ECE 445
Design Document
Smart Pulse Oximeter

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1. Introduction

1.1 Problem

The problem at hand is the inaccuracy of pulse oximeters in individuals with darker skin tones due to the way these devices interpret oxygen saturation levels. Pulse oximeters function by emitting light through the skin and measuring how much is absorbed to determine oxygen levels in the blood. However, higher concentrations of melanin absorb more light, leading to less accurate readings and potential overestimation of oxygen saturation in individuals with darker skin tones. This discrepancy can lead to delayed treatment or underestimation of how severe a patient's condition is. Addressing this problem is essential to improving equitable healthcare access. A more inclusive and reliable pulse oximetry technology is needed—one that accounts for diverse skin tones and ensures accurate readings for all individuals.

1.2 Solution

This project aims to develop an adaptive pulse oximeter that adjusts the number of wavelengths used based on the user's skin tone (melanin concentration). Traditional pulse oximeters often produce inaccurate readings for individuals with darker skin tones due to increased melanin absorption, which interferes with light-based oxygen saturation measurements. Many modern devices attempt to address this by using multiple wavelengths, but this approach increases power consumption. Our solution integrates a camera and computer vision algorithms to determine skin tone and a wavelength-switching mechanism to optimize accuracy while conserving power. The device will also measure heart rate using the same optical components, making it a multifunctional health monitoring tool. All collected data will be displayed digitally for real-time user feedback.

1.3 Visual Aid:

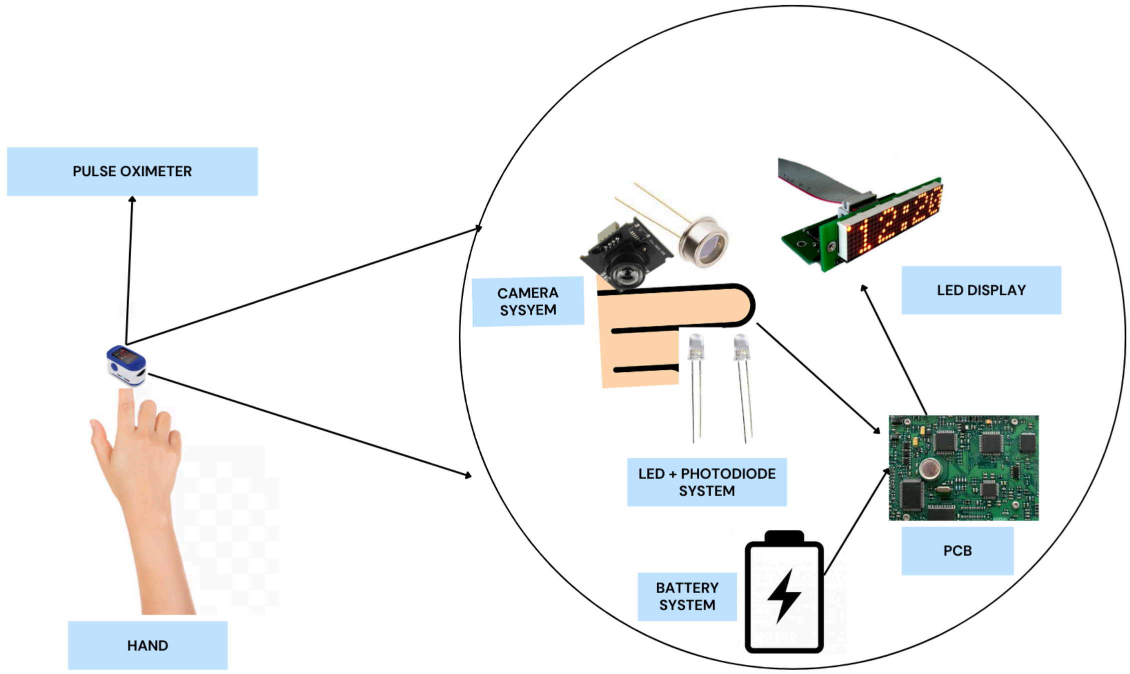

Fig. 1: Visual Aid

1.4 High-level Requirements

1. All sensors must measure blood oxygen saturation (SpO_2) within ±5% absolute error compared to a commercial pulse oximeter across a 70–100% SpO_2 range and heart rate within ±5 BPM across 40–180 BPM. Measurements must meet this accuracy for at least 95% of test subjects under standard indoor lighting conditions.

2. A computer vision system must analyze skin tone using a 16-bit RGB or YUV color space with a minimum resolution of 640x480 pixels, selecting optimal LED wavelengths from a 600–700 nm (red), 850–950 nm (infrared), and 570–590 nm (yellow) range within 200 ms.

3. The external LED display must update SpO_2 and heart rate at a minimum refresh rate of 1 Hz, displaying SpO_2 and heart rate. The system must process and display new readings within 500 ms from sensor acquisition to output.

2. Design

2.1 Block Diagram

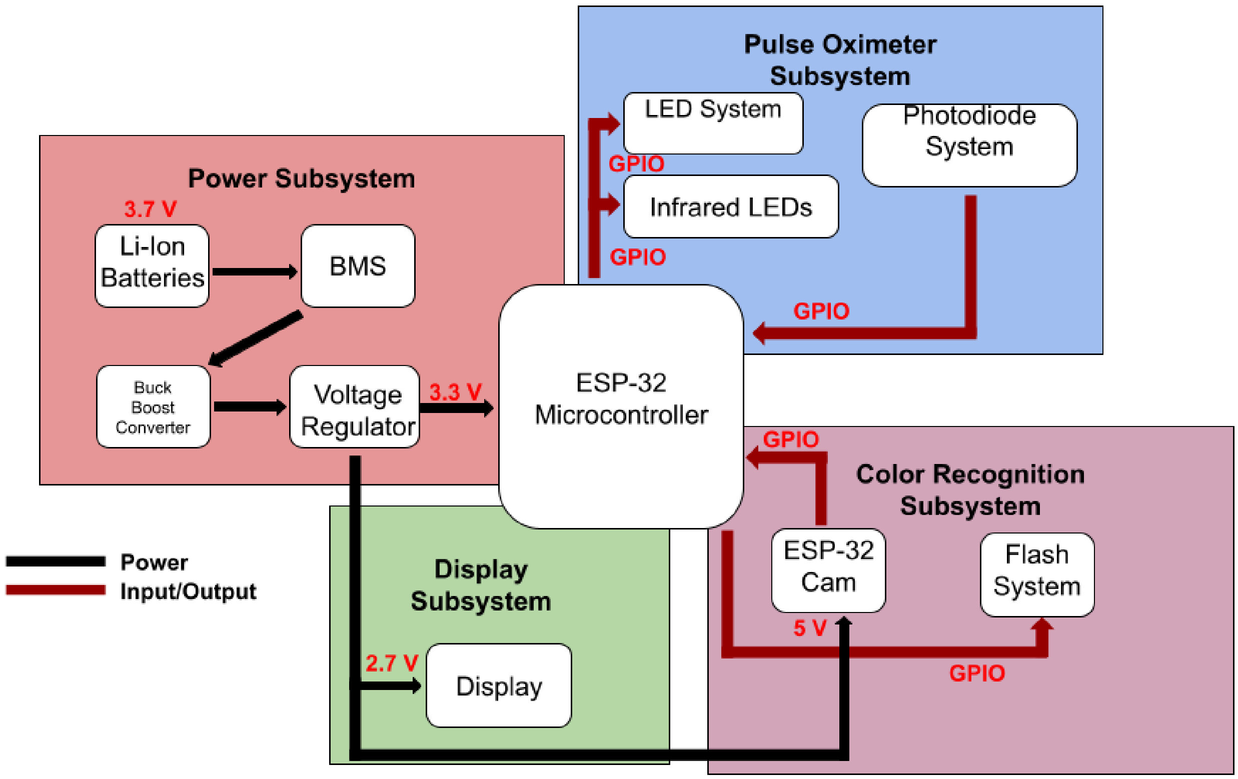

Fig. 2: Block diagram

The block diagram for the Smart Pulse Oximeter outlines the functional structure of the device, illustrating how each subsystem interacts to achieve accurate and reliable blood oxygen saturation (SpO_2) and heart rate measurements. The system is composed of four primary subsystems: the pulse oximeter subsystem, the color recognition via computer vision subsystem, the digital display subsystem, and the power supply subsystem. The pulse oximeter subsystem is responsible for capturing SpO_2 and heart rate data using a combination of infrared, red, and yellow LEDs along with a photodiode sensor. The computer vision subsystem utilizes an ESP-32 Camera Module to analyze the user's skin tone, ensuring that the correct wavelength combination is selected to improve measurement accuracy across diverse skin tones. The digital display subsystem processes and presents real-time SpO_2 and heart rate data on an external LED screen, ensuring user accessibility and feedback. Finally, the power supply subsystem integrates a rechargeable lithium-ion battery with a Battery Management System (BMS) and DC-DC converters to ensure a stable power supply while optimizing energy efficiency. Together, these subsystems work in a cohesive and adaptive manner, ensuring the device meets high standards of accuracy, efficiency, and reliability in medical monitoring.

2.2 Subsystem Overview

2.2.1 Pulse Oximeter Subsystem

This subsystem will use infrared and red light to measure blood oxygen levels as well as heart rate. The way this works is that oxygenated blood will absorb more infrared light and pass through more red light. Deoxygenated blood does the opposite. Knowing this, we can capture and calculate the total blood oxygen level (SpO2) based on the ratio of red and infrared light passing through with a photodetector and a calibration algorithm. In order to properly measure the heart rate, the system will measure the photoplethysmography signal (PPG). When the photodetector records the light intensity, the blood volume increases as the heart beats, causing more light to be absorbed, reducing the signal. These wave-like pattern peaks correspond to the heartbeats and use the time difference between each successive peak to calculate the heart rate in BPM. Utilizing the red LED with lighter skin tones and when detecting higher melanin concentrations will implement a yellow LED which is less absorbent to melanin.

<u>Schematic:</u>

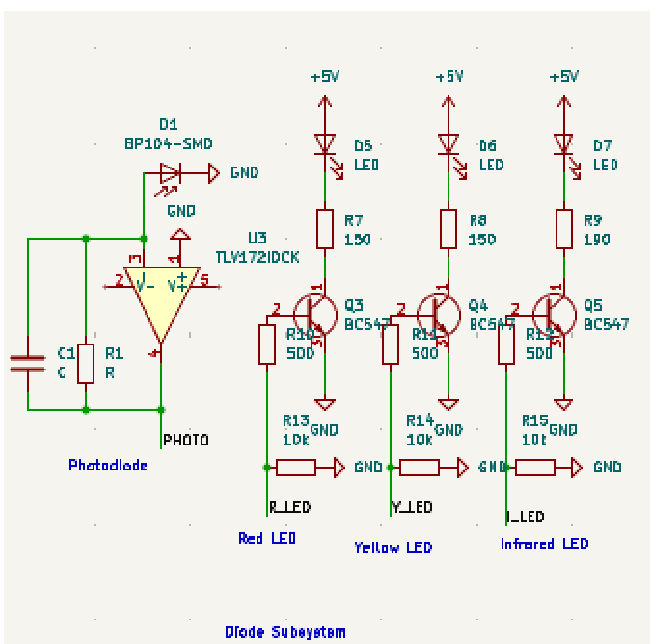

Fig. 3: LED and Photodiode Schematic

Requirements	**Verification**
Red LED (660nm), yellow LED(590nm) and infrared LED(940nm) emit the correct wavelength and are read by photodiode.	Equipment: Use a photodiode to verify the wavelengths of the LEDs. Test Procedure: 1. Power each LED individually and measure the emitted wavelength. 2. Place the photodiode in the circuit and measure the output signal when each LED is turned on. 3. Confirm that the photodiode detects a signal for each LED at the specified wavelengths. Presentation of Results: Record the measured wavelengths in a table.
Based on the computer vision subsystem utilize the necessary LEDs. Either choosing the red and infrared LEDs or the red, infrared and yellow LEDs.	Equipment: Camera module, image processing software, and controlled lighting conditions. Test Procedure: 1. Capture images of different subjects under controlled lighting using the camera module. 2. Process the images using the computer vision algorithm to determine the detected skin tone classification. 3. Verify that the system correctly categorizes skin tones and selects the corresponding LEDs based on predefined thresholds. 4. Compare the system's LED selection decision against a manually verified skin tone classification. Presentation of Results: ● Display a table mapping test subjects, their actual skin tone classification (as determined manually). ● Include statistical data showing the accuracy of the skin tone detection and LED selection.
Blood oxygen saturation and pulse measurement within 5% accuracy	Equipment: Commercial pulse oximeter for reference, test subjects, and data collection software.

comparative to commercial store bought pulse oximeters.	Test Procedure: 1. Measure blood oxygen saturation and pulse rate using the designed system and a commercial pulse oximeter simultaneously. 2. Collect data from at least 10 different individuals under different conditions (e.g., rest, mild activity). 3. Compare the recorded values from both systems and calculate the percentage error. Presentation of Results: Present results in a table showing measured values from both systems and error percentages, along with statistical analysis confirming the accuracy within 5%

2.2.2 Color Recognition via Computer Vision Subsystem

This subsystem will utilize the "ESP-32 Camera Module" in conjunction with a flashing light to image the skin tone of the user. Using these images, color recognition will be employed to determine whether multiple wavelengths of light would need to be used to provide higher blood oxygen level measurement accuracy depending on user skin tone.

Schematic:

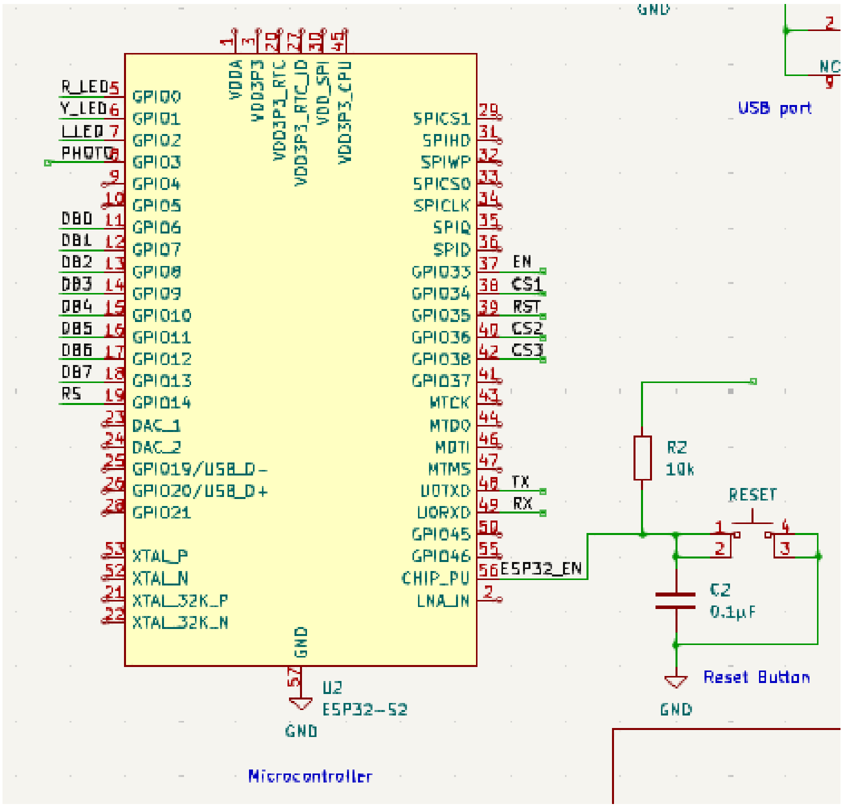

Fig. 4: ESP-32 Module with Reset Button

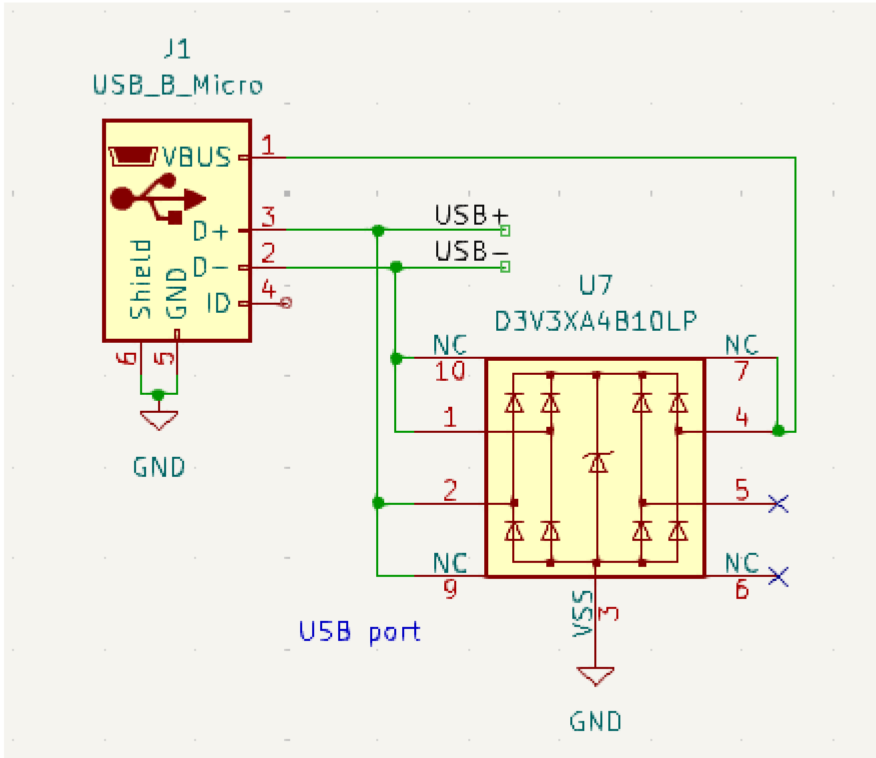

Fig. 5: ESP-32 USB Connection

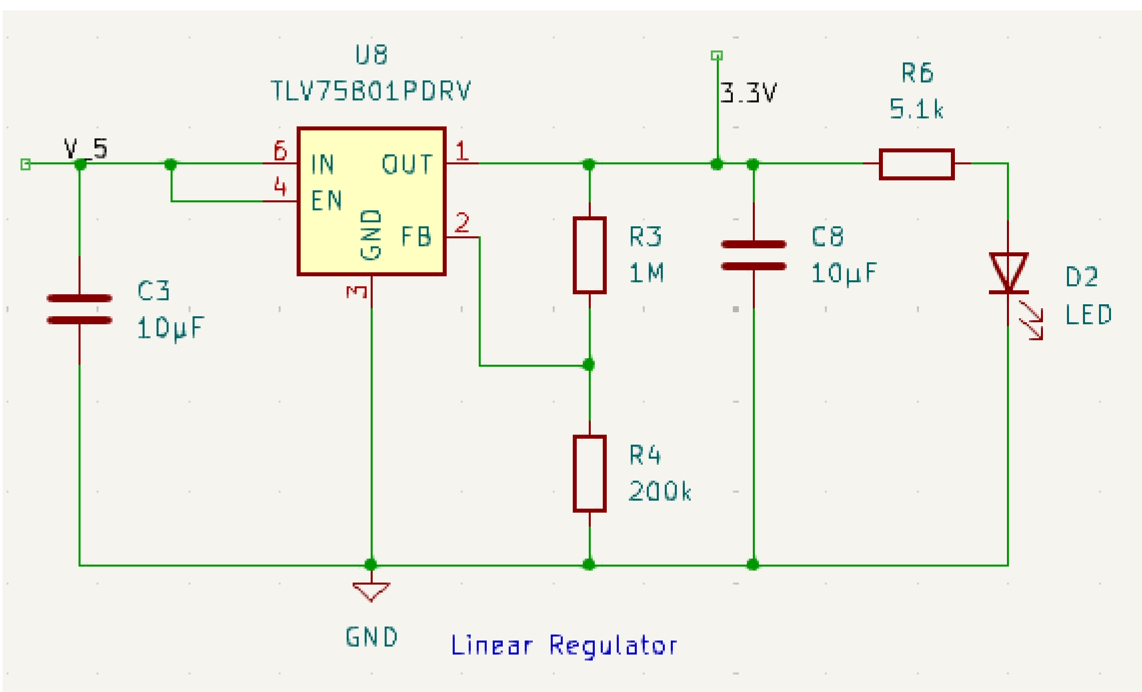

Fig. 6: ESP-32 3V3 Regulator

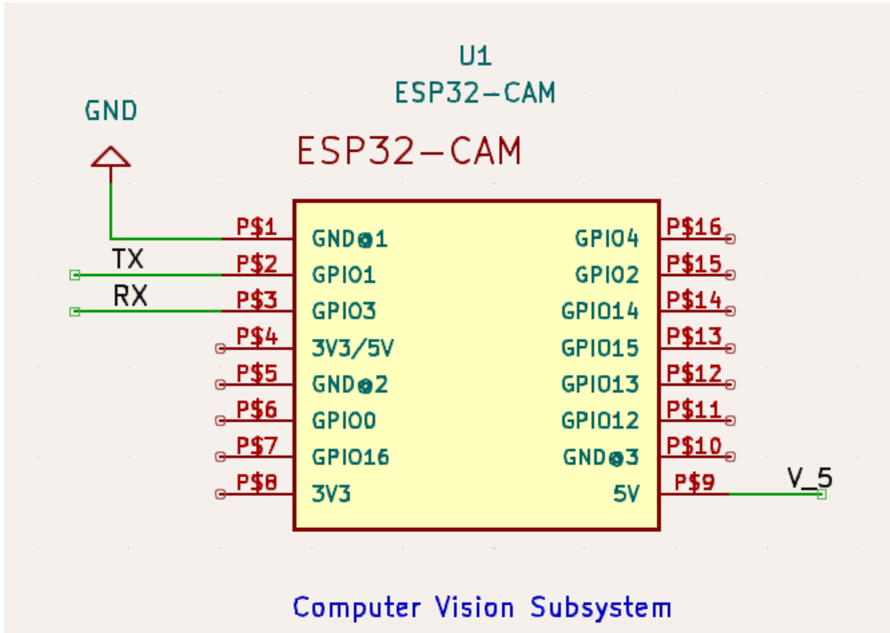

Fig. 7: ESP32-CAM Module

Requirements	**Verification**
ESP-32 Camera Module outputs correct RGB data to ESP-32 Microcontroller.	Equipment: ESP-32 Camera Module, ESP-32 Microcontroller, color calibration chart, image processing software. Test Procedure: 1. Capture an image using the ESP-32 Camera Module under controlled lighting conditions. 2. Transfer the image data to the ESP-32 Microcontroller and extract the RGB pixel values. 3. Compare the extracted RGB values with expected color values from a color calibration chart 4. Verify consistency of RGB values over multiple tests with different lighting conditions. Presentation of Results: Sample images processed by the ESP-32 with extracted RGB values.

<table>
<tr><td>Process the module data and selecting optimal LED wavelengths within 200 ms.</td><td><u>Equipment:</u>
ESP-32 Camera Module, ESP-32 Microcontroller, timing software, image processing software.
<u>Test Procedure:</u>
1. Capture an image with the ESP-32 Camera Module and pass it to the microcontroller.
2. Start a timer upon image reception.
3. Process the image to analyze skin tone and select the appropriate LED wavelengths.
4. Stop the timer when the LED selection decision is made.
5. Repeat the test for at least 20 trials and verify that the processing time does not exceed 200 ms.
<u>Presentation of Results:</u>
Confirmation that all trials meet the 200 ms requirement</td></tr>
<tr><td>Flash system operates in conjunction with ESP-32 Camera Module to provide color-accurate visuals of skin tone.</td><td><u>Equipment:</u>
ESP-32 Camera Module, ESP-32 Microcontroller, flash system, color calibration chart, image analysis software
<u>Test Procedure:</u>
1. Capture an image of a color calibration chart with the ESP-32 Camera Module, with and without the flash system.
2. Analyze the RGB values of the captured image and compare them to the known color values in the chart.
3. Verify that the flash system improves color accuracy by reducing deviations in RGB values.
4. Test under different lighting conditions and confirm consistent performance.
<u>Presentation of Results:</u>
● Before-and-after comparison of images taken with and without the flash system.
● Table comparing expected vs. measured RGB values with and without flash.</td></tr>
</table>

	• Error analysis showing color accuracy improvement due to the flash system

2.2.3 Digital Display Subsystem

To display the contents of our measurements, data will be taken from the microcontroller and will be displayed on an external digital display. This will show the blood oxygen levels and heart rate to the user in real time.

Schematic:

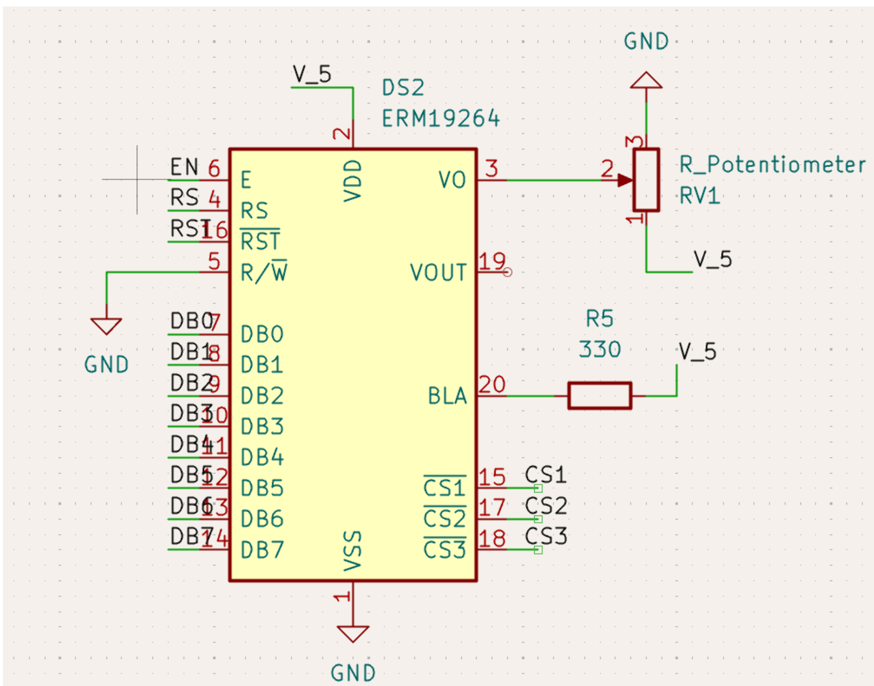

Fig. 9: ERM19264-1 LCD Display Schematic

Requirements	**Verification**
Displays SpO2 to LED display in real time (minimum refresh rate of 1 Hz) updating as values change through algorithmic calculation.	Equipment: ESP-32 Microcontroller, LED display, commercial pulse oximeter (for reference) Test Procedure: 1. Capture SpO_2 data from the sensor and process it using the microcontroller. 2. Display the calculated SpO_2 value on the LED display. 3. Use a logic analyzer to verify that the

	display updates at least once per second (1 Hz refresh rate). 4. Compare displayed values to a commercial pulse oximeter and ensure updates reflect algorithmic calculations in real time. Presentation of Results: ● Table comparing displayed vs. reference SpO_2 values. ● Screenshot or recorded log showing real-time updates on the LED display.
Displays heart rate to LED display in real time (minimum refresh rate of 1 Hz) updating as values change through algorithmic calculation.	Equipment: ESP-32 Microcontroller, LED display, commercial pulse oximeter (for reference), oscilloscope Test Procedure: 1. Capture heart rate data from the sensor and process it using the microcontroller. 2. Display the computed heart rate value on the LED display. 3. Use an oscilloscope to measure the update interval of the display, ensuring it refreshes at least once per second. 4. Compare displayed heart rate values to those from a commercial pulse oximeter in real-time Presentation of Results: ● Table comparing displayed vs. reference heart rate values. ● Screenshots or recorded logs from the LED display demonstrating real-time updates.
The system must process and display new readings within 500 ms from sensor acquisition to output.	Equipment: ESP-32 Microcontroller, LED display, oscilloscope, timing software Test Procedure: 1. Start a timer when new data is acquired from the sensor. 2. Process the data using the microcontroller and update the display. 3. Measure the time taken from sensor data acquisition to LED display update using a logic analyzer or oscilloscope.

	4. Repeat the test for multiple readings to ensure processing time remains below 500 ms. Presentation of Results: ● Table showing the time delay for each trial (sensor to display). ● Graph of processing time trends across multiple readings. ● Confirmation that all trials meet the ≤500 ms requirement.

2.2.4 Power Supply Subsystem

This system must be able to operate on a rechargeable lithium-ion battery. This subsystem will provide appropriate power to each other subsystem/component using this battery with DC-DC converters (buck/boost converters). Reasonable operation time must also be available from one charge of the li-ion battery. Power efficiency can be managed via the switching of the oximeter from one to two wavelengths depending on skin tone, leading to longer operation time on one charge and higher efficiency.

Schematic:

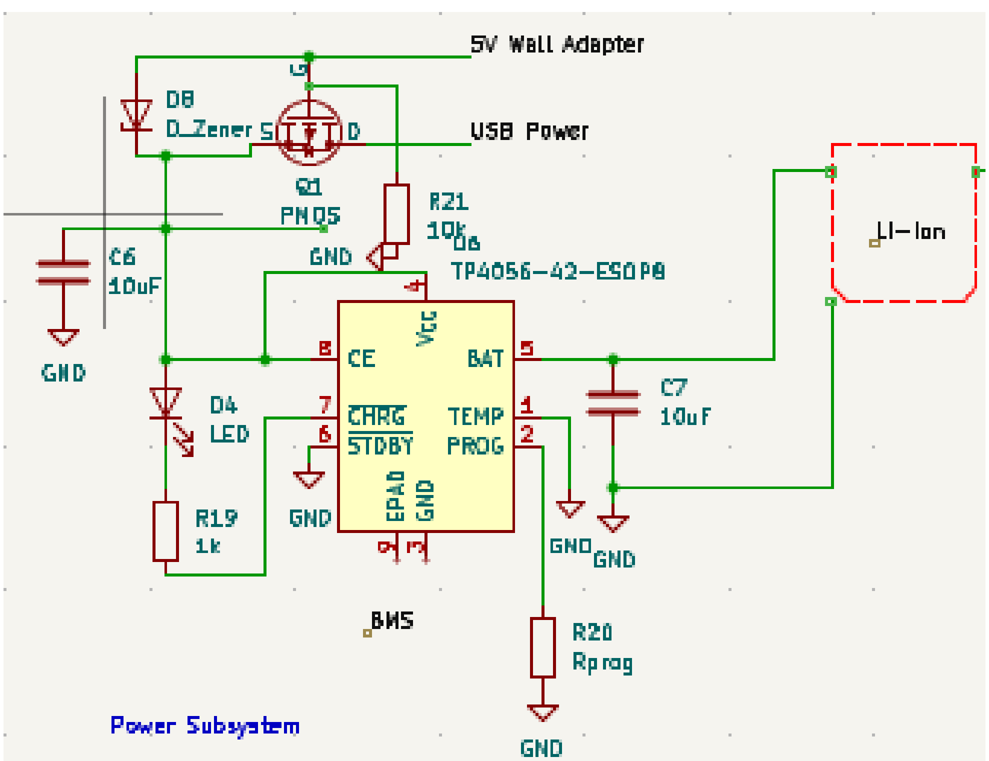

Fig. 10: BMS Schematic

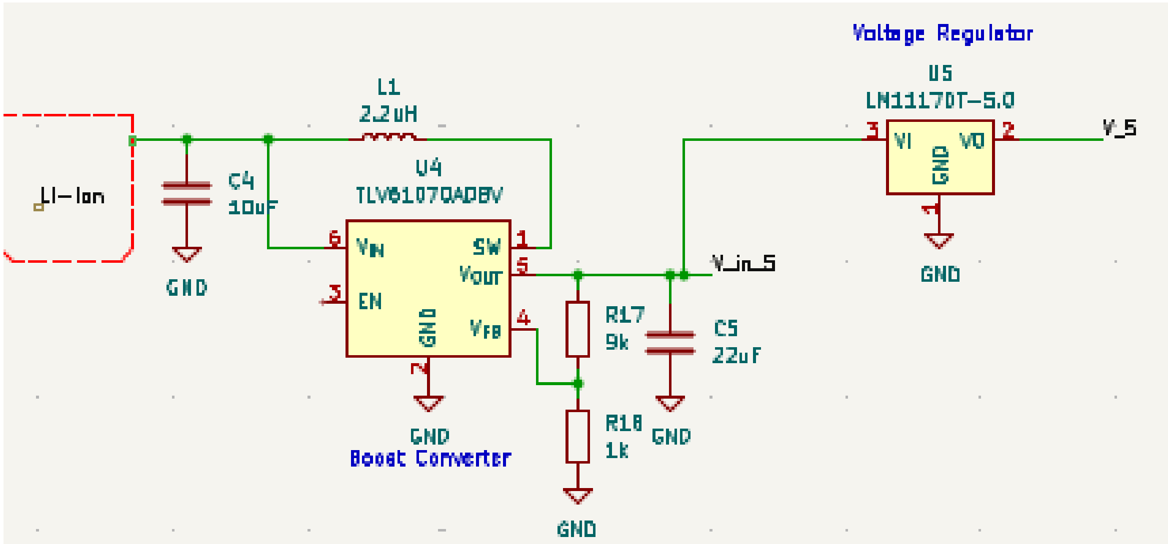

Fig. 11: Boost Converter and Voltage Regulator Schematics

<u>Requirements</u>	**<u>Verification</u>**
Provide stable 5V power for the microcontroller and its modules.	<u>Equipment:</u> Digital Multimeter (DMM), Oscilloscope, Power Supply. <u>Test Procedure:</u> 1. Power the system using the designated power source. 2. Measure the voltage output at the microcontroller's power input pin using a DMM. 3. Use an oscilloscope to check for voltage fluctuations over time. 4. Ensure that the measured voltage remains stable at 5V under different operating conditions (idle, processing, and transmitting data). <u>Presentation of Results:</u> ● Table comparing measured voltage stability. ● Confirmation that voltage remains at 5V within allowable variations.
Provide 5V +/- 0.1V for the voltage regulators to step down for other subsystems.	<u>Equipment:</u> Digital Multimeter (DMM), Oscilloscope, Power Supply.

	<u>Test Procedure:</u> 1. Power the system and measure the 5V output before it reaches the voltage regulators. 2. Use an oscilloscope to analyze voltage fluctuations and confirm that the voltage remains within the 4.9V to 5.1V range. 3. Apply different loads (idle and full operation) and verify that the voltage does not drop or exceed limits. <u>Presentation of Results:</u> ● Table showing voltage readings under different loads. ● Confirmation that the 5V supply stays within the ±0.1V tolerance range
Must supply at least 1A current to the system.	<u>Equipment:</u> Digital Multimeter (DMM), Oscilloscope, Power Supply. <u>Test Procedure:</u> 1. Connect an adjustable electronic load to the power supply output. 2. Gradually increase the load current and monitor the voltage to ensure it remains stable at 5V. 3. Confirm that the system can provide at least 1A of current without significant voltage drops or overheating. 4. Repeat the test under different operating conditions (idle, processing, and transmitting data). <u>Presentation of Results:</u> ● Table showing current supplied and corresponding voltage stability. ● Confirmation that the power supply can maintain 1A output without failure.
Shutdown safely when the device is not being actively used. Predefined period of inactivity.	<u>Equipment:</u> Digital Multimeter (DMM), Electronic Load, Power Supply, oscilloscope, timer. <u>Test Procedure:</u> 1. Set up the system and allow it to run. 2. Measure power consumption over time using a power monitoring circuit.

	3. Allow the system to idle and verify that it enters a low-power or shutdown mode after a predefined period of inactivity. 4. Check for a safe power-down process by ensuring no voltage spikes or unexpected resets occur during shutdown. <u>Presentation of Results:</u> ● Table displaying power consumption before, during, and after shutdown. ● Graph showing power draw over time during inactivity. ● Confirmation that the system safely powers down as expected.

2.3 Tolerance Analysis

One critical aspect of the design that poses a risk to the successful completion of the project is the accuracy of the skin tone-based wavelength adjustment mechanism. If the computer vision system does not correctly determine the user's skin tone, the pulse oximeter may either use an incorrect number of wavelengths or fail to compensate for melanin absorption, leading to inaccurate SpO_2 readings. We can run multiple simulations of different skin tone levels while comparing it to an FDA approved pulse oximeter to quantify any deviation.

Power:

Component	Peak Voltage	Peak Current
ESP32-WROOM-32[10]	2.7 ~ 3.6V	80mA
Ai-Thinker ESP32-CAM WiFi + BT + BLE SoC with 2MP Camera [7]	5V	180mA
151051RS11000 - Red LED [8]	2.1V	30mA
151051YS04000 - Yellow LED	2.0 V	20 mA
BC547 NPN Transistor	$V_{CE,MAX} = 45\ V$	$I_{C,MAX} = 100\ mA$
QSD2030 - Photodiode [9]	1.3V	10nA

XTNI11W - Infrared LED [6]	1.2V	20mA
WEA012864DBPP3N00003- LED Display [11]	3.3V	20mA
Samsung 25R 18650 Lithium Ion Battery	$V_{nominal} = 3.7\,V$ $V_{full\ charge} = 4.2\,V$ $V_{discharge\ cutoff} = 2.5\,V$	20 A (Continuous Discharge) 2500 mAh (Capacity)

Based upon the peak voltages we can determine that the power supply must supply at least 5V to the system in order to function properly. The 5V is within a very safe and comfortable range from the maximum ratings for all the components in the circuit. Making sure that the system is able to provide the necessary current to run each subsystem together we need to calculate the total current that is needed. The total current being under 1A meaning that the system must be able to provide a supply of 1A with room to spare.

The current batteries that are being used within our system are the Samsung 25R 18650 batteries. Two of these batteries in parallel will provide us with a total capacity of 5000 mAh or 40 A of continuous discharge. Since our system will need a 5V voltage at some areas as stated above, the following calculations can be done to find out our current after the usage of a boost converter to boost the 3.7 V Li-ion to a 5 V.

$$P_i = I_i * V_i = P_f$$
$$I_i = 40\,A,\ V_i = 3.7\,V,\ V_f = 5\,V$$
$$P_i = 40 * 3.7 = 148\,W = 5 * I_f$$
$$I_f = 29.6\,A$$

We see that the current flowing out of our boost converter will be 29.6 A at 5 V. To ensure that each of our components that need a voltage are not being overloaded with current, a current limiting resistor can be placed in front of each component. These resistors will be at relatively high resistances such that much less current will flow through them. Looking at our above voltage requirements, we can calculate the limiting resistor values by the following.

$$R_{limiting} = \frac{V_{supply} - V_{max}}{I_{max}}$$

Using Ohms law, the following resistor values can be used to limit current at each device.

ESP32-WROOM-32: $R_{limiting} = 17.5\ to\ 28.75\ \Omega$

151051RS11000 - Red LED [8]: $R_{limiting} = 96.67\ \Omega$

151051YS04000 - Yellow LED: $R_{limiting} = 150\ \Omega$

XTNI11W - Infrared LED [6]: $R_{limiting} = 190\ \Omega$

When limiting the current to our ESP32-CAM device, a different approach must be used so that there is much less of a voltage drop across our current limiting method which will allow for almost the full 5 V to drop across the ESP32-CAM device. This can be achieved with the use of an OpAmp and MOSFET circuit.

We must also take into account the possible hazards of overcurrent and overvoltage. In the case of the Li-Ion battery, the battery management system will ensure that there is no overdischarge of the Lithium ion battery. This BMS will also take care of the overcharge, temperature, and other components of battery recharging which need maintenance. The power subsystem will also be utilizing a voltage regulator which will ensure that overvoltages are dealt with and do not cause irreparable damage to our circuit. These protections will prevent harm to our Smart Pulse Oximeter circuit.

Pulse Oximetry:

The main variation of error that is introduced into this project is reading of blood oxygen saturation. To break it down you must first take into account the Beer-Lambert law which is used in pulse oximetry to calculate the amount of oxygen in your blood.

$$I = I_0 e^{-\epsilon c L}$$

I_0= Incident light intensity

I = Transmitted light intensity

ϵ = Molar Absorptivity

C = Concentration of the absorbing substance

L = Path length of light through the tissue.

To simplify this equation for use of the three LED wavelengths we can split the equations into 2 equations solving for the ratio R. The R ratio is calculated from the AC and DC components of the light signals. AC component being the light absorbed due to arterial blood and the DC component being the light by tissues, skin and venous blood.

$$R = \frac{(AC_{red}/DC_{red})}{(AC_{infrared}/DC_{infrared})}$$

$$Y = \frac{(AC_{yellow}/DC_{yellow})}{(AC_{infrared}/DC_{infrared})}$$

The SpO2 is derived from a calibration curve based on the data read from the sensors using this equation: $SpO_2 = A - B * R$. To then account for the extra wavelength you need to factor in the yellow to infrared absorption to estimate and correct for the melanin interference. Thus the new equation becomes $SpO_2 = A - B * R - C * Y$. With A, B and C being calibration constants, to estimate these values we can simulate the model.

The use of multiple wavelengths will be beneficial to the increased accuracy of different skin tones within our project. However, utilizing multiple wavelengths of visible light simultaneously results in issues with blood oxygen measurements as the very small difference in their wavelength will be difficult to pick up by the photodiodes.

Time-Multiplexing, where the LEDs turn on and off in a rapid, alternating pattern, can be used as a solution. Sequential pulsing is also another viable method. To utilize the sequential pulsing method, each LED would be turned ON for a few hundred microseconds before switching to the next one (with a cycle of red, yellow, infrared, and then a dark period to measure ambient light levels). This would repeat at a high frequency so that multiple cycles can occur within a heartbeat allowing for reliable SpO2 calculations. The following equations can be used to find the correct values from the photodiodes, taking into account ambient light noise.

$$I_{R,FINAL} = I_R - I_{DARK}$$
$$I_{Y,FINAL} = I_Y - I_{DARK}$$
$$I_{IR,FINAL} = I_{IR} - I_{DARK}$$

Another method to solve this issue would be phase-division multiplexing. This employs a phase difference between our LEDs which allows for us both LEDs to be on without interfering with each other. We see that the total waveform that the photodiode detects is the following.

$$I(t) = A_R cos(\omega t) + A_Y cos(\omega t + 120) + A_{IR} cos(\omega t + 240)$$

Then using FFT (Fast Fourier Transform) analysis, each contribution can be extrapolated by looking at the three dominant frequency components corresponding to red, yellow, and infrared signals.

3. Cost and Schedule

3.1 Cost Analysis

Labor:

The average starting salary for an electrical engineering graduate is $88,321 with an average signing bonus of $5,000. With this estimation, we can determine the cost for labor per hour to be approximately $40 an hour. This is a value taking the current socio economic state of the country into account. To account for us being students, we are lowering the salary by $5 an hour. The total hours nearing approximately 9 hours a week for each member of the group over the span of 8 weeks.

$(\$/hour)\ x\ 2.5\ x\ hours\ to\ complete\ =\ TOTAL$

$(\$35/hr)\ x\ 2.5\ x\ 9\ x\ 8\ =\ \$6300$ per person or a total of $18,900.

Parts:

Description	Manufacturer	Part #	Quantity	Cost
Infrared LED	SunLED	XTNI11W	1	$0.38
Yellow LED	Wurth Elektronik	151051YS04000	1	$0.20
Red LED	Wurth Elektronik	151051RS11000	1	$0.15
Green LED	Wurth Elektronik	151051VS04000	1	$0.24
NPN General Purpose Transistor	OnSemi	2N4401	3	$0.78
Photodiode PD-6	OnSemi	QSD2030	1	$0.63
Dual General Purpose Operational Amplifier	Texas Instruments	MC1458P	1	$0.49
ESOP-8 Battery Management ROHS	TOPPOWER (Nanjing Extension Microelectronics)	TP4056-42-ESOP 8	5	$0.88
18650 3.7 V Lithium-Ion Battery	PKCELL	ICR18650-2600-B	1	$6.00

Rechargeable 2.6 Ah				
Boost Switching Regulator IC Positive Adjustable 2.2V 1 Output 2.5 A SOT-23-6	Texas Instruments	TLV61070ADBVR	1	$0.38
Linear Voltage Regulator IC Positive Fixed 1 Output 800 mA TO-252-3	Texas Instruments	LM1117DT-5.0/NOPB	1	$1.69
P-Channel 60 V 300 mA 270 mW Surface Found MOSFET	Nexperia USA Inc.	BSS84AKW	1	$0.18
Zener Diode 5.6 V 300 mW Surface Mount	Diodes Incorporated	BZT52C5V6T-7	1	$0.11
Graphic LCD Display Module	EastRising Technology Co., Limited	ERM19264-1 Series	1	$14.76
ESP32, OV2640 - Image Sensor Evaluation Board	CANADUINO, UNIVERSAL-SOLDER Electronics Ltd	26387	1	$11.38
Resistors		140 Ohm 196 Ohm 510 Ohm 10.02k Ohm 330k Ohm 1k Ohm 9k Ohm	2 1 3 4 1 1	$0
Capacitors		10 uF 22 uF	3 1	$0
Inductors		2.2 uH	1	$0

Total Part Cost: $43.33
Total Cost including labor and parts: $18,943.33

3.2 Schedule

Week	Goals and Work
2/24	Work: Finish each subsystem schematic and try to finish PCB in time for first order, Work on Design document. (All) Due: PCB Review - 2/28
3/3	Work: Design Document and Schematic work (All) Breadboard Parts - Jason, Sidney Breadboard Implementation (All) Due: First Round PCBway AUDIT - 3/3 Teamwork 1 Evaluation - 3/5 Design Document - 3/6
3/10	Work: Breadboard Implementation (All) PCB schematic finish and review for Second Round (All, Sidney) Order all Parts (All) Due: Breadboard Demo - 3/11 Second Round PCBway AUDIT - 3/13
3/17	SPRING BREAK If time, work on the software aspect.
3/24	Work: Computer Vision and SpO2 / Heart Rate programming - Stage 1 Aim to Complete (Faris, Jason) Camera Integration and Code (Faris) Battery and Power System (Sidney) If PCB, then Solder PCB and begin assembly to test (All) Due: NA
3/31	Work: Computer Vision and SpO2 / Heart Rate programming - Stage 2 Aim to

	complete (Faris, Jason) Camera Integration and Code (Faris) Battery and Power System (Sidney) If PCB does not work then prepare and fix for round 3 (All) <u>Due:</u> Third Round PCBway AUDIT - 3/31 Individual Progress Reports - 4/2
4/7	<u>Work:</u> Complete initial testing stages to fix problems and debug (All) Begin Final Paper write up (Jason then All) <u>Due:</u> Fourth Round PCBway AUDIT - 4/7
4/14	<u>Work:</u> Begin Final Paper write up (All) Testing stages to fix problems and debug (All) Prepare for Mock Demo with TA (All) <u>Due:</u> Team Contract Assessment - 4/18
4/21	<u>Work:</u> Final Testing and preparation for final demo (All) Prepare for Mock Demo with TA (All) Prepare for Final Demo (All) Final Paper write up (All) <u>Due:</u> Mock Demo with TA - 4/21
4/28	<u>Work:</u> Prepare for Final Demo (All) Final Presentation Prep (All) Final Paper write up (All) <u>Due:</u> Final Demo with Instructors Mock Presentation with Comm and TA
5/5	<u>Work:</u> Final Presentation Prep (All) Final Paper write up (All) <u>Due:</u>

	Final Presentation FInal Paper Due - 5/7 Lab Checkout - 5/8 Lab Notebook - 5/8

Jason Machaj
Faris Zulhazmi
Sidney Gresham

4. Ethics

The development of an adaptive pulse oximeter aligns closely with the IEEE Code of Ethics, particularly in promoting fairness, safety, accuracy, and societal well-being. Traditional pulse oximeters have been shown to disproportionately misread oxygen saturation levels in individuals with darker skin tones, leading to potential delays in medical intervention. By addressing these inaccuracies, this project directly supports IEEE Principle #1, which emphasizes the welfare of the public and the advancement of human well-being.

This project integrates adaptive technology, such as computer vision for skin tone detection, to ensure more accurate readings across diverse populations. This improvement upholds IEEE Principle #3, which stresses the importance of honesty and transparency, as the device provides reliable and unbiased data for medical use. Additionally, the inclusion of real-time safety alerts for abnormal readings further enhances patient outcomes and prevents potential misdiagnoses.

Another ethical consideration is data privacy and security. Since the device processes personal health information (PHI), it is essential to implement secure data handling measures, including encryption and secure storage, to protect users' sensitive medical data. This commitment aligns with IEEE Principle #5, which encourages engineers to respect privacy and confidentiality while striving for continuous improvement in technology.

Moreover, this design promotes equity in healthcare technology (IEEE Principle #8) by addressing racial disparities in medical device performance. Developing a more inclusive pulse oximeter ensures equal access to accurate medical monitoring, supporting fairness and justice in healthcare.

Finally, the project embraces sustainable and responsible engineering practices, ensuring that power efficiency and resource optimization are factored into the design. By minimizing energy consumption and maximizing device longevity, the project adheres to IEEE Principle #6, which promotes environmentally responsible technology development.

To ensure safe operation, we have incorporated multiple safety mechanisms in both hardware and software design. The battery system includes a Battery Management System (BMS) that protects against overcharging, over-discharging, and overheating, preventing potential fire hazards. Additionally, the LED intensity is regulated to meet photobiological safety standards, ensuring safe exposure levels for the user.

The system also includes automatic shutoff mechanisms to prevent prolonged exposure to light and secure encryption methods to safeguard user data. By implementing these measures, we protect both the end-user and developers from potential risks while ensuring compliance with industry safety and ethical guidelines.

Overall, the Smart Pulse Oximeter represents a significant ethical advancement in medical technology, prioritizing accuracy, inclusivity, and patient safety, while fully aligning with the IEEE Code of Ethics.

5. References

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