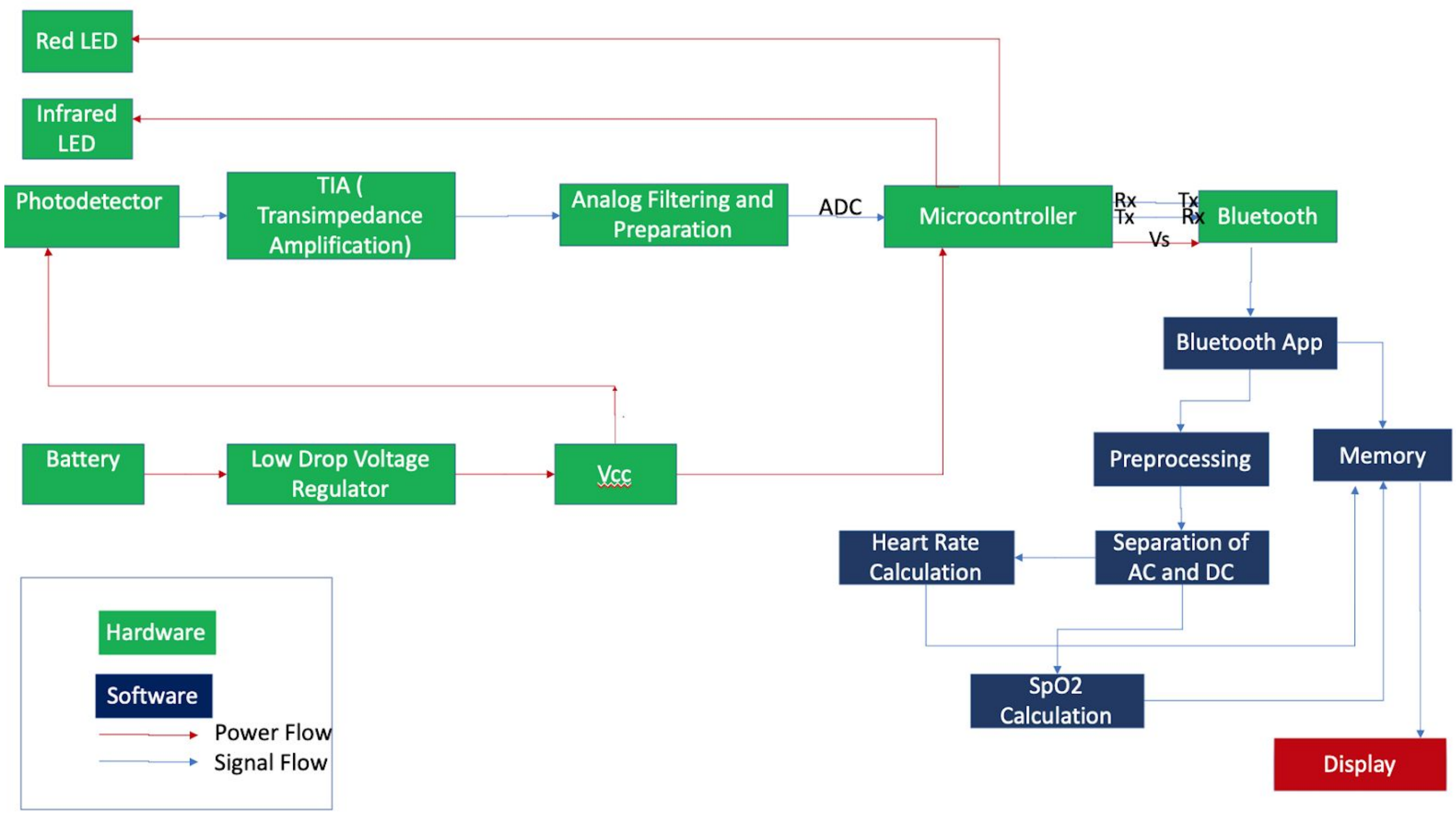

Figure 8.10: The Flow Diagram of the System.

LEDs:

Estimation of both the oxygenated and deoxygenated hemoglobin concentrations is the aim of this project. In order to differentiate between the concentrations from one another, two wavelengths have to be looked at where the difference in light absorption of each is visible greatly.

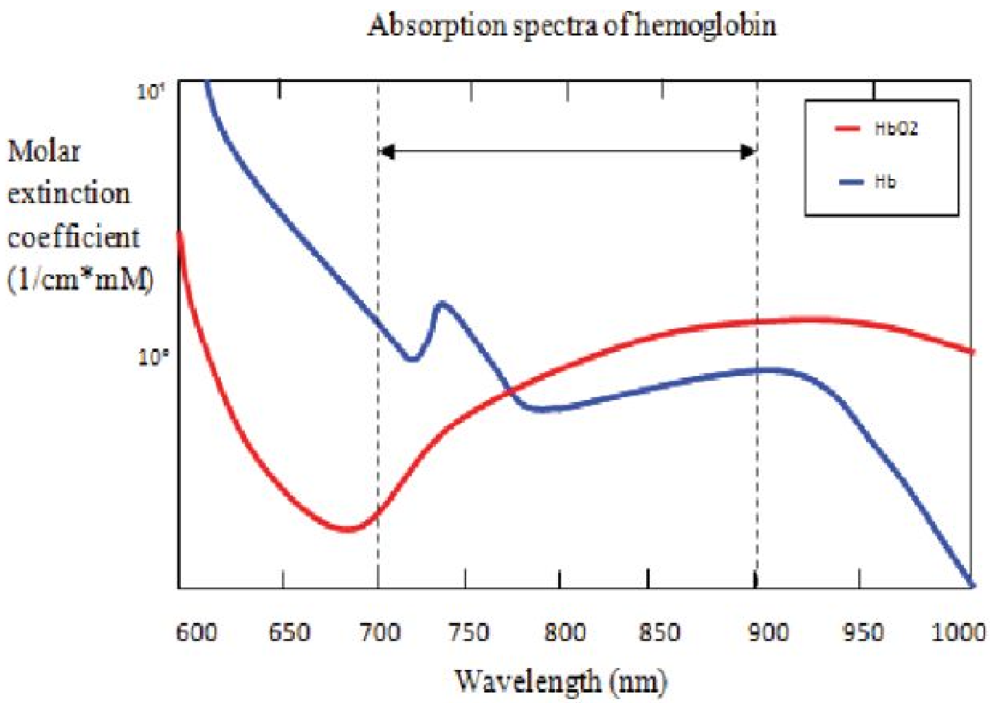

Figure 8.11: The absorption of the oxygenated and deoxygenated hemoglobin [7].

As seen in the figure above, at around 650 nm, deoxygenated hemoglobin concentration is significantly higher than the oxygenated hemoglobin concentration. Additionally, at 940 nm the oxygenated hemoglobin concentration is higher than the deoxygenated hemoglobin concentration. The isosbestic wavelength, where the absorption of both oxygenated and deoxygenated are equal, is approximately 777 nm as seen in the above figure. The isosbestic point is the point of equal concentrations. This wavelength would not be used in our design, and as it does not show any difference in the concentrations of the two target molecules, which is required to obtain an accurate saturation ratio. Therefore, absorption at the 650 and 940 wavelengths will be used to calculate the oxygen concentration. Two LEDs with different wavelengths of emitting light would be used. One would be red, and the other would be infrared. The Rohm Semiconductor SML-310LTT86 (Red) and Everlight R17-21C/TR8 (Infrared) were used as the light sources, with their bandwidths being 635 - 685 nm and 895-985 nm, respectively. Further information about their specifications can be found in their data sheet listed in the appendix.

The important thing to note about these LEDs is that their spectral range does not overlap one another. This is key because the overlapping of the frequency ranges would result in inaccurate data acquisition . Both of the LEDs have low power consumption which makes them efficient. The LEDs are powered individually by the microcontroller with the use of resistors. The values of the resistors are set based on the calibration of the oximeter, and location of the LEDs in the ring, with regards to the photodetector.

Photodetector:

The chip that was used for receiving light consists of both the photodetector and the TIA circuit. The OPT101 Monolithic module was used as the sensor. This sensor was used for a couple of reasons. One being that it contains both the photodiode and the transimpedance amplifier. The transimpedance amplifier (TIA) is a necessity for the circuit and the role of it would be explained further in the report. By having both the Photodiode and TIA within the same module, the data acquisition quality would increase greatly as well as simplify the design of the overall circuit. Secondly, the sensor has a large bandwidth of sensitivity (400 to 1050 nm) with greater sensitivity to the chosen LEDs wavelengths (650 and 940 nm), requiring only the use of a single sensor unit. The following are the important specifications of this component and more information can be found in the appendix:

Sensitive to 400 nm to 1050 nm wavelength [8]
Fast switching time within the specified wavelength
Forward Voltage = 0.8 nm [8]
Photocurrent Range = 1.2 - 1.4 µA
Internal 1-MΩ Feedback Resistor
Single Supply: 2.7 to 36 V
Photodiode Size: 2.29 mm × 2.29 mm
High Responsivity: 0.45 A/W (650 nm)
Bandwidth: 14 kHz at RF = 1 MΩ

By having a spectral range of 400 nm to 1050 nm, which cover the essential wavelengths, this photodetector was suitable for the project.

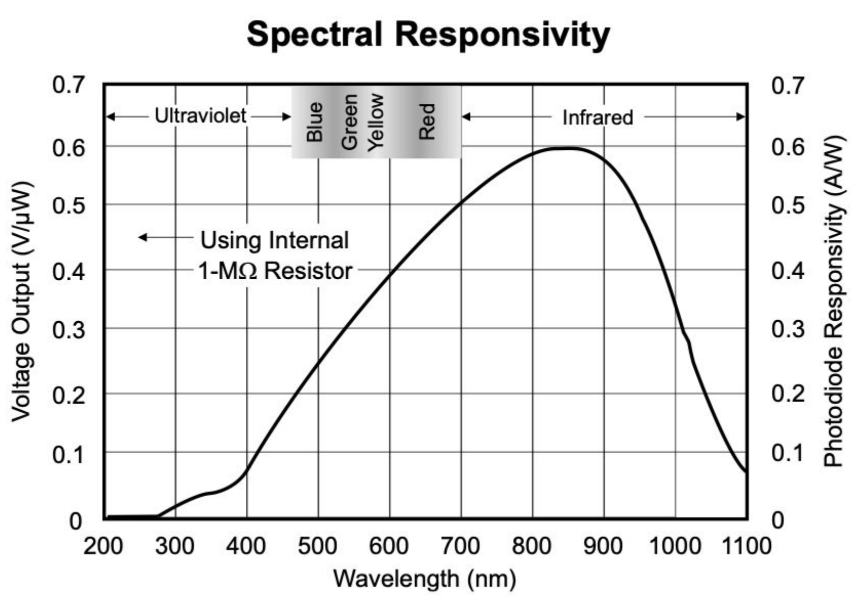

Figure 8.12: The Relative Spectral sensitivity of the Photodiode [8].

In addition to its wide spectral range, it is important to note that the relative sensitivity at both 940 nm and 650 nm are very close in value. This can be seen in the above figure which represents the Spectral sensitivity of the photodiode. This feature means that separate circuitry would not be required for each of the LEDs, which makes the overall design more effective. Although the responsivity is slightly different at both 940 and 650 nm, this slight change was calibrated with the LED positioning within the ring. With that being said, an additional resistance was added to OPT101 module for the purpose of increasing the gain, and improving the AC coupling. An extra $4M\Omega$ resistance was connected to the feedback loop. The choice of this value was totally based on trial and error. By observing the output signal on the oscilloscope, the signal was adjusted to fit within the microcontroller's ADC range. The gain needed and obtained was 6,000,000. The information about which pins received additional resistance can be found in the appendix.

Since the signal received was in the form of a current and the microcontroller was voltage sensitive, it was required to convert the current to voltage using a transimpedance amplifier. The TIA exists within the photodetector module. The reason for this choice is to eliminate the impedance noise early in the circuit. In addition to conversion, additional gain was also required. This is due to receiving the signal from the photodetector in the current range of microamps, and requiring a signal in voltage range of 0 - 3.3 V for the microcontroller. In theory, the gain for the TIA was set by:

$$\frac{V_{out}}{I_{in}} = -R_f \qquad \text{Equation 8.1 [9]}$$

Analog Front End Amplification (AFE):

Although most of the filtering would occur in software, as it is easier to implement and modify, some analog filtering was still done to prepare the signal for the ADC of the microcontroller. A passive analog low pass filter was added to reduce the high powerline noise and any other major noises. Initially the high pass filter was used to remove the low frequency noise, but after using the OPT101 module, the low pass noise was not observable in the signal anymore. As a result, the high pass filter was removed for further simplicity of the overall circuit. The cut-off frequency of this filter was set to be 6 Hz. The formula for the low pass filter goes as follows:

$$f_c = \frac{1}{2\pi RC} \qquad \text{Equation 8.2 [10]}$$

This formula was used to calculate the values for the resistor and the capacitor of the filter. The AD680 op-amp was used to provide the amplification during the TIA. The choice for this op-amp is due to its low power consumption, as well as being able to amplify up to 3 V for the microcontroller.

Power Management Unit:

Battery

Before making a decision on the battery, the electrical power consumption of the system needed to be calculated . The following table is the power consumption of each component based on their data sheet.

Table 8.2: The power consumption details of the system.

Component	Power
LEDs	64 mW
Microcontroller	21.8 mW
Bluetooth	2.5 mW
Amplifiers	0.32 mW
Resistors and capacitors	4.2 mW
Total	92.82 mW

By rearranging and using the power equation P/V=I, the consumption in Ampere hours is 25 mAh. However, after implementing the circuitry on a breadboard, it was measured that the system's current draw is 150 mA. Therefore, for a 2.5 hour operation, the minimum capacity of around 400 mAh is required. The microcontroller and bluetooth, a voltage of at least 5 volts is required. For the summing amplifier, it has to be powered at 9 volts. The battery has to be able to fit in the wristband structure without making it uncomfortable for the user.

The “Li-Ion 9V 500mAh (4.5Wh each) Rechargeable Battery (UN 38.3 Passed) ” battery provided all of the features that are needed from the battery. The following are the specifications of the battery:

- Lithium-Ion battery [11]
  - 26.8mm (1.05") x 17.8mm (0.7") x 49.2mm (1.94")
  - 9 V
  - Able to provide up to 500 mA
  - capacity 500 mAh.

Figure 8.14: The battery chosen to power the system. [11]

Low-drop voltage regulator, RLC filter, and Vref voltage

The Low-drop voltage regulator was designed to regulate and set the desired voltage for the system. LM338T was used to provide this feature. It also maintains a steady voltage throughout the system [12]. Capacitors were connected between pins 1-2 and pins 2-3 of the voltage regulator. This was used to remove the distortions and ripples caused from high consumption of current by LEDs. The ripples in the voltage would affect the output signal. The outcome of the voltage regulator is the Vcc. The schematic for the explained circuit goes as follows:

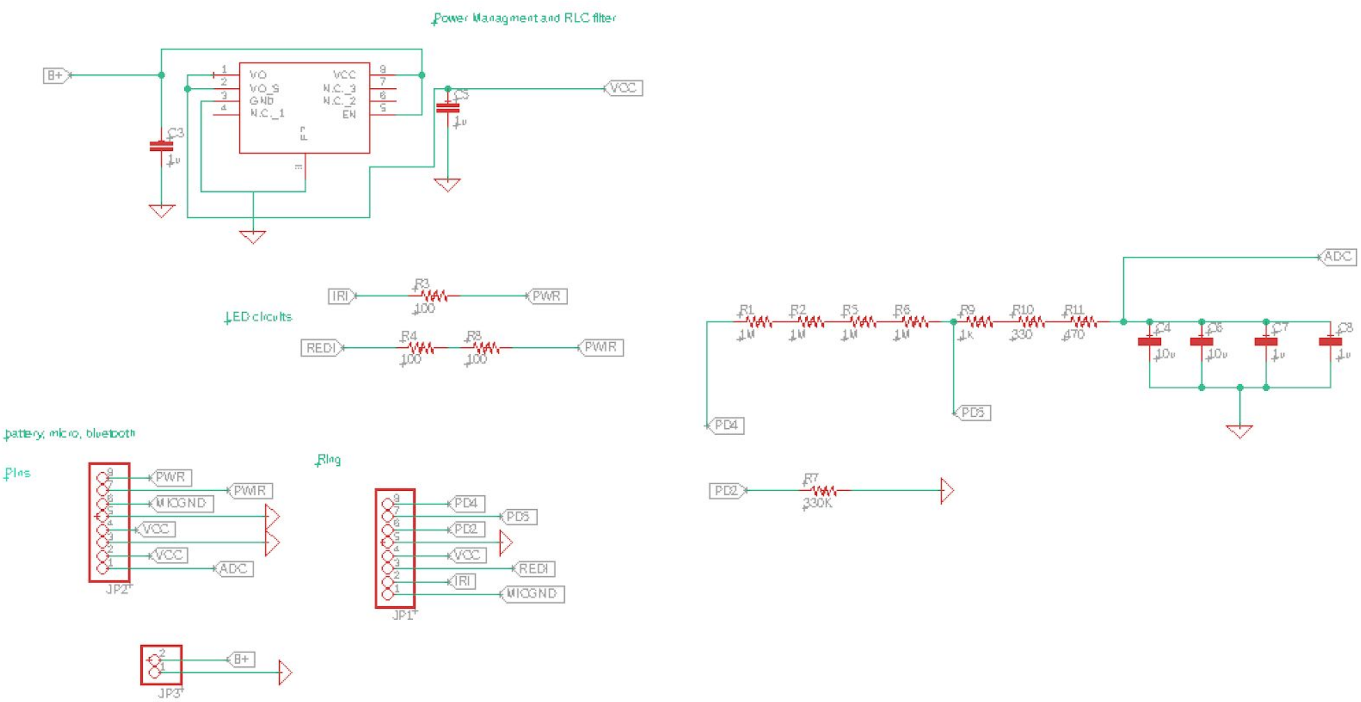

Figure 8.15: Circuit and Power Management Schematics.

PCB (Printed Circuit Board):

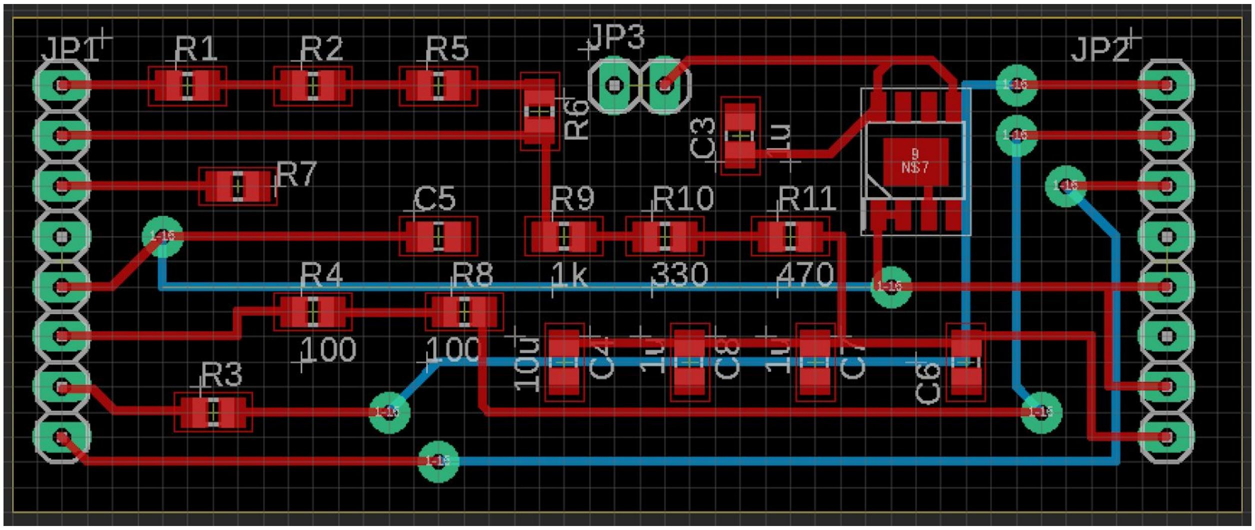

Figure 8.16: The PCB of the designed circuit schematic.

The use of a PCB was essential in reducing the size of the overall circuit. It also provides an organized structure of the components within the circuit. The ground of the system was set to be the PCB’s top layer itself. The area on the circuit that is not used as connections between components (black colored) was used as the common ground. This approach improves the complexity of the connection and also lets the board release the heat effectively.

Microcontroller and Bluetooth

Bluetooth:

We need to transmit the collected data to the interface in some manner. Since we want to avoid using wired connections as they contribute to motion artifacts in the readings and the transmission will be over a relatively short distance, we will use some form of wireless connection. Bluetooth was chosen as the specific wireless method for this device over other methods such as Wifi and NFC as it could exchange data over a moderate distance and would not require the addition of any external hardwares or antennas. As for the specific module to attain bluetooth connection, the HC-05 Bluetooth module was used for the device because of its size and its ability to operate in both slave and master modes, allowing for the collection of data from the microcontroller as well as transmittance of data to the user interface [13]. In addition, it simply can be connected to the microcontroller, its AT commands can be easily set by the microcontroller which would allow for us to alter some of its key settings such as its password and baud rate [13]. Furthermore, it operates in the range of 9m which allows the device to have some leeway in terms of transmittance distance and we do not need to worry that the Bluetooth may interface with the nearby frequencies [13]. Moreover, as we want to design the pulse oximeter with the lowest power consumption possible, the HC-05 Bluetooth module power consumption is 2.5mW [13]. And last but not least, this module is relatively cheap and easy to obtain [13]. HC-05 Bluetooth needs exactly 5 Volts to operate and its Tx and Rx pins need 3.3 volt to operate, thus we have to use a voltage regulator to give 5 V to Bluetooth constantly.

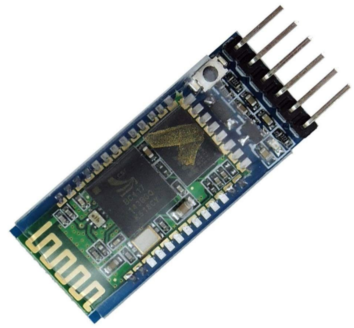

Figure 8.17: HC-05 Bluetooth Module.

Table 8.3: Characteristics of the HC-05 Bluetooth module [13] [14] [15].

Operating Status	Slave and Master
AT commands	Yes
Operating range	9m
Power Consumption	5V
Tx/Rx input voltage	3.3 V
Operating Frequency	2.4 GHz
Physical Dimension	26.9mm*13mm*2.2mm
Price	$2.99 USD
Memory Storage	16 KB

Microcontroller:

A microcontroller was an essential part of our design as its programming would allow for independent functionalities such as data transmission and Analog-to-Digital Conversion (ADC). We chose to use the Arduino Pro Mini ATMega328 that operates at 5V and 16 MHz [16]. Its small size as well as adequate functionality features mainly contributed to its implementation, as it was essential that we have a microcontroller that would fit in the wearable device. This specific microcontroller has 14 digital input/output pins in total of which we are using two (pin 11 and pin 12) as outputs to control the power to the LEDs separately [16]. In addition, the microcontroller has 6 analog input pins in total of which we are using one (pin AD0) as the input to collect the data from the sensor [16]. The Pro Mini would provide 3.3 V for each of the LEDs and it can additionally receive a maximum of 40 mA by each one of the pins [16]. Its ADC resolution is 10 bits which is high enough to process the 10 bits output signal. The Pro Mini consumes low power (12.3-21.8 mW) [16].

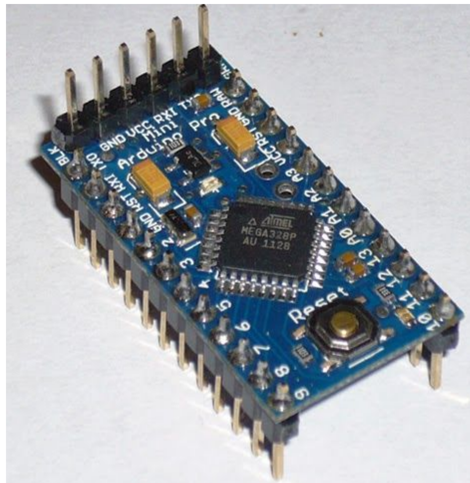

Figure 8.18: Arduino Pro Mini ATMega328.

Table 8.4: Characteristics of the Arduino Pro Mini ATMega328 [16].

Operating Voltage	3V to 5V
ADC Resolution	10 bits
ADC Sampling rate	9615 Hz
Number of Analog Input Pins	6
Number of I/O Pins	14
Power	12.3-21.8 mV
Price	$10
Physical Dimension	2.5 cm x 1.5 cm
Memory Storage	16 KB

The microcontroller was connected to the bluetooth module and programmed using the Arduino IDE and C language. The program was designed such that once triggered it would blink the LEDs separately while holding the state for two seconds, read in the data from the sensor and send it to the phone application through bluetooth serial communication.

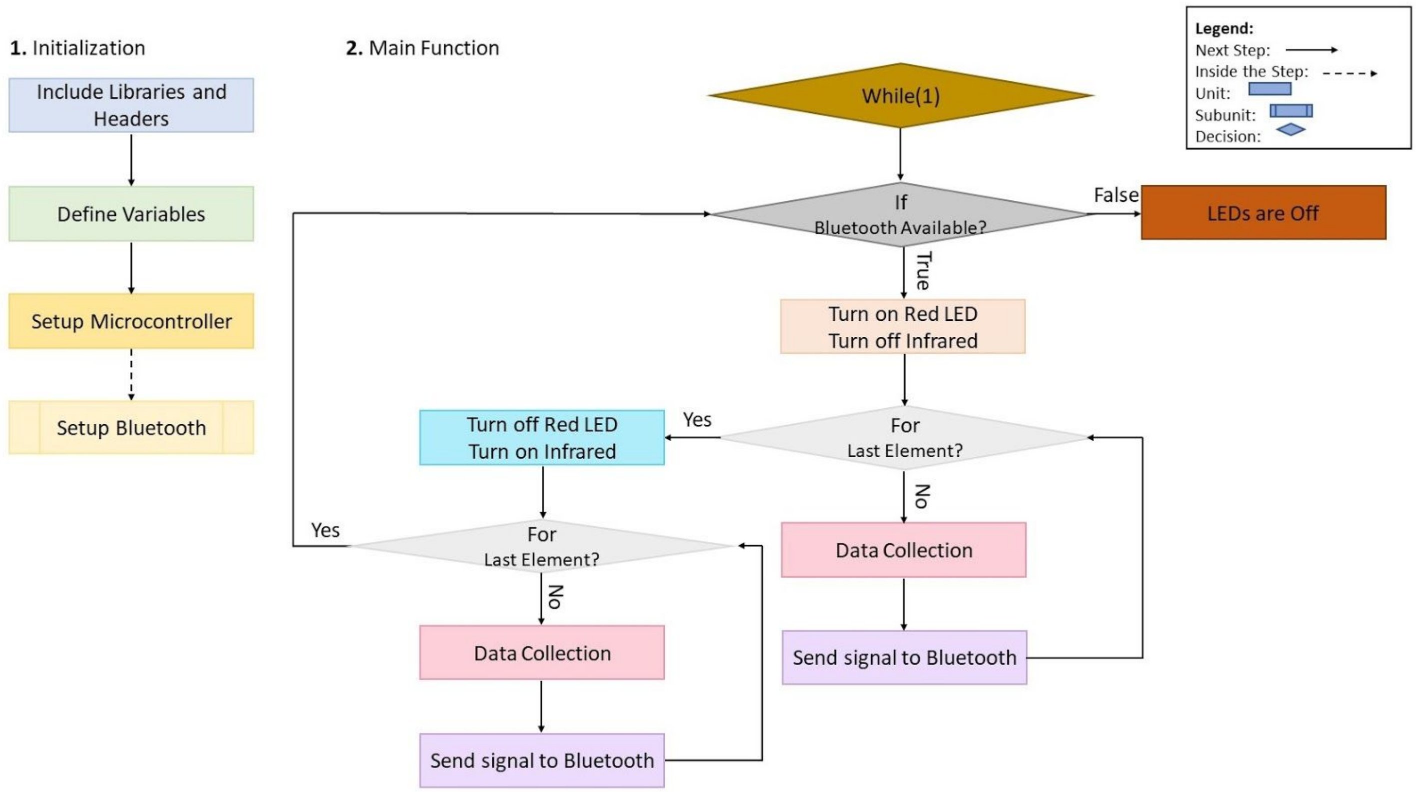

Figure 8.19: The flow chart of the microcontroller code.

According to the block diagram above, there are two parts that need to be considered in the runtime process; first the variables and functions will have to be initialized, then the main function in which tasks that microcontroller must follow is to be written in order. It is important to note that one LED would be on for 2 seconds while the other one is off, and then vice versa.

Software Layout

Software Filtering and Pre-Processing of data

To preprocess and filter the collected PPG (Photoplethysmogram) signals such that readable real-time values are obtained, Python will be used as it is a high level language that is easy to understand, works very well in processing applications, as well as having a variety of open source libraries that would allow for the creation of the designed algorithm into a code for the Android device. For further analysis, we chose to filter the signal to remove signal's artifacts, to select the desired frequency range of the signal and to make the signal more clear and readable. The filtering algorithm went as follows:

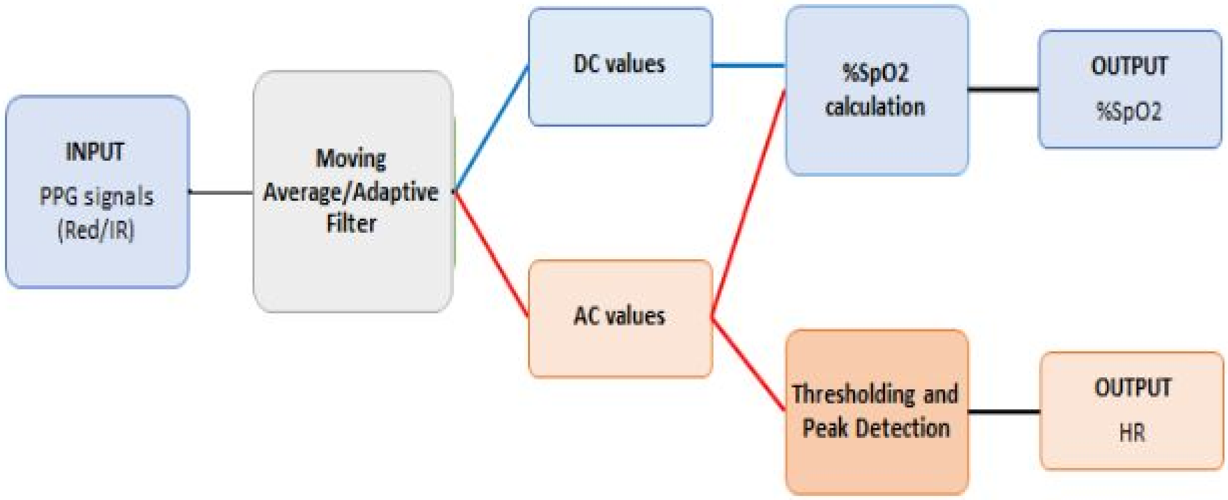

Figure 8.20: Flow chart of the preprocessing/filtering of the signals.

Step 1 The Inputs are PPG (Photoplethysmogram) signals of the Red and IR absorption.

Step 2 Sampling frequency was approximately 250 Hz [17].

Step 3 In order to eliminate motion artifacts from the readings, a moving average filter was used [18]. An adaptive filter uses an external design response to eliminate the error signal in the input, which means it may require a real-time EMG reading to do so which will require an extra sensor component in the device. Whereas the moving average filter would not require any additional components to be added to the build and can be implemented through software. A more robust form of the moving average, such as a Savitsky-Golay weighted moving average filter was used to account for extreme displacements of the devices.

Step 4 Heart rate values were calculated by creating a threshold to compare and contrast all peaks in the AC signal and then do peak detection on the observed peaks [19].

Step 5 SpO2 values were calculated by placing the red and infrared signals into the following equation to calculate the absorption ratio between the two signals [19]:

$$R = \frac{AC_R/DC_R}{AC_{IR}/DC_R} \qquad \text{Equation 8.3 [19]}$$

$$R = \frac{mean\ of\ Red\ signal}{mean\ of\ IR\ signal} \times 100 \qquad \text{Equation 8.4 [19]}$$

The two equations above are equivalent to each other when the DC offset is eliminated. Where R is the absorption ratio. The absorption ratio is then to be placed into the following equation to calculate the the SpO2 percentage [19]:

$$\%SpO_2 = K \times R$$ Equation 8.5 [19]

Where K is a proportionality constant that can be adjusted through calibration in the algorithm. After testing and modifying, the specific value for this calibration constant was determined to be approximately 1.32.

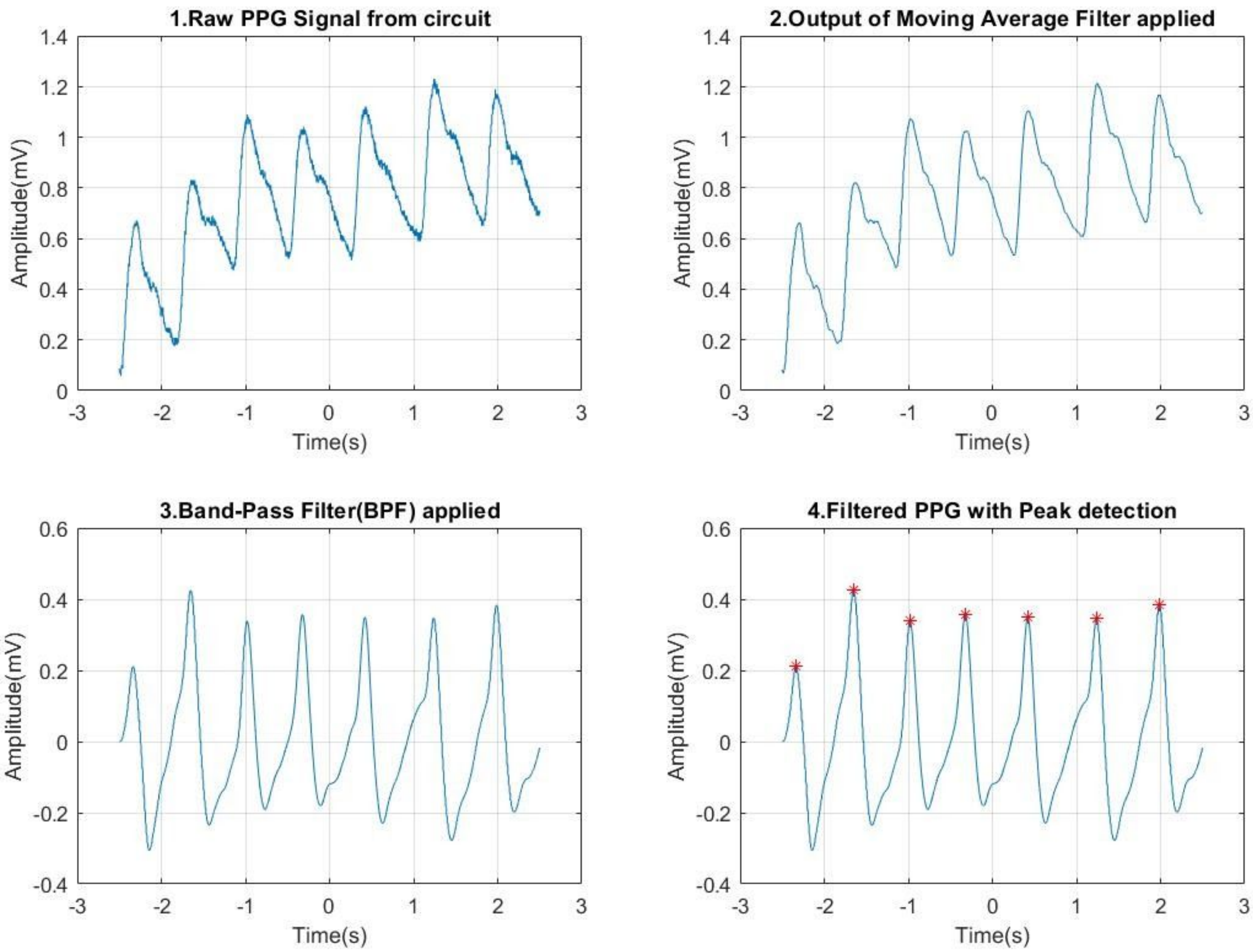

Figure 8.21: MATLAB plot of original Analog filtered PPG signal, with Moving Average (MA) filter applied, 4th order butterworth Band pass filter applied and peak detection.

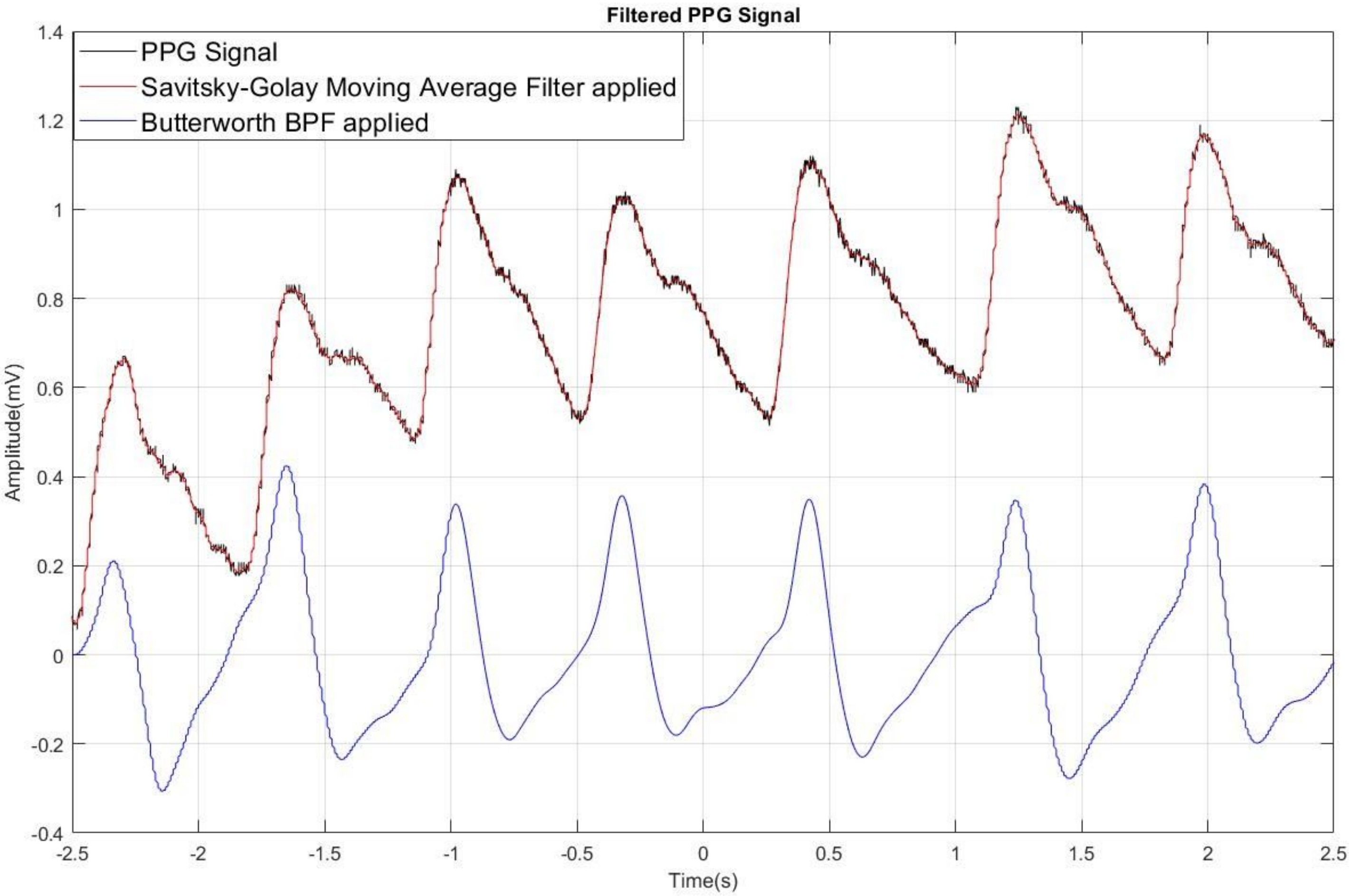

Figure 8.22: MATLAB plot of filtered PPG sample signal using Steps 1 to 3.

After the filtering algorithm is completed, it will be paired with the Python code for the application which will be mentioned in the next section, allowing it to be integrated as a part of the app. The python packages *numpy* and *scipy* will be utilized for this aspect.

User Interface Development - Android Application

Several options for user interfaces were explored before finally settling on designing an Android App, such as websites and LCD/OLED screens. We are currently in the age of smartphones, where individuals use devices to quickly access information through local/offline storage or online databases. Wired communications would prove to disrupt mobility, and even durability in terms of connections, of the device. These reasons forced us to eliminate the use of hardware screens in our proposed design. Although websites would enable quicker processing and transmission of data, it would require internet access, which people do not have during many situations. As offline use is much more practical and quicker in terms of accessibility to the user, the idea of using websites was discarded and all the focus was on using mobile applications [20].

Applications come in two ecosystems: iOS and Android; they are very similar to each other in terms of their potential to be used in the proposed device, making the decision incredibly difficult. However, in the end the decision was made to create a user interface in the form of an Android app. Android apps are able to call the Bluetooth features in the devices much more easily. Android also reaches out to a wider range of people, as more people globally use Android [20]. The function of our phone app was to record the real time heart rate and oxygen saturation data by clicking the "Read Data" button on the user interface. A pseudo code was proposed for the application runtime process, which is as seen below:

```
Connect to Bluetooth module using serial communication;
if serial port is open
 "Bluetooth connection successful";
{
  Start reading in data values from HC-05;
  Place them into an array of 4000 points (for 4 secs);
  Feed data into MATLAB filtering algorithm;
  for As long as Bluetooth is connected;
  {
       Display HR & SPO2 real time values
  }
}
else {
  "no Bluetooth connection";
}
```

The application was developed using Python 3.7 and the PyCharm IDE. Python packages such as *kivy* and *pyserial* were utilized to create an application interface that is able to connect with a specific bluetooth module and read in data through serial bluetooth communication. This app was then exported to an Android device. The following figures are the designed interface pages:

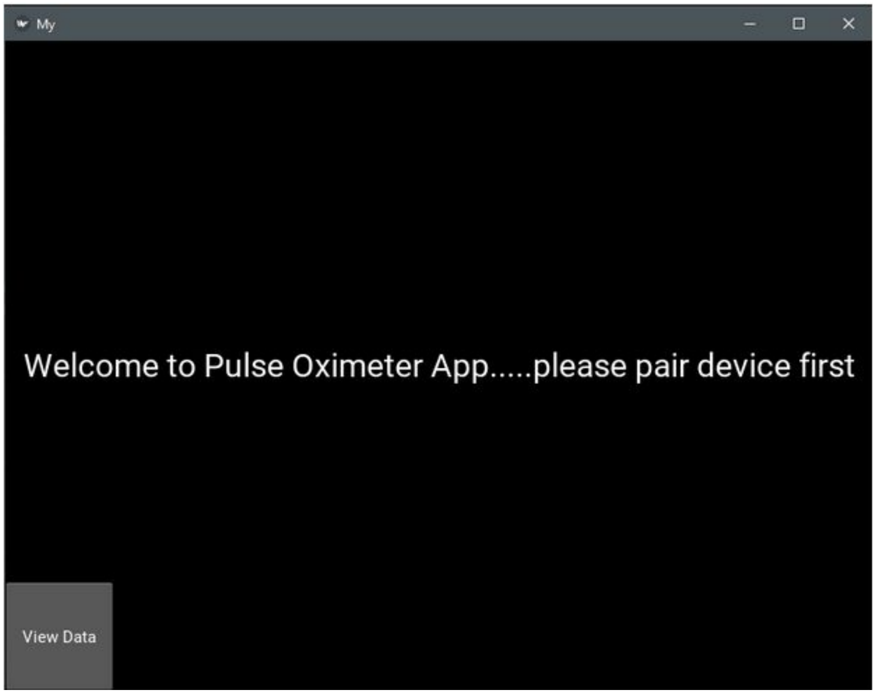

Figure 8.23: Designed App interface - main page.

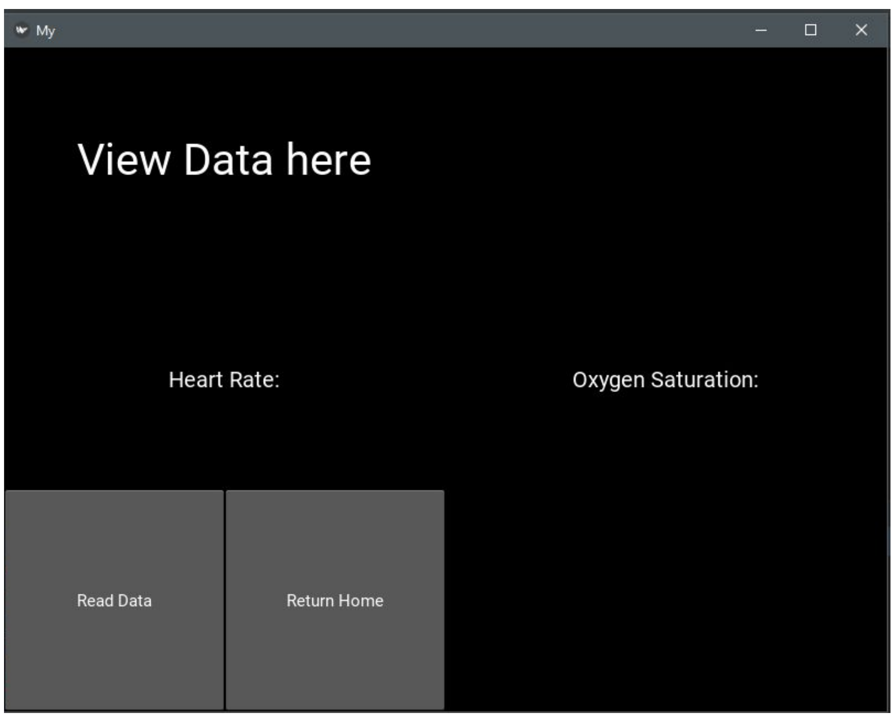

Figure 8.24: Designed App interface - display page.

Alternative Designs

Alternative design ideas to the Pulse Oximeter device were a finger clip design which is the most common form a pulse oximeter comes in. Another alternative design is if the device were to collect oximetry data from the earlobe of the user. The reason the ring design was chosen in our approach was because it allows more flexibility for the user in order to continue with their daily tasks since they will still have the ability to touch or grip on things, unlike the finger clip design. Also, the ring design is more convenient to use than the earlobe design since it is a very common form of accessory known to be worn by people regardless of the gender. The earlobe design can be inconvenient to use due to its placement on the ear and it can easily fall off the ear.

The hardware components were originally decided to be placed inside the ring, including the microcontroller, bluetooth, circuitry as well as the battery. All these components take lots of space and placing them inside the ring was not possible without a flexible PCB. This approach was looked into and since ordering a flexible PCB seemed more complicated and time consuming than the team imagined, the decision was made to not move forward with this approach. An alternative approach to this was a glove design. The user wearing a glove and the hardware components being placed inside the ring. The challenge with this design idea was finding a glove that had enough spacing for all the hardware components. Therefore, the decision was made to propose a wristband container design. This container was 3D printed and was placed on the wrist of the user. The size of the container was modeled in a way that it would fit all the hardware components including the microcontroller, bluetooth, PCB and the battery for the device.

The collected data is transmitted to the app through wireless communication, however the alternative solution was using a wired communication to link hardware to software. Using wireless communication makes the design more complex since it needs to be defined for the app. On the hand, using a wired communication makes the design not suitable for all situations, for instance users cannot use it while they are doing excessive motion. Another alternative design was to use other wireless methods such as Wifi over bluetooth. Wi-fi can send 600M bit-per-second that is much higher than the Bluetooth bit rate which is 2.1M bit-per-second, however, in case of using Wifi we needed to add an antenna to the design and also wi-fi may not be available everywhere.

Alternatives to the proposed software interface werean IOS or Web-based/Cloud application if using wireless communication. Using IOS instead of Android would cause the application development to be more difficult and implement less open source aid, but the end result would not be significantly different from the proposed plan. A web-based application would allow for storage and processing of data in a non-physical space which would be advantageous, however it would require the use of WiFi based technologies which would reduce accessibility.

Material/Component Cost

In this section, we summarize the cost of our design in Table 9.1 below. The table contains the cost of each component used in the design. We also include the backup parts that were purchased in advance in case one part gets damaged.

Table 10.1: Costs of utilized components.

3D Printing/Modelling (3 pieces)	$20
Microcontroller (+ backup)	$15
PCB	$25 for 5 pieces
Bluetooth (+ backup)	$4.50
Batteries	$18
Circuit components (resistors, op-amps,sensor)	$70
App publishing fee (optional)	$25
Total	**$157.5 ~ $177.5**

Measurement and Testing Procedures

Properties of the device hardware such as comfortability, aesthetics and durability were tested by having a user wear it during the testing process for an appropriate length of time. The user's feedback was used to constantly modify or redesign the printed portions.

As for the circuitry aspect of the device was tested using tools such as oscilloscopes and multimeters to ensure that the obtained electrical signals appeared as Photoplethysmography (PPG) signals, which are the type of signals emitted from the designed circuit. The PPG signals were double checked by comparing them with scholarly papers. A multimeter was used to check the voltage before and after the voltage regulator to make sure sufficient voltage was supplied. In addition, the device was used to measure the values of the resistors and potentiometers used. Potentiometers were essential components for calibration. They were mostly used to adjust the gain, and replaced with a resistor for the final prototype. The oscilloscope was the major device used for measurement/ testing throughout the circuitry. Firstly, it was used to test the output signals at every section of the circuit. These sections include after the photodetector, amplification and filtering, and before ADC.

<u>After photodetector</u>: The device was used to test if the photodetector module is photosensitive to a stimuli.

<u>Amplification and Filtering:</u> The device was used with the addition of the function generator to test the filters and their gains. The input and the output of the filters were compared using the oscilloscope.

<u>Before ADC</u>: The device as used before the ADC to make sure signal is marginalized for voltage range of ADC

Secondly, the oscilloscope was used to test pulses received from the DAC pins of the microcontroller which was meant to power the LEDs. Their voltages and the frequency of the pulses were measured, to design accordingly. Simultaneously, variables such as the overall circuit current drain was measured for the purpose of measuring the power consumption of the circuit using the multimeter. The circuit was improved as it was constantly being tested for acquirable data for the microcontroller.

As the software aspect of the device was packaged into a single application, testing could be done all at once. However, to test for the individual components such as dual-way bluetooth transmission and microcontroller functionality, a separate microcontroller and bluetooth module was obtained and the written softwares was tested and modified until it was consistent. To test other components such as the filtering algorithm, oscilloscope readings were obtained as csv files and fed into the algorithm. Modifications and testing were conducted until results appeared accurate and consistent. After this was ensured, the components were packaged together and connected to the physical circuit. Additional calibration was also used to ensure that the results were accurate. The runtime of the code was also looked at during the development process, since we wanted the quickest delivery of results possible. After modifications to the functions and format to increase code efficiency, the final overall runtime took approximately 6-10 secs to display the results upon triggering the runtime.

Measurement Results

The following is the output Analog PPG signal of the circuit:

Figure 12.1: Initial output signal of the circuit. The pink represents the filtered signal and the yellow represents the initial signal from the TIA.

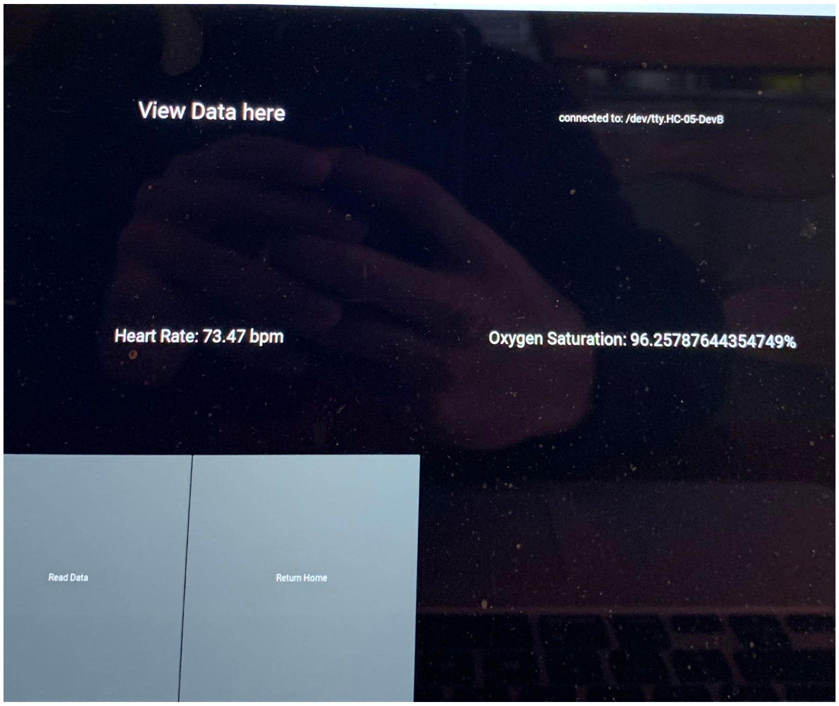

Figure 12.2: Displayed heart rate and saturation outputs from the app interface.

The designed device was tested and compared to a pulse oximeter module on a Samsung phone for three trials of Heart rate and Oxygen saturation outputs. The following are the results of the trials:

Table 12.1: Comparison between the designed pulse oximeter and a samsung pulse oximeter.

	Samsung Pulse Oximeter		Designed Pulse Oximeter	
	HR (bpm)	**SPO2 (%)**	**HR (bpm)**	**SPO2 (%)**
Trial 1	65	99.9	71.2	123.7
Trial 2	69	99.9	73.5	96.3
Trial 3	66	99.9	78.4	101.6
Mean	66.7	99.9	74.4	107.2
Std	2.08	1.74e-14	3.68	14.53

A T-test was conducted to compare the results from the Samsung Pulse Oximeter and the Designed Pulse Oximeter in this project. The equation used in obtaining the values for the T-test is as below:

$$T = \frac{|mean1 - mean2|}{\sqrt{\frac{std1^2}{n1} + \frac{std2^2}{n2}}} \qquad \text{Equation 12.1 [21]}$$

The T-test for the Heart Rate (HR) and the Oxygen Saturation (SPO2) levels are calculated below:

$$T_{HR} = \frac{|66.7 - 74.4|}{\sqrt{\frac{(2.08)^2}{3} + \frac{(3.68)^2}{3}}} = 3.15$$

$$T_{spO2} = \frac{|99.9 - 107.2|}{\sqrt{\frac{1.74e{-}14^2}{3} + \frac{14.53^2}{3}}} = 0.87$$

Post Analysis

The printed ring was deemed to be adequately durable and comfortable to wear. However, because of the modifications to improve the structural integrity, the ring lost its flexibility which would have allowed for adjustability and a customized fit for any user.

The circuit was continuously tested, measured and edited. When the expected results were not observed from the testings, Every component was re-analysed to see if it is performing the way we expected. When a component came as a source of error. First, the connections were checked to see if it matched the theoretical design. Afterwards, if the expected results were not observed, the theory of the design was re-evaluated. At the end, the component was replaced with another one to see if the component was malfunctioned

As observed in the previous section of this paper, the obtained results were compared with a working pulse oximeter module. A T-test was conducted on the two features using the obtained results, which resulted in T scores of 3.15 and 0.87 for the heart rate and oxygen saturation, respectively. The scores are ratios which represent the difference between the two samples [21]. A larger T score indicates a greater difference between the two samples, while a small score represents similar samples [21]. By observing the heart rate values for both oximetry devices/modules, it can be observed that there is a large difference, justifying the larger score obtained. As for the oxygenation T score, it was relatively small which was further justified by the small differences between both sample results. However, there were inconsistencies in the displayed results, especially in the oxygen saturation readings which were assumed to have stemmed from sudden changes in the read signals. Additionally, the prototype application was designed to only update the readings and display through a constant manual reset of the application, which could contribute to the inconsistency.

Conclusions

In general, a portable and accessible pulse oximeter was designed using essential components while maintaining comfortability for the user and simultaneously enabling use during everyday life, as well as obtaining initial feasibility data. The user's heart rate and oxygenation was successfully displayed on the interface in real time. Parameters such as device usage for at least two hours as well as power consumption was considered and successfully implemented. Based on the theory, our pulse oximeter used red (660 nm wavelength) and infrared (940 nm wavelength) LEDs to fire beams of light into the target tissue, which then reflected back into the The OPT101 photodetector/TIA module to transduce PPG signals, which were then exploited to calculate the desired features of the subject using a microcontroller accompanied by a bluetooth module to transmit the resulting signals into a preprocessing algorithm and user interface app.

One of the few compromises faced was that the final interface was not able to be successfully exported to an Android device without crashing, which was one of the major objectives of the project. Another was that a PCB could not be finalized in time due to the circumstances and closures due to the COVID-19 pandemic. The team encountered many difficulties throughout the design process, such as finalizing designs for their assigned aspects and components while making sure those aspects integrate well with each other. During the development process, many ideas and components were ignored as a result of their failure to integrate into the system. However, the team collaborated with each other to resolve issues using alternative solutions and complete most of the project objectives to deliver a functioning wearable pulse oximeter.

For future developments, more functions could be added in the device such as detecting blood pressure. Additional features such as allowing the customers to add their own body parameters would help to further tailor the data to the user.

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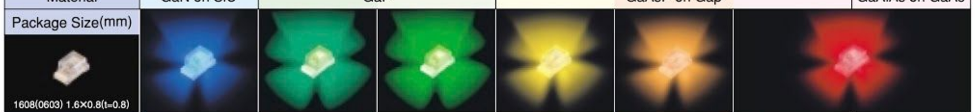
Appendices

0603<1.6×0.8 t=0.8mm Standard Type

SML-310 Series

Emitting Color	Blue	Pure Green	Green(Yellowish Green)	Yellow	Orange	Red	
Material	GaN on SiC	GaP			GaAsP on Gap		GaAlAs on GaAs
Package Size(mm) 1608(0603) 1.6×0.8(t=0.8)							
Part No.	SML310BAT	SML-310PT	SML-310MT	SML-310YT	SML-310DT	SML-310VT	SML-310LT



note) "-" will be taken out for emitting color B/E series.

■ Absolute Maximum Ratings (Ta=25°C)

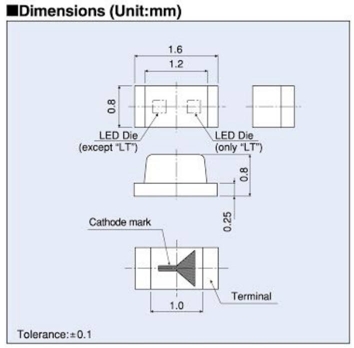
Part No.	Emitting color	Power dissipation P_D (mW)	Forward current I_F (mA)	Peak forward current ※I_{FP} (mA)	Reverse voltage V_R (V)	Operating temperature T_{opr} (°C)	Storage temperature T_{stg} (°C)
SML310BAT	Blue	94		70	5		-40 to +100
SML-310PT	Pure Green						
SML-310MT	Green (Yellowish Green)		20				
SML-310YT	Yellow	55		60		-30 to +85	
SML-310DT	Orange				4		-40 to +85
SML-310VT	Red						
SML-310LT	Red	60	25	75			

※:Duty ≦1/5, pulse width ≦ 1ms.

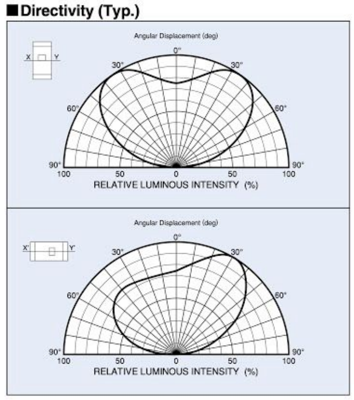
■ Electrical Optical Characteristics (Ta=25°C)

Part No.	Resin Color	Forward voltage V_F		Reverse current I_R		Light wavelength Peak λp	Half-wave $\Delta\lambda$		Brightness I_V		
		Typ. (V)	I_F (mA)	Max. (μA)	V_R (V)	Typ. (nm)	Typ. (nm)	I_F (mA)	Min. (mcd)	Typ. (mcd)	I_F (mA)
SML310BAT		3.8			5	428	65		1.4	3.6	
SML-310PT		2.2				555				4	
SML-310MT						570			3.6	16	
SML-310YT	Transparent Colorless	2.1	20	100		585	40	20			20
SML-310DT		2.0			4	610			2.2	6.3	
SML-310VT						650			1.4	4	
SML-310LT		1.75				660	25		3.6	10	

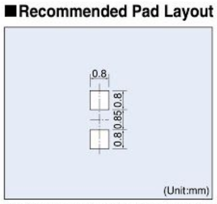
■Dimensions (Unit:mm)



■Directivity (Typ.)



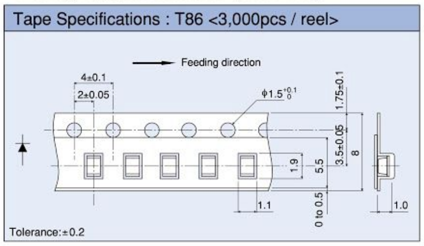
■Recommended Pad Layout



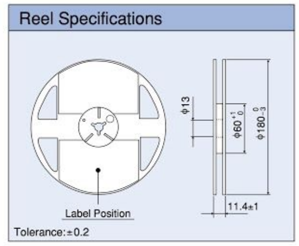
The recommended thickness of the screen mask for soldering is between 100 and 150μm. The hole size of the screen mask should be same as the recommended land pattern or smaller.

■Packaging Specifications (Unit : mm)

Tape Specifications : T86 <3,000pcs / reel>



Reel Specifications



Rev.C

EVERLIGHT

DATASHEET

0805 Package Infrared Chip LED

IR17-21C/TR8

Features

- Small double-end package
- Low forward voltage
- Good spectral matching to Si photo detector
- Pb free
- The product itself will remain within RoHS compliant version.

Descriptions

- IR17-21C/TR8 is an infrared emitting diode in miniature SMD package which is molded in a water clear plastic with flat top view lens.
- The device is spectrally matched with silicon photodiode and phototransistor.

Applications

- PCB mounted infrared sensor
- Infrared emitting for miniature light barrier
- Floppy disk drive
- Optoelectronic switch
- Smoke detector

Device Selection Guide

Part Category	Chip Material	Lens Color
IR	GaAlAs	Water Clear

1

www.everlight.com

Revision : 3

LifecyclePhase: 正式發行 Approved

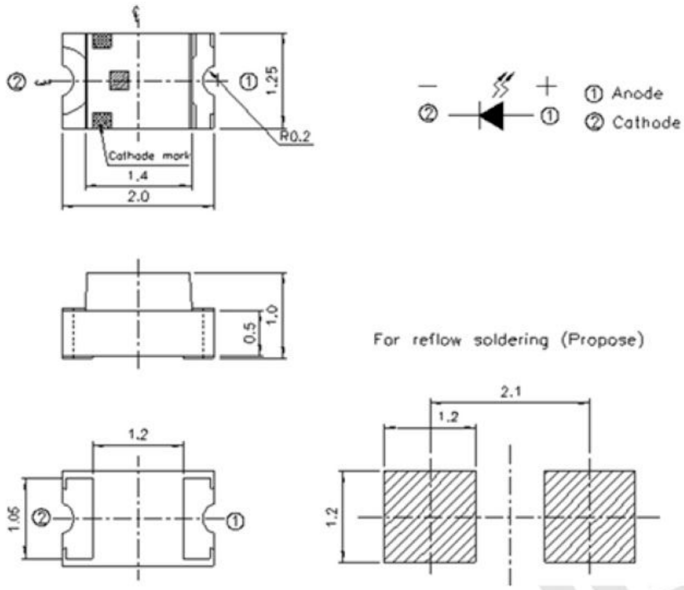
Release Date:2013-07-05 13:31:37.0

Expired Period: Forever

Data Sheet
0805 Package Infrared Chip LED
IR17-21C/TR8

EVERLIGHT

Package Dimensions



Notes: 1.All dimensions are in millimeters

2.Tolerances unless dimensions ±0.1mm

Absolute Maximum Ratings (Ta=25℃)

Parameter	Symbol	Rating	Units
Continuous Forward Current	I_F	65	mA
Reverse Voltage	V_R	5	V
Operating Temperature	T_{opr}	-25 ~ +85	℃
Storage Temperature	T_{stg}	-40 ~ +85	℃
Soldering Temperature *1	T_{sol}	260	℃
Power Dissipation at(or below) 25℃Free Air Temperature	P_d	130	mW

Notes: *1:Soldering time≦ 5 seconds.

Data Sheet
0805 Package Infrared Chip LED
IR17-21C/TR8

EVERLIGHT

Electro-Optical Characteristics (Ta=25℃)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units
Radiant Intensity	Ee	I_F=20mA	0.2	0.8		mW/sr
Peak Wavelength	λ p	I_F=20mA	--	940	--	nm
Spectral Bandwidth	Δ λ	I_F=20mA	--	45	--	nm
Forward Voltage	V_F	I_F=20mA	--	1.2	1.5	V
Reverse Current	I_R	V_R=5V	--	--	10	μ A
View Angle	2θ 1/2	I_F=20mA	--	120	--	deg

Revision : 3
Release Date:2013-07-05 13:31:37.0
LifecyclePhase: 正式發行 Approved
Expired Period: Forever

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TEXAS INSTRUMENTS

OPT101

SBBS002B – JANUARY 1994 – REVISED JUNE 2015

OPT101 Monolithic Photodiode and Single-Supply Transimpedance Amplifier

1 Features

- Single Supply: 2.7 to 36 V
- Photodiode Size: 0.090 inch × 0.090 inch (2.29 mm × 2.29 mm)
- Internal 1-MΩ Feedback Resistor
- High Responsivity: 0.45 A/W (650 nm)
- Bandwidth: 14 kHz at R_F = 1 MΩ
- Low Quiescent Current: 120 µA
- Packages: Clear Plastic 8-pin PDIP and J-Lead SOP

2 Applications

- Medical Instrumentation
- Laboratory Instrumentation
- Position and Proximity Sensors
- Photographic Analyzers
- Barcode Scanners
- Smoke Detectors
- Currency Changers

3 Description

The OPT101 is a monolithic photodiode with on-chip transimpedance amplifier. The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered in discrete designs, such as leakage current errors, noise pick-up, and gain peaking as a result of stray capacitance. Output voltage increases linearly with light intensity. The amplifier is designed for single or dual power-supply operation.

The 0.09 inch × 0.09 inch (2.29 mm × 2.29 mm) photodiode operates in the photoconductive mode for excellent linearity and low dark current.

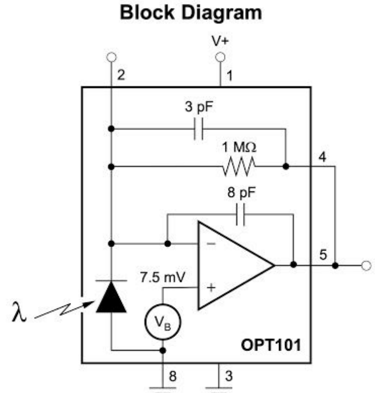
The OPT101 operates from 2.7 V to 36 V supplies and quiescent current is only 120 µA. This device is available in clear plastic 8-pin PDIP, and J-lead SOP for surface mounting. The temperature range is 0°C to 70°C.

Device Information[1]

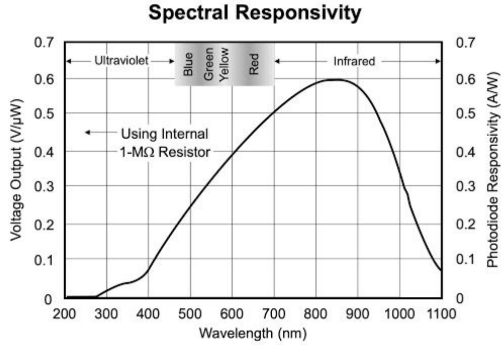
PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPT101	PDIP (8)	9.53 mm × 6.52 mm
	SOP (8)	9.52 mm × 6.52 mm

(1) For all available packages, see the package option addendum at the end of the data sheet.

Block Diagram



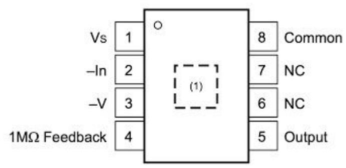
Spectral Responsivity



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

5 Pin Configuration and Functions

DTL and NTC Packages
8-pin SOP and 8-pin PDIP
Top View



(1) Photodiode location.

Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	V_S	Power	Power supply of device. Apply 2.7 V to 36 V relative to –V pin.
2	–In	Input	Negative input of op amp and the cathode of the photodiode. Either do not connect, or apply additional op amp feedback.
3	–V	Power	Most negative power supply. Connect to ground or a negative voltage that meets the recommended operating conditions.
4	1MΩ Feedback	Input	Connection to internal feedback network. Typically connect to Output, pin 5.
5	Output	Output	Output of device.
6	NC	—	Do not connect
7	NC	—	Do not connect
8	Common	Input	Anode of the photodiode. Typically, connect to ground.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Supply voltage (V_S to Common pin or –V pin)		0	36	V
Output short-circuit (to ground)		Continuous		
Temperature	Operating	–25	85	°C
	Junction		85	°C
	Storage, T_{stg}	–25	85	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
POWER SUPPLY				
Operating voltage	2.7		36	V
TEMPERATURE				
Specified	0		70	°C
Operating	0		70	°C

6.4 Thermal Information

THERMAL METRIC (1)		OPT101 DTL (SOP) 8 PINS	OPT101 NTC (PDIP) 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	138.6	128.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	96.4	113.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	126.6	107.0	°C/W
ψ_{JT}	Junction-to-top characterization parameter	17.8	24.2	°C/W
ψ_{JB}	Junction-to-board characterization parameter	118.8	105.9	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics

At T_A = 25°C, V_S = 2.7 V to 36 V, λ = 650 nm, internal 1-MΩ feedback resistor, and R_L = 10 kΩ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
RESPONSIVITY					
Photodiode current			0.45		A/W
Voltage output			0.45		V/μW
Voltage output vs temperature			100		ppm/°C
Unit-to-unit variation			±5%		
Nonlinearity[1]	Full-scale (FS) output = 24 V		±0.01		% of FS
Photodiode area	0.090 in × 0.090 in		0.008		in^2
	2.29 mm × 2.29 mm		5.2		mm^2
DARK ERRORS, RTO[2]					
Offset voltage, output		5	7.5	10	mV
Offset voltage vs temperature			±10		μV/°C
Offset voltage vs power supply	V_S = 2.7 V to 36 V		10	100	μV/V
Voltage noise, dark	f_B = 0.1 Hz to 20 kHz, V_S = 15 V, V_{PIN3} = –15 V		300		μVrms
TRANSIMPEDANCE GAIN					
Resistor			1		MΩ
Tolerance			±0.5%	±2%	
Tolerance vs temperature			±50		ppm/°C
FREQUENCY RESPONSE					
Bandwidth	V_{OUT} = 10 V_{PP}		14		kHz
Rise and fall time	10% to 90%, V_{OUT} = 10-V step		28		μs
Settling time	to 0.05%, V_{OUT} = 10-V step		160		μs
	to 0.1%, V_{OUT} = 10-V step		80		μs
	to 1%, V_{OUT} = 10-V step		70		μs
Overload recovery	100%, return to linear operation		50		μs
OUTPUT					
Voltage output, high		(V_S) – 1.3	(V_S) – 1.15		V
Capacitive load, stable operation			10		nF
Short-circuit current	V_S = 36 V		15		mA
POWER SUPPLY					
Quiescent current	Dark, V_{PIN3} = 0 V		120		μA
	R_L = ∞, V_{OUT} = 10 V		220		μA

(1) Deviation in percent of full scale from best-fit straight line.
(2) Referred to output. Includes all error sources.

Arduino code:

```
#include <SoftwareSerial.h> //use for connecting to Bluetooth
#define ANApin A0 // select the analog pin connected to sensor, pin A0
#define Rx 0 //select the reading pin in serial communication, pin 1
#define Tx 1 //select the transmiting pin in serial communication, pin 0
#define red 11 //pin 11 is connected to red LED
#define infr 12 //pin 12 is connected to infrared LED

int count[2000]; // 1000 = 1s
int value;

SoftwareSerial Bluetooth(Rx, Tx); //configure the selected pins
void setup() {
  pinMode(red, OUTPUT); //configure pin 11 as an output to connect to the Red LED
  pinMode(infr, OUTPUT); //configure pin 12 as an output to connect to the infrared LED
  digitalWrite(red, LOW); //initially red LED is on
  digitalWrite(infr, LOW); //initially infrared LED is off
  BluetoothSetup(); //setup bluetooth
  Serial.begin(9600); //we are sending 10 bits/s thus baud rate = 9600
}

void BluetoothSetup() {
  Bluetooth.begin(9600); //set baud rate of bluetooth or set it to 9600
}

void loop() {
    digitalWrite(infr, LOW); //turn off IR LED
```

```
  digitalWrite(red, HIGH); //turn on red LED
  for(int i=0; i<2000; i++) //Collects data for 2s
  {
   count[i] = analogRead(ANApin);
   value = count[i];
   Serial.println(value);
   }

  digitalWrite(infr, HIGH); //turn ON IR LED
  digitalWrite(red, LOW); //turn off red LED
  for(int i=0; i<2000; i++) //Collects data for 2s
  {
   count[i] = analogRead(ANApin);
   value = count[i];
   Serial.println(value);
   }
 }
```

Python code:

```
import pandas as pd
from scipy.signal import find_peaks
import numpy as np
from numpy import sqrt
import matplotlib.pyplot as plt
import scipy as sp
import math
from datetime import datetime
import kivy
```

```
import statistics

import os

import bluetooth

import sys

import serial

import time

import io

from kivy.app import App

from kivy.uix.label import Label

from kivy.lang import Builder

from kivy.uix.floatlayout import FloatLayout

from kivy.uix.gridlayout import GridLayout

from kivy.uix.screenmanager import ScreenManager, Screen

from kivy.properties import ObjectProperty


class FirstScreen(Screen):

  pass


class SecondScreen(Screen):

  def Calc(Button):

      global ser

      ser = serial.Serial(port='COM3', baudrate=9600, timeout=1)

      time.sleep(2)

      global HR

      global SPO22

      data = []

      print("connected to: " + ser.name)
```

```
    for i in range(0, 4000):
        blueData = ser.readline().decode().rstrip()
        dataArr = float(blueData)
        data.append(dataArr)

    # Moving Average filter
    mov = np.convolve(data, 20)
    R = mov[0:2000]
    IR = mov[2000:4000]

    # Oximetry measurement
    mean1 = np.mean(IR)
    mean2 = np.mean(R)
    SPO2 = (mean2 / mean1) * 100
    SPO22 = SPO2*1.32 #calibration

    # Peak Detection
    peaks, _ = find_peaks(IR, distance=50)

    # Measure Heart rate
    num = len(IR)
    HR = ((len(peaks) / num) * 60)*79

    return (HR,SPO22)

  def update_text(self):
```

```
        text = ('connected to: ' + ser.name)

        text1 = ('Heart Rate: ' + str(HR) + ' bpm')

        text2 = ('Oxygen Saturation: ' + str(SPO22) + ' %')

        self.ids.labelconn.text = text

        self.ids.label1.text = text1

        self.ids.label2.text = text2


class MyScreenManager(ScreenManager):

    pass


present = Builder.load_string('''


MyScreenManager:

    FirstScreen:

    SecondScreen:


<Button>:

    font_size: 15


<FirstScreen>:

    name: 'first'

    color: 1,0,1,1

    FloatLayout:

        Label:

            text: 'Welcome to Pulse Oximeter App.....please pair device first'

            font_size: 30
```

```
        FloatLayout:
            Button:
                text: 'View Data'
                on_release:
                    app.root.current = 'second'
                    root.manager.transition.direction = "left"

<SecondScreen>:
    name: 'second'
    GridLayout:
        rows: 3
        orientation: 'vertical'
        Label:
            text: 'View Data here'
            font_size: 40
        Label:
            id: labelconn
            text: ' '
            font_size: 10
        Label:
            id: label1
            text: 'Heart Rate:'
            font_size: 20
        Label:
            id: label2
            text: 'Oxygen Saturation:'
            font_size: 20
```

```
    GridLayout:
        cols: 2
        Button:
            text: 'Read Data'
            on_release:
                root.Calc()
                root.update_text()

        Button:
            text: 'Return Home'
            on_release:
                app.root.current = 'first'
                root.manager.transition.direction = "right"
''')

class MyApp(App):
    def build(self):
        return present

if __name__ == '__main__':
    MyApp().run()
```