Bangladesh University of Engineering and Technology
Department of Electrical and Electronic Engineering

EEE 416 (July 2023)

Microprocessors and Embedded Systems Laboratory

Final Project Report

Section: C1 Group: 01

Connecting Health: Empowering Lives Through IoT-Based Patient Monitoring using Arduino

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Signature of Instructor: ______________________________

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. <u>Type the student ID and name, and put your signature</u>. *You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.*

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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1 Abstract

This project reports the design and development of an Arduino-based system for monitoring vital signs. The system utilizes an Arduino Uno microcontroller to collect data from a DS18B20 temperature sensor and a MAX30100 pulse oximeter sensor. An LCD display is incorporated to present the collected temperature and pulse oximeter readings in real-time. The software for the system was developed using the Arduino IDE and the Liquid Crystal library for LCD communication. The report details the hardware components, software development, and assembly process. Additionally, the report presents steps for testing the functionality of the system. This project demonstrates a functional and cost-effective approach to monitoring vital signs using readily available components.

2 Introduction

Health monitoring is a critical aspect of modern healthcare, and the integration of Internet of Things (IoT) technologies can significantly enhance the efficiency and effectiveness of patient care. The primary goal is to design a scalable and reliable solution for continuous health progress monitoring of patients. Traditional methods often involve manual measurements, which can be time-consuming and potentially inaccurate. This project presents the development of an Arduino-based system for continuous vital sign monitoring, offering a more efficient and potentially more reliable solution.

The system leverages the versatility of the Arduino Uno microcontroller to collect data from two key sensors:

- **DS18B20 temperature sensor:** This sensor accurately measures body temperature, a vital indicator of overall health and potential underlying conditions.
- **MAX30100 pulse oximeter sensor:** This sensor provides measurements of heart rate and blood oxygen saturation, offering valuable insights into cardiovascular function and respiratory health.

For real-time data visualization, a 16x2 LCD display is integrated into the system. This allows for convenient monitoring of the collected vital signs, facilitating informed decision-making in healthcare settings.

This report details the design, development, and testing of the Arduino-based vital sign monitoring system. It delves into the hardware components employed, the software development process using the Arduino IDE, and the assembly procedures. Additionally, the report provides a step-by-step guide for testing the system's functionality to ensure accurate data collection and display.

By utilizing readily available and cost-effective components, this project demonstrates a practical approach to continuous vital sign monitoring. This system has the potential to be a valuable tool in various healthcare applications, offering real-time data for improved patient care.

3 Design

3.1 Problem Formulation

3.1.1 Identification of Scope

This project focuses on developing a functional prototype of an Arduino-based vital sign monitoring system. The scope encompasses the following key elements:

- **Hardware Selection:** Identifying and integrating appropriate sensors (DS18B20 temperature sensor and MAX30100 pulse oximeter sensor) and an LCD display (16x2) for data visualization.
- **Microcontroller Platform:** Utilizing the Arduino Uno as the central processing unit for data acquisition, processing, and display control.
- **Software Development:** Developing code using the Arduino IDE to program the Arduino Uno for sensor communication, data processing, and LCD control. The LiquidCrystal library will be used to facilitate communication with the LCD display.
- **System Assembly:** Following a defined schematic diagram to physically connect all hardware components using jumper wires.
- **Functionality Testing:** Implementing a testing procedure to verify the system's ability to:
  - Collect data accurately from both sensors.
  - Process and format the collected data for display.
  - Continuously update the LCD display with real-time vital sign readings.

Important Exclusions

The scope of this project excludes the following aspects:

- **Medical Certification:** The system is not intended for use as a certified medical device and the data collected should not be used for diagnostic purposes without further validation.
- **Advanced Data Analysis:** The project focuses on real-time data display. Further development would be required to incorporate features like data logging, trend analysis, or alarm generation.
- **Power Management:** A basic power source (e.g., USB cable) is assumed for the prototype. For real-world applications, a more robust power management solution would be needed.
- **Clinical Validation:** The project does not involve clinical trials to assess the system's accuracy and effectiveness in a healthcare setting.

3.1.2 Formulation of Problem:

Traditional methods of vital sign monitoring often rely on manual measurements, leading to several limitations:

- **Inefficiency:** Manual measurements can be time-consuming, requiring dedicated healthcare personnel and interrupting patient care routines.
- **Potential Inaccuracy:** Manual measurements can be prone to human error, leading to inconsistencies and unreliable data collection.
- **Limited Data Capture:** Manual measurements typically capture vital signs at

specific intervals, missing potential fluctuations that may be crucial for diagnosis or treatment decisions.

These limitations highlight the need for a more efficient and reliable system for vital sign monitoring. This project aims to address these issues by developing an Arduino-based system offering:

- **Continuous Monitoring:** The system continuously collects data from the sensors, providing a more comprehensive picture of a patient's condition.
- **Automated Data Collection:** Data collection is automated, eliminating human error and improving data reliability.
- **Real-Time Data Visualization:** The LCD display offers real-time visualization of vital signs, allowing for immediate assessment and informed decision-making.

By addressing these limitations, this project strives to contribute to a more efficient and reliable approach to vital sign monitoring in healthcare settings.

3.1.3 Analysis:

This project presents a well-defined approach to developing a functional prototype for an Arduino-based vital sign monitoring system. Here's a breakdown of the strengths, weaknesses, opportunities, and threats (SWOT analysis) to provide a comprehensive analysis:

Strengths

- **Cost-effective**: The project utilizes readily available and affordable components, making it a practical solution for resource-constrained settings.
- **Continuous monitoring**: The system offers continuous data collection, providing a more complete picture of a patient's condition compared to traditional methods.
- **Real-time data visualization:** The LCD display allows for immediate viewing of vital signs, facilitating faster clinical decision-making.
- **Open-source platform:** The Arduino platform offers a user-friendly environment for development, making the system adaptable and potentially customizable for specific needs.

Weaknesses

- **Limited scope:** The project focuses on a basic prototype, excluding features like data logging, advanced analysis, and alarm generation.
- **Accuracy and Validation:** The system is not medically certified, and its accuracy requires further testing and validation in a clinical setting.
- **Power Management:** A basic power source is assumed, but real-world applications would necessitate a more robust solution.
- **Limited number of vital signs:** The current design monitors temperature and blood oxygen saturation; incorporating additional sensors would require further development.

Opportunities

- **Advanced development**: The project can be expanded to include data logging, trend analysis, and alarm generation for critical events.
- **Clinical validation:** Studies can be conducted to assess the system's accuracy and effectiveness in a clinical setting, paving the way for potential medical device certification.
- **Integration with existing systems:** The system could be integrated with existing hospital monitoring systems for centralized data management.

- **Exploration of additional sensors:** The project can be extended to incorporate sensors for monitoring other vital signs like heart rate, blood pressure, or respiratory rate.

Threats

- **Competition:** Established commercial solutions for vital sign monitoring exist, posing competition.
- **Data security**: Security measures would need to be implemented to protect sensitive patient data.
- **User acceptance:** Healthcare professionals may require training and familiarization with the system for widespread adoption.
- **Technical limitations:** The Arduino platform may have limitations in processing power or data handling for highly complex monitoring scenarios.

3.2 Design Method

This project appears to follow a standard iterative design process for developing an electronic device. Here's a breakdown of the likely design method involved:

1. **Identifying Needs and Requirements:**
    - ❖ The project began by recognizing the limitations of traditional manual vital sign monitoring and the potential benefits of a continuous monitoring system.
    - ❖ This initial phase likely involved defining specific requirements for the system, such as the vital signs to be monitored, desired data display format, and cost limitations.
2. **Conceptual Design and Research:**
    - ❖ Based on the identified needs, potential solutions were explored. Research into Arduino technology and available sensors suitable for vital sign monitoring (temperature and pulse oximetry) likely occurred at this stage.
3. **System Design and Development:**
    - ❖ The project most likely involved creating a schematic diagram outlining the electrical connections between the Arduino Uno, sensors, LCD display, and power source.
    - ❖ The Arduino IDE software was then used to develop code for the following functionalities:
        - ▪ Communication with the temperature and pulse oximeter sensors to collect data.
        - ▪ Processing and formatting the collected data for display on the LCD.
        - ▪ Controlling the LCD to display the vital sign readings in real-time.
4. **Prototyping and Testing:**
    - ❖ The next step likely involved constructing a physical prototype by connecting the hardware components based on the schematic diagram.
    - ❖ Testing procedures were then implemented to verify the system's functionality:
        - ▪ Does it accurately collect data from both sensors?
        - ▪ Does it correctly process and format the data for display?
        - ▪ Does the LCD display update continuously with real-time readings?

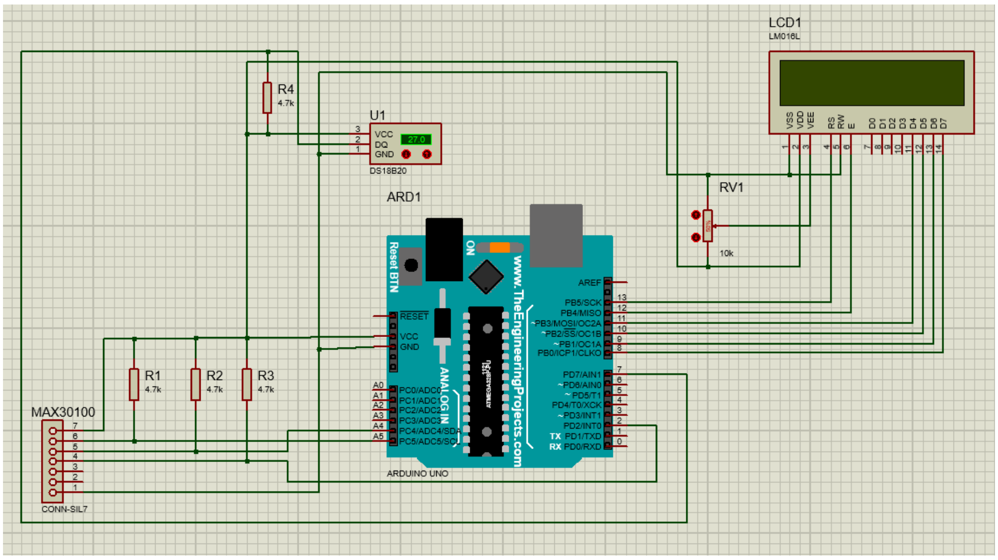
5. **PCB design and making a compact design:**

    - ❖ We have designed a PCB for this project so that in can be easily portable to any place in any time. We also made it in a compact form so that users can understand and use easily.

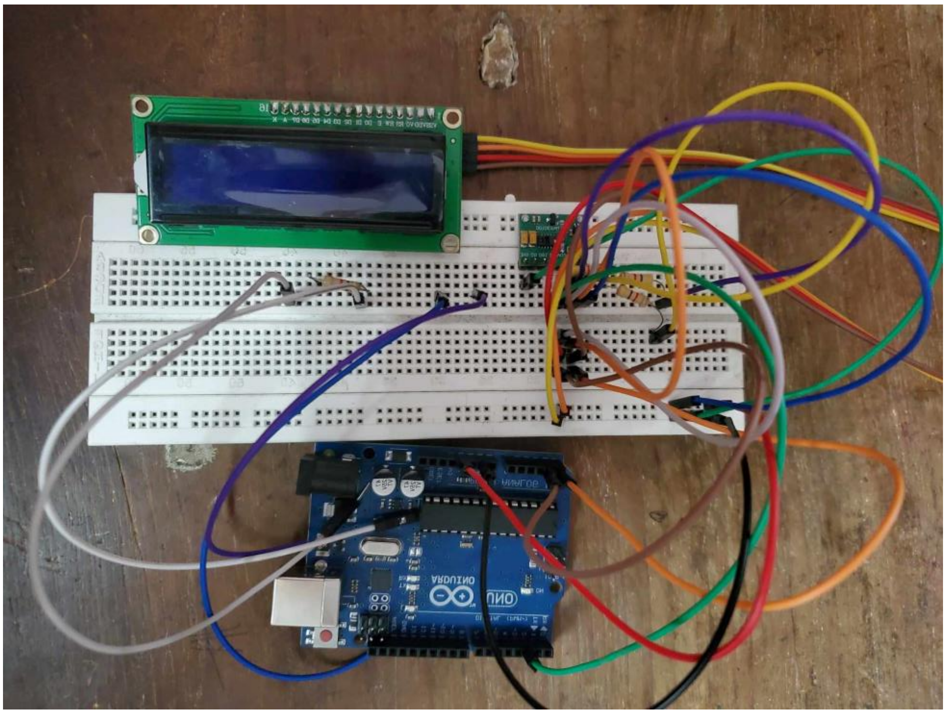
6. **Security and Privacy:**
    - ❖ Implement measures to ensure the confidentiality and integrity of patient data. This involves taking steps to protect patient data from unauthorized access and to ensure that the data is not tampered with.
7. **Evaluation and Refinement:**
    - ❖ Based on the testing results, the design may have undergone iterative refinements.
    - ❖ For instance, the code might be adjusted to improve data accuracy or optimize display formatting.
    - ❖ Potential limitations identified during testing, such as power management or user interface issues, could be addressed in future iterations.

This design method emphasizes a practical and iterative approach, allowing for ongoing improvement and adaptation based on testing and evaluation.

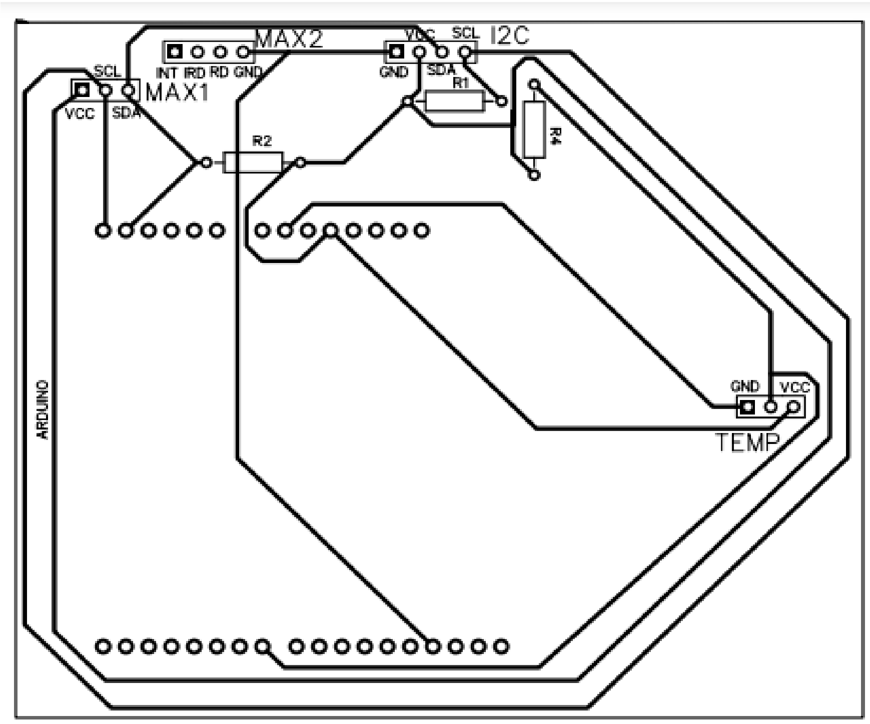
3.3. Circuit Diagram:



3.4 Hardware Design



3.5 PCB Design



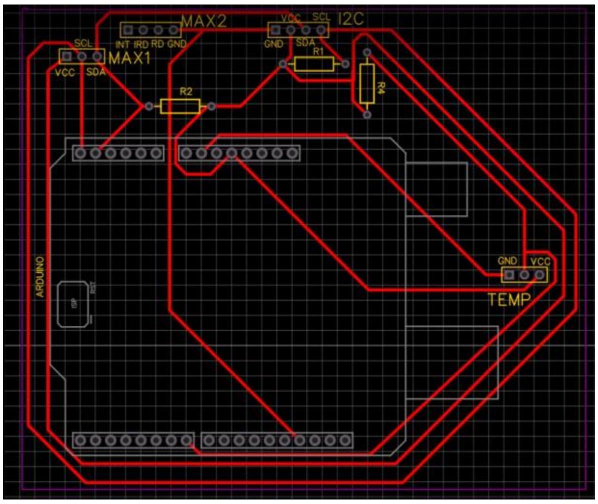
3.6Full Source Code of Firmware

```
#include <LiquidCrystal_I2C.h> // Include the I2C
library #include <Wire.h> #include
"MAX30100_PulseOximeter.h" #include <OneWire.h>
#include <DallasTemperature.h> // Create an LCD object
with the I2C address of your converter LiquidCrystal_I2C
lcd(0x27, 16, 2); // Replace 0x27 with the actual address
if different #define ONE_WIRE_BUS 7 OneWire
oneWire(ONE_WIRE_BUS); DallasTemperature
sensors(&oneWire); float Celsius = 0; float Fahrenheit
= 0; #define REPORTING_PERIOD_MS 1000 PulseOximeter pox;
uint32_t tsLastReport = 0; void onBeatDetected()
{ Serial.println("Beat!"); } void setup()
{ Serial.begin(9600); sensors.begin(); // Initialize
temperature sensor Serial.print("Initializing pulse
oximeter and temperature sensor.."); lcd.init(); //
Initialize the LCD lcd.backlight(); // Turn on the
backlight lcd.print("Initializing..."); delay(1000);
lcd.clear(); // Initialize the PulseOximeter instance if
(!pox.begin()) { Serial.println("FAILED"); for(;;); }
else { Serial.println("SUCCESS"); }
pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA);
pox.setOnBeatDetectedCallback(onBeatDetected); } void
loop() { sensors.requestTemperatures(); // Update
temperature sensor Celsius = sensors.getTempCByIndex(0);
Fahrenheit = sensors.toFahrenheit(Celsius);
Serial.print("Temperature: ");
Serial.print(Celsius); Serial.print(" °C / ");
Serial.print(Fahrenheit); Serial.println(" °F");
pox.update(); // Update pulse oximeter if (millis()
- tsLastReport > REPORTING_PERIOD_MS)
{ Serial.print("Heart rate:");
Serial.print(pox.getHeartRate()); Serial.print("bpm
/ SpO2:"); Serial.print(pox.getSpO2());
Serial.println("%"); lcd.clear(); lcd.setCursor(0,
0); lcd.print("Temp: "); lcd.print(Fahrenheit);
lcd.print(" °F"); lcd.setCursor(0, 1);
lcd.print("HR: "); lcd.print(pox.getHeartRate());
lcd.print(" bpm / "); lcd.print("SpO2: ");
lcd.print(pox.getSpO2()); lcd.print(" %");
tsLastReport = millis(); delay(1000); } }
```

Table: Source Code for the main program

4 Implementation

4.1 Description



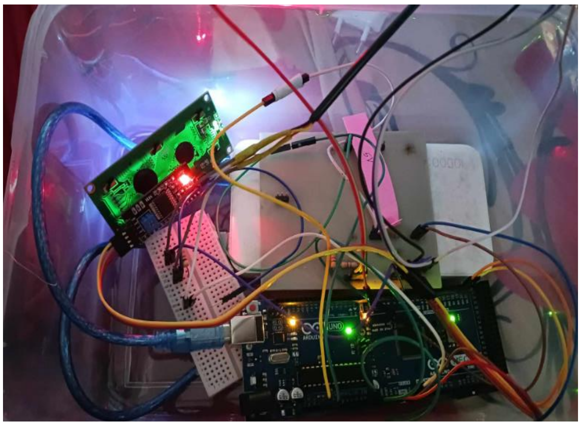


Figure 2: (Left) PCB Layout and (Right) Implementation of Design

5 Design Analysis and Evaluation

5.1 Novelty:

While the concept of using Arduino for vital sign monitoring isn't entirely new, the novelty of this project lies in its specific design and focus. Here's how to address it in your report:

- Focus on Cost-Effectiveness: Highlight that this project prioritizes affordability by utilizing readily available and inexpensive components. This makes it a potentially attractive solution for resource-constrained settings.
- Open-Source Platform: Emphasize the use of Arduino, an open-source platform. This allows for customization and adaptation to specific needs, potentially leading to novel applications beyond the current prototype's functionalities.
- Simplicity and Ease of Use: If the design prioritizes user-friendliness and straightforward operation for healthcare workers, this can be considered a novel aspect, particularly in settings where complex monitoring systems may pose challenges.

5.2 Design Considerations

5.2.1 Considerations to public health and safety:

- **Limited Scope Disclaimer:** Clearly state that, this is a prototype and not a certified medical device. The data collected should not be used for diagnostic purposes without further validation.
- **Data Security:** Although not a PCB design consideration, emphasize the importance of data security measures in future iterations. This could involve encryption or secure data storage protocols to protect patient privacy.
- **User Training:** Acknowledge the need for proper training for healthcare professionals using the system. This ensures accurate interpretation of data and proper device operation to minimize safety risks.
- **Potential for Improved Patient Care:** Frame the project's potential to contribute to public health by enabling continuous monitoring, potentially leading to earlier detection of health issues and improved patient outcomes.

5.2.2 Considerations to environment

- E-waste Management: Briefly discuss the importance of responsible e-waste management practices when dealing with electronic components in the prototype and any future iterations.
- Component Selection: If the project emphasizes the use of environmentally friendly components (e.g., lead-free solder, RoHS-compliant materials), this can be highlighted as a positive consideration. However, for a basic prototype, this may not be a significant factor.

5.3 Investigations

5.3.1 Design of Experiment:

The project involved the creation of experimental setups to test the system's functionality and accuracy. These experiments included controlled water level measurements and the analysis of sensor data in different scenarios.

5.3.2 Data Collection:

Data collected from experiments was analyzed, confirming the system's accuracy and reliability. Interpretation of the data highlighted the effectiveness of the system in providing accurate value of heart rate body temperature and blood oxygen label.

5.3.3 Results and Analysis:

Our project can accurately measure body temperature, blood oxygen saturation label and heart rate.

5.3.4 Limitations of Tools

Hardware Limitations

- **Sensor Accuracy:** While the chosen sensors (DS18B20 and MAX30100) offer reasonable accuracy, they may not meet the stringent requirements of medical-grade devices. Further calibration and validation might be necessary for clinical applications.
- **Sensor Range:** The DS18B20 sensor has a typical operating range of -55°C to +125°C. This may not be suitable for monitoring extreme body temperatures. Similarly, the MAX30100 may have limitations in detecting very low or very high blood oxygen levels.
- **Arduino Uno Processing Power:** The Arduino Uno is a basic microcontroller and might struggle with complex algorithms or data processing tasks if the project were to be significantly expanded in future iterations.

Software Limitations

- **Software Libraries:** The LiquidCrystal library used for LCD communication offers basic functionalities. For more advanced display features or user interface elements, additional libraries or custom code development might be required.
- **Data Logging Limitations:** If the current project doesn't include data logging functionalities, implementing them might require additional libraries or software tools, introducing potential complexities.
- **Limited Error Handling:** The provided code might not have extensive error handling routines. Unexpected sensor readings or communication issues could lead to system malfunctions in future use.

User Interface Limitations

- **LCD Display Size:** The 16x2 LCD display offers limited space for data visualization. Displaying multiple vital signs or detailed information might be challenging.

- **Lack of User Interaction:** The current design likely doesn't allow for user interaction with the system beyond viewing the displayed data. Future iterations might benefit from including buttons or other input mechanisms for user control.

5.4 Impact Assessment

5.4.1 Assessment of Health and Safety Issues:

- **Accuracy and Validation:** As mentioned previously, the system is not a certified medical device, and sensor accuracy limitations exist. Highlight the need for further validation and potential risks associated with relying on this system for critical healthcare decisions.
- **User Training:** Healthcare professionals using the system may require training to ensure proper interpretation of data and to minimize misuse or misdiagnosis.
- **Data Security:** Although not a core functionality yet, emphasize the importance of data security measures in future iterations to protect patient privacy, especially if data logging or wireless transmission are implemented.

5.4.2 Assessment of Legal Issues

- **Regulatory Requirements:** For the system to be used in a clinical setting, it might need to comply with medical device regulations in your specific region. Discuss the potential need for regulatory approvals in future iterations.
- **Data Privacy Laws:** Depending on your location, data privacy laws might dictate how patient data collected by the system can be stored, used, and shared. Future development should ensure compliance with relevant data privacy regulations

5.5 Sustainability Evaluation:

- **E-waste Management:** Briefly discuss the importance of responsible disposal practices for electronic components used in the prototype and any future iterations.
- **Power Consumption:** The current power source might not be sustainable in the long term. Future development could explore energy-efficient components or alternative power sources like solar panels.
- **Material Selection**: If applicable, discuss the use of environmentally friendly materials in the prototype construction. This could be a positive aspect, but for a basic prototype, it might not be a significant factor.

5.6 Ethical Issues:

While the project offers potential benefits for healthcare, it's crucial to consider the ethical issues surrounding its development and use. Here are some key areas to address:

- Informed Consent: If the system is used in a clinical setting, patients should be informed about the limitations of the prototype and obtain their consent before data collection.
- Data Privacy and Security: As mentioned earlier, data security measures are critical to protect patient privacy. Future iterations should implement robust encryption and secure data storage protocols.
- Accuracy and Reliance: The project emphasizes the importance of acknowledging the limitations in sensor accuracy. Overreliance on this system for critical healthcare decisions without proper validation could lead to ethical concerns.
- Equity and Accessibility: The cost-effectiveness of the system is a positive aspect, but there might still be accessibility barriers for some communities. Efforts should be made to ensure affordability and equitable access in future development.
- Potential for Misuse: The project is intended for healthcare professionals, but there's a potential risk of misuse if the system falls into the wrong hands. Measures might be needed to control access and prevent unauthorized data collection.

6 Reflection on Individual and Team work

6.1 Individual Contribution of Each Member

1906135: Component management, Circuit implementation.
1906153: Planning and Schematic diagram design.
1906154: Circuit building in breadboard and testing.
1906155: PCB design and connection.

6.2 Mode of Team Work

In person meeting and work together

6.3 Log Book of Project Implementation

Date	Milestone achieved	Individual Role	Comments
15-12-23	Planning and schematic	1906153	Successfully done
11-02-24	Buying components	1906154, 1906135	Successfully done
15-02-24	Circuit Building	1906153-154	Successfully done
25-02-24	PCB Design	1906155	Successfully done
27-02-24	PCB circuit connection	1906135	Successfully done
01-03-24	Main circuit design and Testing	1906154, 1906135	Successfully done

7 Communication to External Stakeholders

7.1 Executive Summary

We have created a prototype system that continuously monitors vital signs using readily available components! This system could offer a cost-effective solution for healthcare facilities, particularly in resource-limited settings. The prototype uses an Arduino microcontroller to collect data from sensors that measure temperature and blood oxygen levels. This data is then displayed on a small screen for easy viewing by medical professionals. While still under development, this project holds promise for improving access to continuous vital sign monitoring and potentially leading to better patient care.

7.2 User Manual

- Touch the lead of the temperature sensor for about 30 seconds to measure your body temperature.

- Keep your finger in the Pulse-oximeters shown part for measuring heart rate and blood oxygen label.

- You will see two LCD display in one will show your body temperature and the other display will show heart rate and blood oxygen label.

8 Project Management and Cost Analysis

8.1 Bill of Materials:

Components	Quantities	Price
Pulse Oximeter (Max30100)	1 piece	340 Tk.
Temperature Sensor (DS18B20)	1 piece	150 Tk.
LCD Display + I2C Converter	2 pieces	200 Tk.
Resistors	9 pieces	10 Tk.
Jumpper Wire	1set	70 Tk.
Header Pin	1 set	30 Tk.
PCB Board	1 piece	500 Tk.
Battery	1 piece	30 Tk.
Total		1330

8.2 Calculation of Per Unit Cost of Prototype: 1330 per unit

9 Future Work:

Expanding Functionality

- **Incorporate Additional Sensors:** Integrate sensors for monitoring other vital signs like heart rate, blood pressure, or respiratory rate. This would provide a more comprehensive picture of a patient's health status.

- **Data Logging and Analysis:** Develop functionalities for data logging and trend analysis. This would allow healthcare professionals to track changes in vital signs over time and identify potential health concerns.

- **Alarm Generation:** Implement an alarm system that triggers alerts for abnormal vital sign readings. This could prompt medical attention for critical events.

- **Wireless Communication:** Integrate wireless communication modules (e.g., Bluetooth, Wi-Fi) for data transmission to smartphones or patient monitoring dashboards. This would enable remote monitoring and improve accessibility.

Enhancing User Experience

- **Mobile App Integration:** Develop a mobile application that connects with the monitoring system via Bluetooth or Wi-Fi. This would allow healthcare professionals to view real-time vital signs and historical data on their mobile devices.

- **Improved Display:** Explore options for a more user-friendly display, such as a larger LCD screen or even a graphical user interface (GUI) for better data visualization.

- **Audio Cues:** Consider incorporating audio cues for critical events, such as alarms for abnormal vital signs. This could be particularly helpful in noisy environments.

Advanced Development

- **Machine Learning Integration:** Exploring the potential of integrating machine learning algorithms to analyze sensor data and identify patterns. This could enable early detection of health issues or predict potential complications.

- **Cloud-based Data Storage:** Investigating the possibility of storing collected data in a secure cloud platform. This would facilitate data access from multiple locations and enable long-term data analysis.

- **Power Management:** Developing a more robust power management system for the device. This could involve incorporating rechargeable batteries or exploring alternative power sources like solar panels.

- **Medical Certification**: Consider pursuing medical device certification for the system if it meets the necessary standards for accuracy and reliability. This would open doors for wider adoption in clinical settings.

10 References:

I. **https://how2electronics.com/iot-patient-health-monitoring-with-esp8266-arduino**

II. **https://how2electronics.com/max30100-pulse-oximeter-with-esp8266**