1.Introduction to Problem Statement
And It's Need

In incubators, it is essential to keep track of the vital signs of neonate patients, especially in cases of severe premature birth. To observe newborns' growth and their body condition, various vital signs such as **heart rate**, **body temperature**, and **SpO_2** are monitored in neonatal rooms of hospitals. At present, these vital signs require to be measured by sensors with cables from large or handheld devices. As a result, the measurement puts a burden on newborns and medical staff. In particular, it is difficult for most newborns to maintain homeostasis of their body including the heart, lung, and liver. Their acute deteriorations in body functionalities lead to serious sequelae such as brain dysfunctions. In the vital signs of the newborns, heart rate, and SpO2 are crucial for monitoring body condition.

For some parents it gets very overwhelming to see their baby in NICU with all the different wired sensors on them and not being able to be with their baby, this poses a perceived barrier of physical contact with the child. Due to the wires attached to the babies, the skin to skin contact with their parents which is the most critical in positively encouraging their physiological and psychological development is not possible.

Thus, the concept of making the neonatal intensive care unit sensors wireless will increase the physical contact of the parent and the premature baby which could lead to better development of the child.

In this project we aim to develop a platform in designing the wearable sensors for the neonates in incubators. Monitoring the newborns for vital signs in heart rate, blood oxygen saturation level (SpO_2 level) and temperature is crucial for their development and well-being. Commercially available sensors and circuit components in the market could be used to develop the wearable and wireless neonatal vital monitoring system measuring these parameters.

In this project, we will be measuring the following parameters in a wireless manner:

1. **Heart Rate**-Neonates, particularly premature infants, often have underdeveloped regulatory systems, making them susceptible to rapid changes in health status. Continuous heart rate monitoring provides detailed information about cardiac function, enabling healthcare providers to detect subtle variations or signs of distress. Bradycardia (slow heart rate) or tachycardia (fast heart rate) can indicate problems such as respiratory distress, infections, or cardiovascular issues.

2. **Body Temperature**-Premature infants have less body fat and a less effective temperature control mechanism, making them prone to hypothermia. Continuous temperature monitoring allows healthcare providers to intervene promptly if the infant's body temperature drops, preventing complications associated with cold stress.

3. **<u>SpO</u>$_2$**-Many neonates, particularly those in neonatal intensive care units (NICUs), may require supplemental oxygen. SpO2 monitoring helps healthcare professionals adjust and optimize oxygen therapy to maintain levels within the target range, avoiding both hypoxemia and hyperaemia.

2.Specifications to Well Define the Problem Statement

The objective is to develop a compact and user-friendly vital monitoring band for neonates that enables continuous measurement of SpO2, heart rate, and body temperature. The device should be easy to use, feature non-intrusive placement on the body, and facilitate wireless data transmission to a mobile app.

2.1 Compact Size: Design the monitoring band with meticulous attention to size and weight, ensuring it is unobtrusive and lightweight for the delicate anatomy of neonates. The dimensions must be thoughtfully tailored to fit snugly without causing any discomfort, emphasizing the importance of a design that prioritizes the well-being and ease of use for neonates.

2.2. Vital Parameters: Integrate cutting-edge sensors that are meticulously calibrated to provide unparalleled accuracy in measuring SpO2, heart rate, and body temperature. The emphasis here is on delivering precise and reliable data for neonatal monitoring, acknowledging the critical nature of these parameters in assessing the health of neonates.

2.3. User-Friendly Interface: Develop an interface that is not just functional but intuitive, allowing caregivers seamless operation and interpretation of vital data. The focus is on creating a system that simplifies the complex task of neonatal monitoring for caregivers.

2.4. Body Placement: Design the band with utmost consideration for the comfort and well-being of neonates, opting for non-intrusive placement on a suitable body part. It's imperative that the band doesn't hinder natural movement or cause irritation, necessitating the use of soft and hypoallergenic materials to enhance comfort and promote the overall well-being of neonates.

2.5. Wireless Data Transmission: Seamlessly incorporate advanced wireless communication technology, such as Bluetooth, to enable efficient data transmission from the band to a dedicated mobile app. The emphasis is on ensuring not only the convenience of wireless connectivity but also prioritizing secure and reliable data transfer to maintain the integrity of vital information.

2.6. Rechargeable Battery: Integrate a rechargeable battery into the Smart Neonatal Vital Monitoring Band, emphasizing the commitment to sustainability and user convenience. The rechargeable feature ensures prolonged use without the need for frequent battery replacements, promoting eco-friendly practices and minimizing operational costs. This thoughtful design choice aligns with the goal of providing an efficient, cost-effective, and environmentally conscious solution for continuous neonatal monitoring.

2.7. Durability and Safety: Prioritize durability by designing the band to withstand environmental factors encountered in neonatal care settings. Adherence to rigorous safety standards and regulations for medical devices is non-negotiable, with a paramount focus on guaranteeing the well-being of neonates through the creation of a robust and resilient monitoring band.

2.8. Mobile App Integration: Develop a user-friendly mobile app that seamlessly pairs with the monitoring band, offering real-time monitoring capabilities, historical data review, and customizable alert settings. The aim is to create a holistic solution that not only addresses the physical device but also extends to an intuitive digital interface for caregivers, enhancing the overall effectiveness of neonatal health monitoring.

By addressing these specifications, the Smart Neonatal Vital Monitoring Band aims to provide a comprehensive solution for monitoring the health of neonates in a safe and efficient manner.

3. Possible Solutions

- **Vital Monitoring Band on Wrist-** This solution is feasible as we can measure all the parameters from the wrist with a good level of accuracy. But the wrist of a newborn is quite small so it is difficult to make such a vital band. Moreover, the bones of a newborn are delicate so we should not make them wear a tight band.

- **Vital Monitoring Strap on Chest-** The bones of a newborn are very delicate so, this could damage their bones. Also, accuracy of measurement of SpO_2 on the chest will be low. But we can also measure breathing patterns from a band on the chest if required. Also they might feel suffocation or might feel uneasy to wear it , So this solution can be dangerous for them.

- **Vital Monitoring Band on Head-** Many parameters are already being measured from the head of a baby so many wires are already connected there so measurement from head is not feasible. We can also measure the bilirubin concentration from the head which can help to detect jaundice.

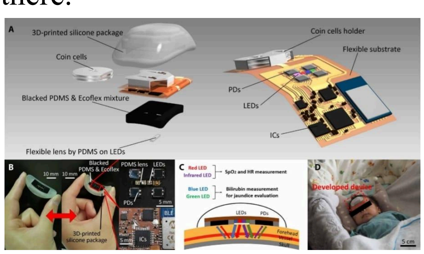
- **Vital Sock**-Integrating sensors into socks poses unique challenges, primarily due to their small size and constant movement. Achieving accurate vital measurements without compromising comfort or durability requires careful consideration of sensor placement, flexibility, and data calibration. Engineers are exploring innovative approaches, such as flexible sensors and smart device integration, to enhance accuracy. Despite these challenges, ongoing advancements in technology hold promise for improving the reliability of vital measurements through wearable sock sensors.

- **Vital Band on Arm**- Accuracy of parameters to be measured will be quite low and there is a possibility of damage to the bones.

- **Vital Band on Waist**- We get a large surface area for measurement of parameters but the accuracy of measured parameters will be low and as the bones of the baby are quite soft it may damage it when we will be trying to measure the vitals as we have to wrap it around the baby's waist.

- **Vital Jacket**- Not feasible, will take a lot of time, is very complicated and wires maybe needed for this.

- **Vital Band on Head (Small sized and Sticky material)**- Many parameters are already being measured from the head of a baby so many wires are already connected there.

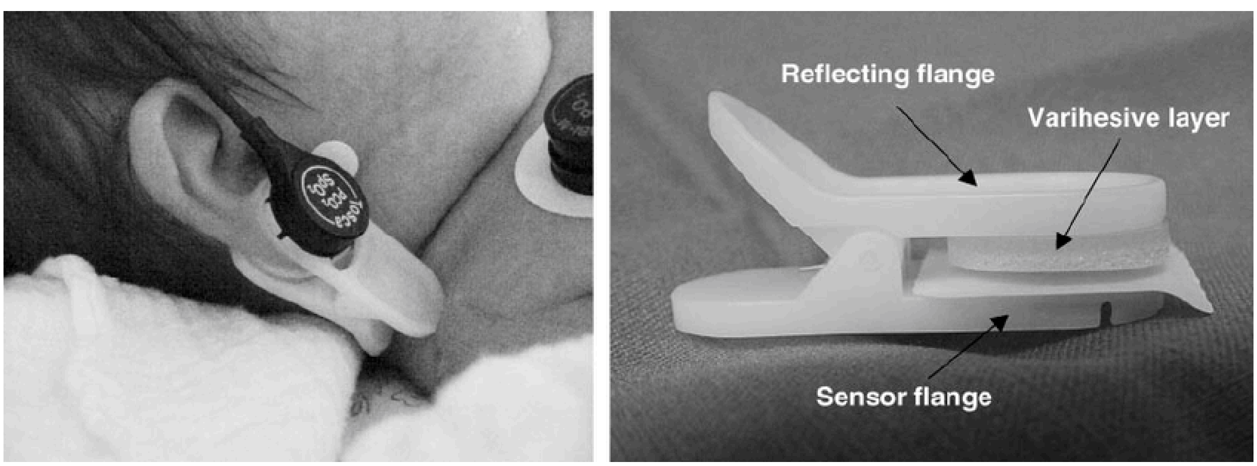


- **Making existing measurement techniques wireless**- The integration of these will be quite difficult and we might still need at least one wire in this case.
- **Fingertip module for vital signs**- The baby's fists are mostly closed and moreover the size of the finger will be quite small, so it is practically really difficult to make this.

- **<u>Vital Band for Ankle</u>**- This is also a feasible solution like on the wrist. We can use the same device for both the ankle and the wrist.

- **<u>Vital Band on Wrist with Separate SpO_2 measurement at Fingertip</u>**- It will be difficult to integrate two devices using one battery and microcontroller. Moreover, the fingers and wrist of the baby are both quite small. And making two different devices will make the process of vital measurement costly.

- **<u>Earlobe clip</u>**- This will be quite small and the measurement of parameters from earlobe is not very accurate. And the skin of the earlobe is very delicate so using a clip might damage the skin.



4.Statistical evaluation of the possible solutions

Solution Description	A	B	D	E	F	G	H	J	I	J	Overall Score
Compact Vital Monitoring device	10	7	8	10	10	9	9	9	9	8	89
Vital Monitoring strap on chest	10	6	8	9	9	10	10	9	8	9	88
Vital Band on the wrist	10	4	7	8	10	8	6	8	8	7	76
Vital Band on head with full band	10	6	8	9	8	9	7	9	8	8	82
Vital sock	10	6	7	10	10	8	7	8	8	10	84
Vital band on arm	10	6	7	7	9	8	6	8	8	7	76
Vital band on waist	10	6	8	3	9	10	10	9	8	3	76
Vital jacket	8	5	7	10	8	10	10	7	7	6	78
Vital Band on head without strap	10	6	7	9	9	5	5	7	6	8	72
Making Wireless	8	5	7	8	7	8	8	9	8	7	75
Fingertip Module for Vital signs	8	4	5	10	10	4	3	6	9	9	68
Diaper Clipper	10	6	8	5	9	8	8	8	8	5	75
Vital Band for foot	10	4	7	7	10	8	6	8	8	6	74
Vital Band on the wrist with separate attachment for fingertip (SpO2)	10	6	6	10	9	6	5	7	8	8	75
Ear Lobe Clip	10	4	5	7	10	3	2	6	9	7	63

A - **Cost of the Idea**

B - **Availability of Parts**

C - **Ease of Manufacturing/Assembly**

D - **Fulfilment of Purpose**

E - **Integration of Power Source**

F - **Integration of Electronics**

G - **Timebound Manufacturing Feasibility**

H - **Overall Feel/Confidence in the Solution**

I - **Ergonomics / Aesthetics**

J - **Maintenance/Servicing Cost**

5.Benchmarking of the proposed solution

<u>Exploration of Solutions</u>:
In the initial phases of our project, we thoroughly examined and brainstormed 10-15 potential solutions to address the stated problem. This involved a comprehensive exploration of various concepts and ideas that could contribute to the development of an effective neonatal vital monitoring device.

<u>Market Research on Existing Products</u>:
To gain insights into the current landscape of neonatal vital sign monitoring, we conducted extensive research on products available in the market. This involved a thorough analysis of both established and emerging solutions. Our focus was on understanding the pros and cons of these existing products.

5.1 AIMON Smart band Baby Monitor Oxygen, Heart Rate, °C, Fall & Crying (Link)

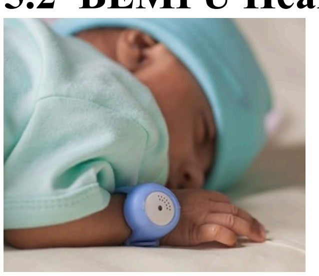
Pros:

1. Great Monitoring capabilities and various data collecting functions being saved onto a cloud server.
2. Easy to use and data is accessible in a wide range of minute intervals (ie. 1 min, 30 min, more) that is easy to understand.

Cons:

1. Device would only stay connected if it was close to the router.
2. Costly.

5.2 BEMPU Health Monitor Pumpkin Bracelet (Link)



Pros:

1.Continuous monitoring with a built in battery which lasts an entire month.

2 .Easy, Safe to use and trusted across the world.

Cons:

1. Battery replacement is not possible.
2. Does not monitor Spo2 and heart rate.

5.3 Mon Baby(A) Baby Monitor with Sensor Alarm That Monitors Temperature, Breathing and Body Movement (Link)

Pros:
1.Wearable monitor that continuously tracks baby's skin temperature plus the ambient temperature around baby's sleeping space: Notifies you when temperature goes outside of preset zones.

2.Pause in breathing movement will be detected by a sensitive smart breathing sensor and an alarm will be sent to your smartphone.

Cons:
1.Battery not rechargeable
2. Costly

5.4 Owlet Dream Sock (Link)

Pros:
1. Use Sleep Data & Expert Tips for Better Sleep - View your baby's sleep data and helpful sleep tips from Owlet sleep experts to support your baby as they learn to embrace sleep and develop life-long healthy sleep habits.

2. See Sleep Quality Indicators - See number of wakings, your baby's heart rate, average oxygen level, and sleep movement and make adjustments to support restful sleep for your baby during every nap and bedtime.

Cons:
1. Costly
2. The Owlet Dream Sock requires both the Owlet device and the connected phone or tablet to be on a 2.4 GHz network during setup. Although this is a standard frequency, it might pose limitations for users who predominantly operate on 5 GHz networks. Users need to perform the initial setup within 10 feet of the router on the 2.4 GHz network, potentially causing inconvenience for those with specific network configurations.

5.5 Sense-U Baby Breathing & Rollover Baby Movement Monitor with Temperature and Humidity Sensors (Link)

Pros:

1. Alert you for no breathing movement, stomach sleeping, overheating and getting cold.
2. No false alarms.

Cons:

1. Had to reset it many times .
2. Costly.

How our product solves the existing problems:

1. Battery Replacement:

Our product would have a replaceable battery, ensuring continuous usage and reducing long-term costs for parents.

2. Cost-Effectiveness:

We would design the product with an emphasis on affordability without compromising on essential features. Our commitment is to provide high-quality baby monitoring at a reasonable price.

3. Comprehensive Monitoring and Data Accessibility:

Our product excels in offering extensive monitoring capabilities, including Spo2, heart rate and skin temperature. The collected data is seamlessly stored on a secure cloud server, allowing parents to access detailed information which is easy to understand, providing a holistic overview of their baby's well-being.

4. False Alarms and Device Reliability: We have prioritized the development of our product to minimize false alarms ensuring that parents only receive critical notifications.

6.Detailed description of the final solution

6.1 Abstract of Solution:

Our project focuses on the development of a Neonatal Vital Monitoring Device, a compact solution for real-time tracking of crucial neonatal parameters—SpO2, heart rate, and skin temperature. Designed with a specialized adhesive for gentle skin attachment, the device wirelessly transmits data using Bluetooth Low Energy (BLE). A corresponding smartphone app interfaces with the monitoring device, enabling healthcare professionals and parents to access timely and accurate information. This report outlines the key aspects of our device, including its design, adhesive material, BLE technology, and the user-friendly smartphone application.

Positioning of sensors: The meticulous strategy of positioning the sensors in direct contact with the delicate skin of the neonate represents a deliberate and judicious design approach that underscores the pursuit of unparalleled accuracy and reliability in monitoring vital signs. By establishing this direct interface, the sensors can effectively capture and interpret nuanced physiological cues, ensuring precise measurements of critical parameters such as SpO2, heart rate, and temperature.

This design philosophy is not merely a technical consideration but a conscious effort to optimize the sensor-skin interface. The intent is to create a symbiotic relationship that harmonizes technological functionality with the paramount need for the neonate's comfort. The direct contact method seeks to minimize any potential discomfort or disruption for the infant, acknowledging the sensitivity of their skin and overall well-being.

A noteworthy outcome of this meticulous approach is the mitigation of external factors that might otherwise interfere with sensor readings. By eliminating barriers between the sensors and the baby's skin, the design minimizes the likelihood of inaccuracies stemming from ambient conditions or external influences. This, in turn, fortifies the reliability of the collected data, providing healthcare professionals with a trustworthy foundation for making timely and informed decisions regarding intervention and care.

In essence, the conscious decision to place sensors in direct contact with the neonate's skin transcends mere technical optimization; it embodies a commitment to precision, comfort, and the generation of reliable data. This comprehensive approach aligns seamlessly with the imperative in neonatal care to balance technological advancements with the delicate needs of the infant, ultimately fostering a framework for vigilant and compassionate healthcare practices.

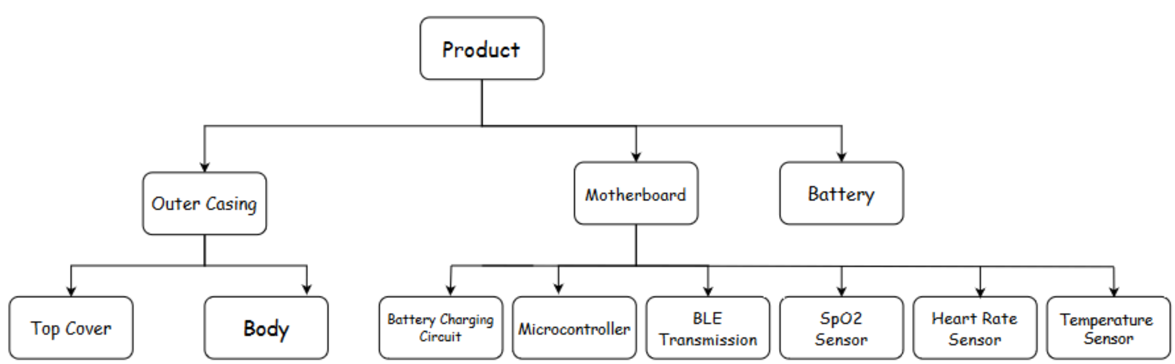
Reason for design without a band: The selection of medical adhesive tape as the means of affixing the device is pivotal, ensuring a secure yet gentle attachment that adheres to stringent medical standards. This approach, characterized by its non-invasiveness, is particularly crucial in neonatal care settings, where the utmost sensitivity and caution are paramount. This method is deemed not only practicable but also profoundly non-intrusive, mitigating any concerns related to potential damage to the infant's fragile skeletal structure.

Furthermore, the emphasis on the lightweight design of the monitoring device amplifies its utility. The intrinsic characteristic of being lightweight contributes significantly to the ease of application and user-friendly experience. This facet is of paramount importance in neonatal care, where the fragility of the patients and the need for precision demand tools that are both efficient and minimally disruptive.

In summary, the comprehensive methodology involves not only the strategic application of medical adhesive tape but also underscores the significance of the device's lightweight construction. This amalgamation of considerations not only ensures the efficacy of vital monitoring but also prioritizes the well-being and comfort of the neonate in the healthcare continuum.

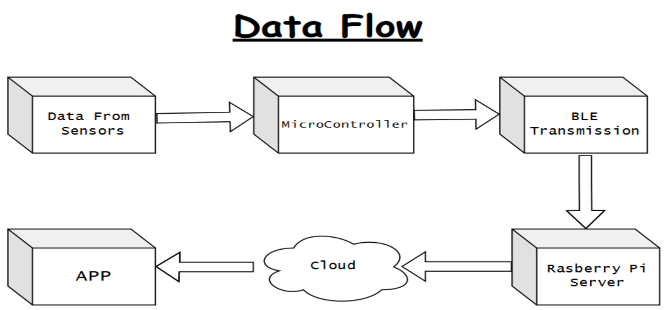
6.2 Working:

6.2.1 Design Schema:



This Smart Vital monitoring device is broken into several components. The outer casing and body protect the delicate inner workings, while the battery keeps everything powered. A tiny computer called a microcontroller runs the show, and sensors like heart rate and SpO2 measure your health metrics.

6.2.2 Dataflow:



The burgeoning need for accessible and efficient remote healthcare solutions propels the development of the Smart Vital Monitoring Band. This wearable device stands as a beacon of innovation, offering continuous monitoring of essential health parameters to enhance patient care and well-being.

The architectural framework is a symphony of interconnected components. Specialized sensors for temperature, SpO2, and heart rate form the sensory core, while a microcontroller with an integrated Bluetooth module serves as the processing hub. This data is seamlessly related to a Raspberry Pi, acting as a central conduit for cloud integration, culminating in a comprehensive and scalable solution.

Sensor Integration: The heart of the system lies in the meticulous integration of temperature, SpO2, and heart rate sensors into the band's design. Calibration and synchronization processes are rigorously executed to ensure precision and reliability in data acquisition, establishing the foundation for accurate health monitoring.

Microcontroller with Integrated Bluetooth Module: At the crux of the system is a microcontroller featuring an integrated Bluetooth module. This sophisticated amalgamation optimizes spatial constraints, power consumption, and communication efficiency. The embedded Bluetooth capability ensures seamless data transmission, maintaining a low-energy channel for reliable, real-time communication between the sensors and the Raspberry Pi.

Raspberry Pi and Cloud Integration: The Raspberry Pi serves as the central processing unit, receiving, and interpreting data from the microcontroller. It acts as a gateway to cloud services, facilitating secure storage and accessibility of health data. This cloud-centric approach not only ensures data integrity and security but also provides scalability and global accessibility.

Cloud Connectivity: Health data is securely transmitted to the cloud infrastructure, allowing for real-time monitoring and historical data analysis. This robust cloud connectivity ensures data availability, enabling healthcare professionals and users to access comprehensive health information remotely.

Mobile Application Interface: The culmination of this integrated system is a user-friendly mobile application interface. This application offers users real-time insights into their vital signs, historical trends, and personalized health recommendations.

The intuitive interface enhances user engagement and empowerment in managing their health proactively.

The Smart Vital Monitoring Band emerges not only as a sophisticated solution for remote health monitoring but as a testament to the synergy of sensor technology, microcontroller with integrated Bluetooth, Raspberry Pi integration, cloud connectivity, and a user-centric mobile application. This holistic approach is poised to revolutionize the landscape of remote healthcare, setting a precedent for innovative and accessible patient care solutions.

6.2.3 BLE Transmission:

One of our key requirements is to monitor vital signals wirelessly. To achieve it we have to consider some wireless transmission techniques to transmit the data to a smartphone or NICU console display. Key factors to consider in the design of a wireless system include frequency bands, transmission power, data modulation and encoding, data encryption, power efficiency, security and compliance, real-time data acquisition, and interoperability.

6.2.3.1 Available options for wireless Transmission3

Technology	Advantages	Disadvantages
BLE (Bluetooth Low Energy)	Very Low Power Consumption	Low Data Rate: Not suitable for high-bandwidth applications.
Wi-Fi	High Data Rate	Moderate Power Consumption: Requires more power than BLE. Security Concerns: Vulnerable to hacking if not properly secured

Technology	Advantages	Disadvantages
ZigBee	Low Power Consumption: Suitable for devices in mesh networks.	Low Data Rate: Limited to simple data transmission. Complexity: Setting up mesh networks can be more complex.
UWB (Ultra-Wideband)	High Data Rate: Offers faster data transfer compared to BLE and ZigBee. Precise Localization: Excellent for applications requiring accurate positioning.	Moderate Power Consumption: Uses more power than BLE but less than Wi-Fi. Limited Device Compatibility: Requires specific UWB-enabled devices.

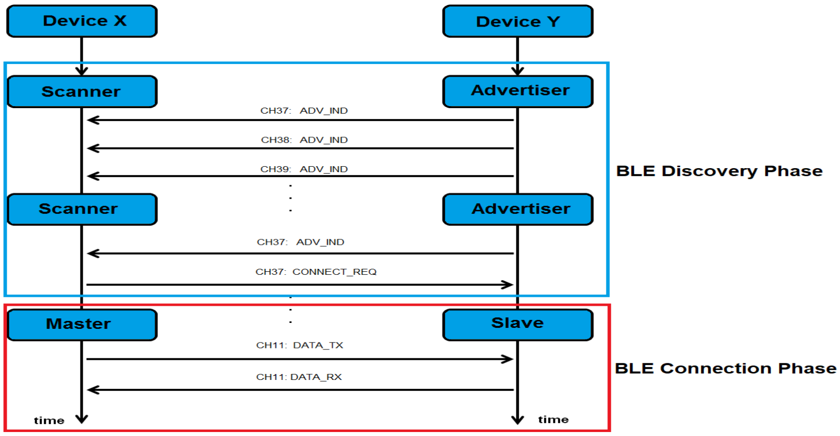
6.2.3.2 Why Choose BLE?

Bluetooth Low Energy (BLE) stands out as an ideal choice for wireless transmission in smart vital band monitoring devices for several reasons. Firstly, its low power consumption extends battery life, a critical factor in wearable medical devices. Secondly, BLE's robust security features, such as encryption and authentication, ensure the protection of sensitive patient data during transmission. Lastly, BLE's widespread adoption in various devices facilitates seamless integration and communication with smartphones and other medical equipment.

6.2.3.3 BLE Architecture and Key Concepts

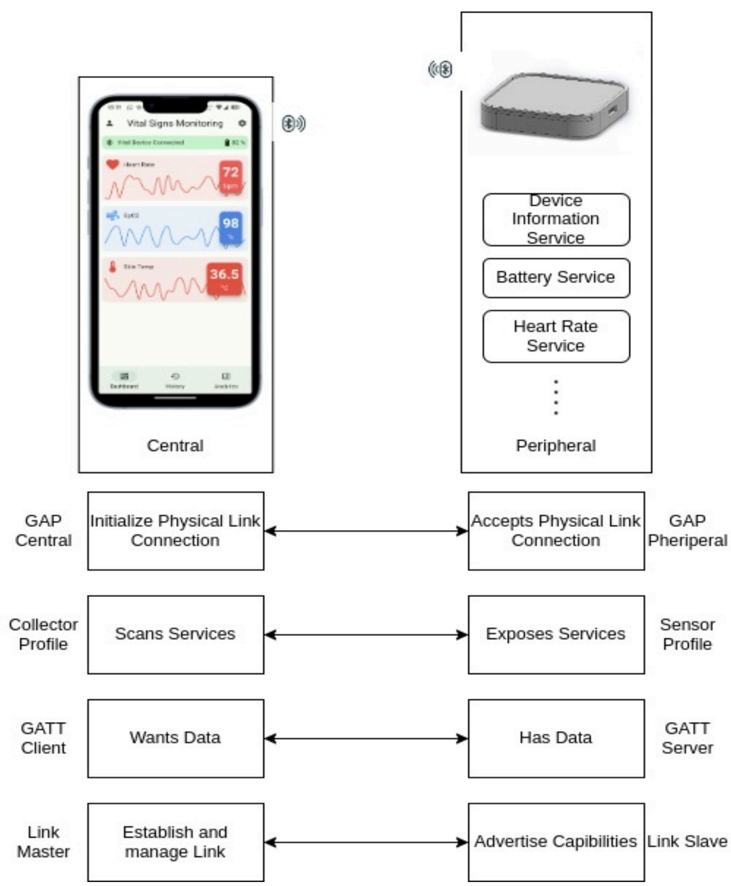
Bluetooth Low Energy (BLE) uses a master-slave architecture, where one device acts as the master and the other device acts as the slave. The master device initiates communication and manages the connection, while the slave device responds to requests from the master. This architecture is designed to be energy efficient, as the slave device only needs to be active when it is responding to a request from the master.

The Generic Attribute Profile (GATT) is a communication protocol that defines a set of attributes that describe the services and characteristics of a BLE device. Services are collections of related characteristics, while characteristics represent individual pieces of data that can be read, written, or subscribed to. This allows for efficient data exchange between devices.

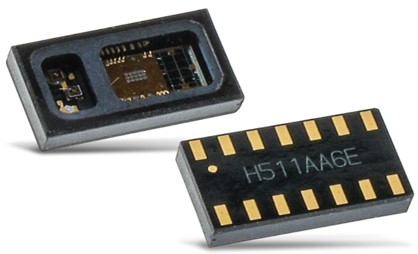


6.2.3.4 System Implementation Plan

The wireless transmission system for the smart vital band monitoring device will be implemented using the Seeed Studio XIAO nRF52840 microcontroller. This compact and powerful microcontroller integrates BLE capabilities, making it an ideal platform for this application. The system's design will prioritize simplicity and ease of integration with other devices.



6.2.4 Specifications:



1. SpO2 and Heart rate Sensor (MAX30100): The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Integrated LEDs, Photo Sensor, and High-Performance Analog Front -End

Tiny 5.6mm x 2.8mm x 1.2mm 14-Pin Optically Enhanced System-in-Package

Programmable Sample Rate and LED Current for Power Saving Ultra-Low Shutdown Current (0.7µA, typ)

2. Temperature Sensor: The Lt Sensors Skin Temperature Probe contains a small biomedical ship thermistor in a metal case with strain relief between the cable and thermistor. The thermistor is designed to operate from 0 °C to 50 °C.

Thermal response time: still air 45 s

Operating range: 0°C to 50°C

Accuracy: ±0.25°C

Height x Diameter: 4.5 x 12 mm (0.18” x 0.47”)

3. Battery: Single Cell 3.7 V Lithium Polymer Battery, thin, light, and powerful.

The output ranges from 4.2V when completely charged to 3.2V. While the nominal voltage of the battery remains at 3.7V, which is also a safe voltage to store the battery at.

7.0mm (Thickness) X 17mm (Width) X 23mm (Length)

4. Microcontroller:

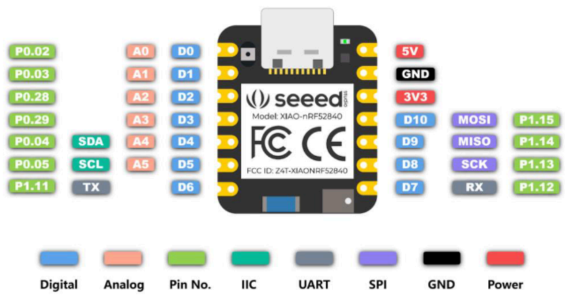
Seeed Studio XIAO nRF5284

4.1 The nRF52840 SoC is the most advanced member of the nRF52 Series. It meets the challenges of sophisticated applications

that need protocol concurrency and a rich and varied set of peripherals and features. It offers generous memory availability for both

Flash and RAM, which are prerequisites for such demanding applications.

4.2 Pinout Reference



4.3 Dimensions:

21 x 17.5 mm

4.4 Power Consumption:

Low power model: <5uA; Normal: 10.38mA

4.5 Operating Voltage:

Type C: 5V; Battery: 3.7V Li-ion

4.6 Charging Current:

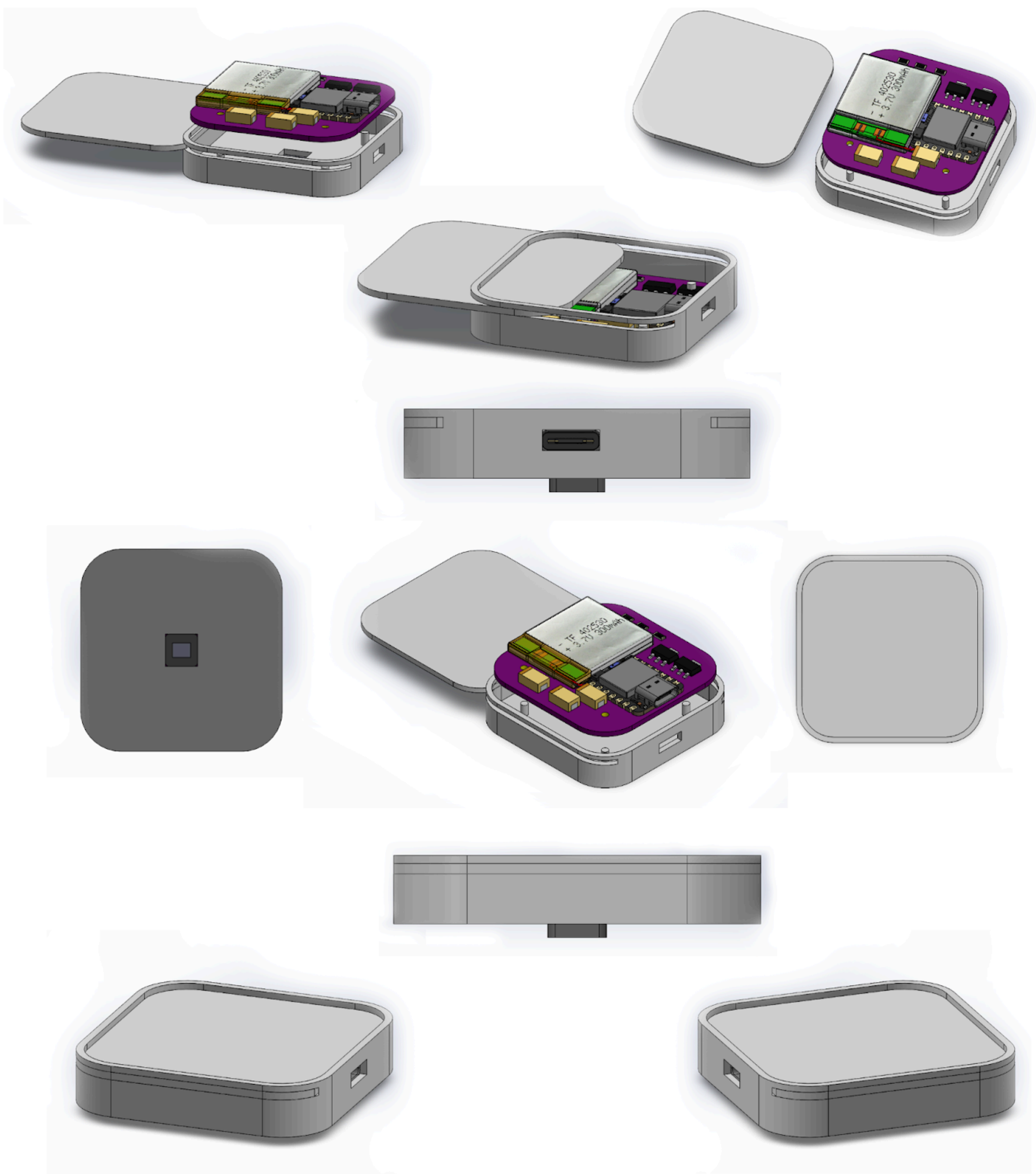
50mA ± 5mA

4.7 Hardware and Software Feature:

Hardware Additional Functionality

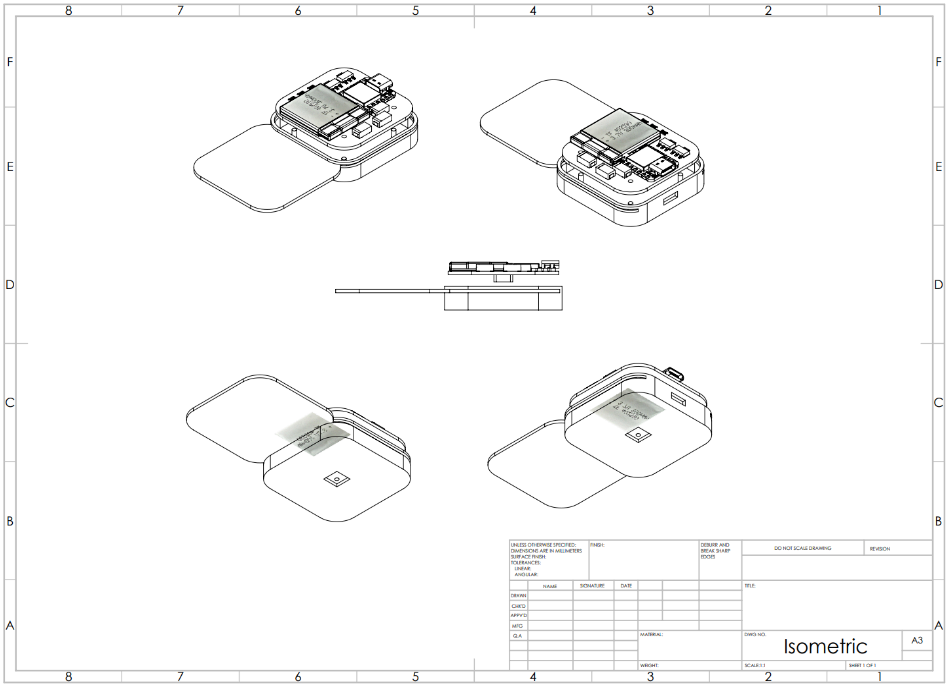
NFC & BLE

6.3 CAD Model

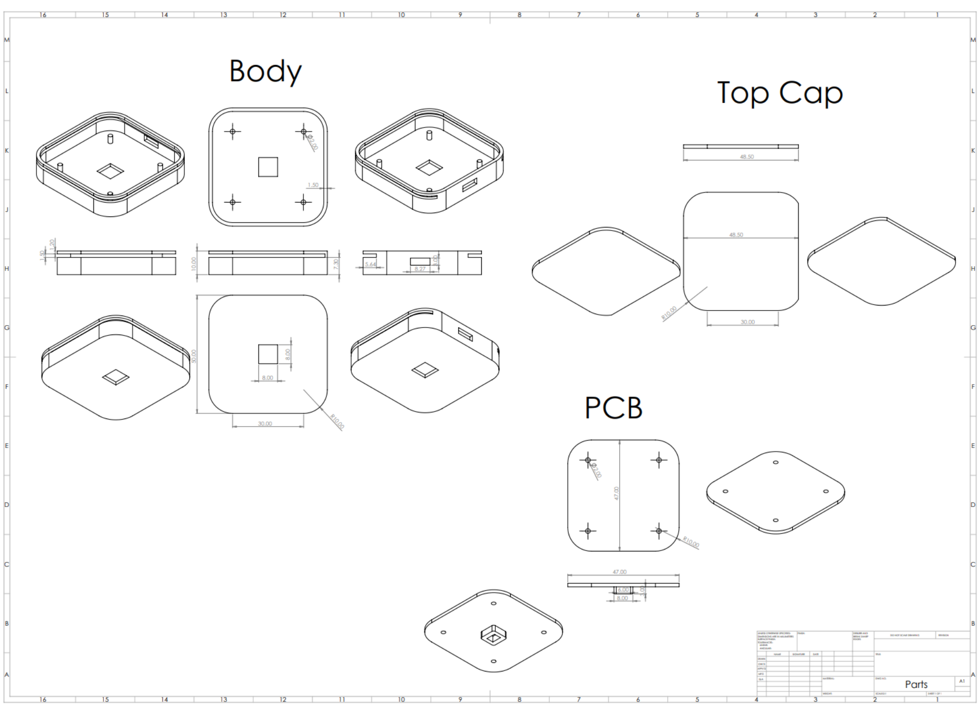


6.4. 2D Drawings

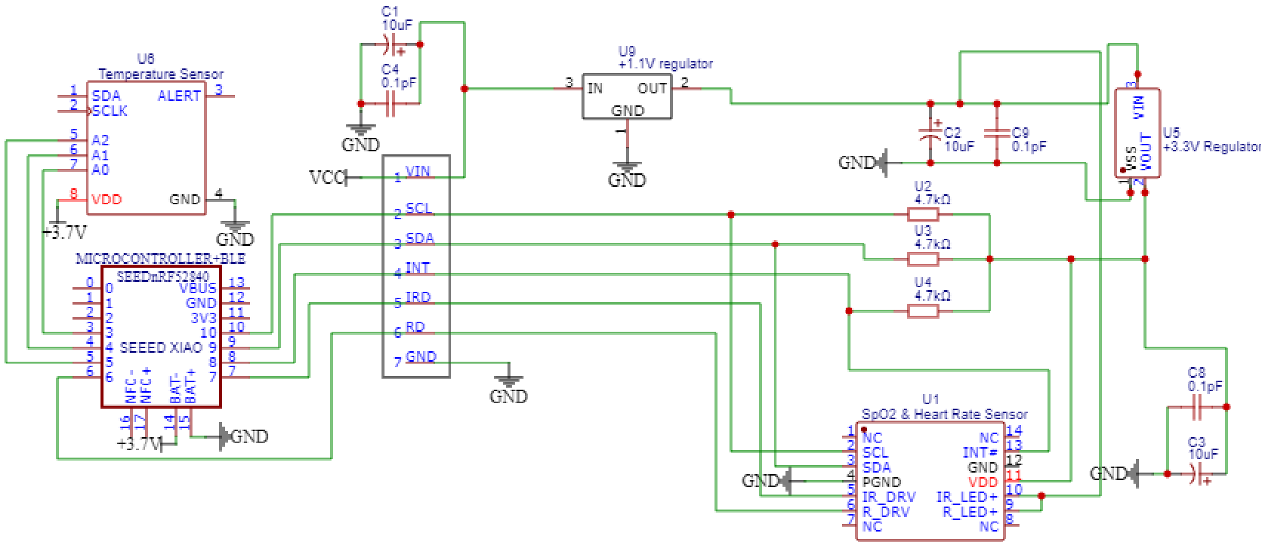
6.4.1. Isometric



6.4.2. Parts



6.5. Circuit schematic diagram



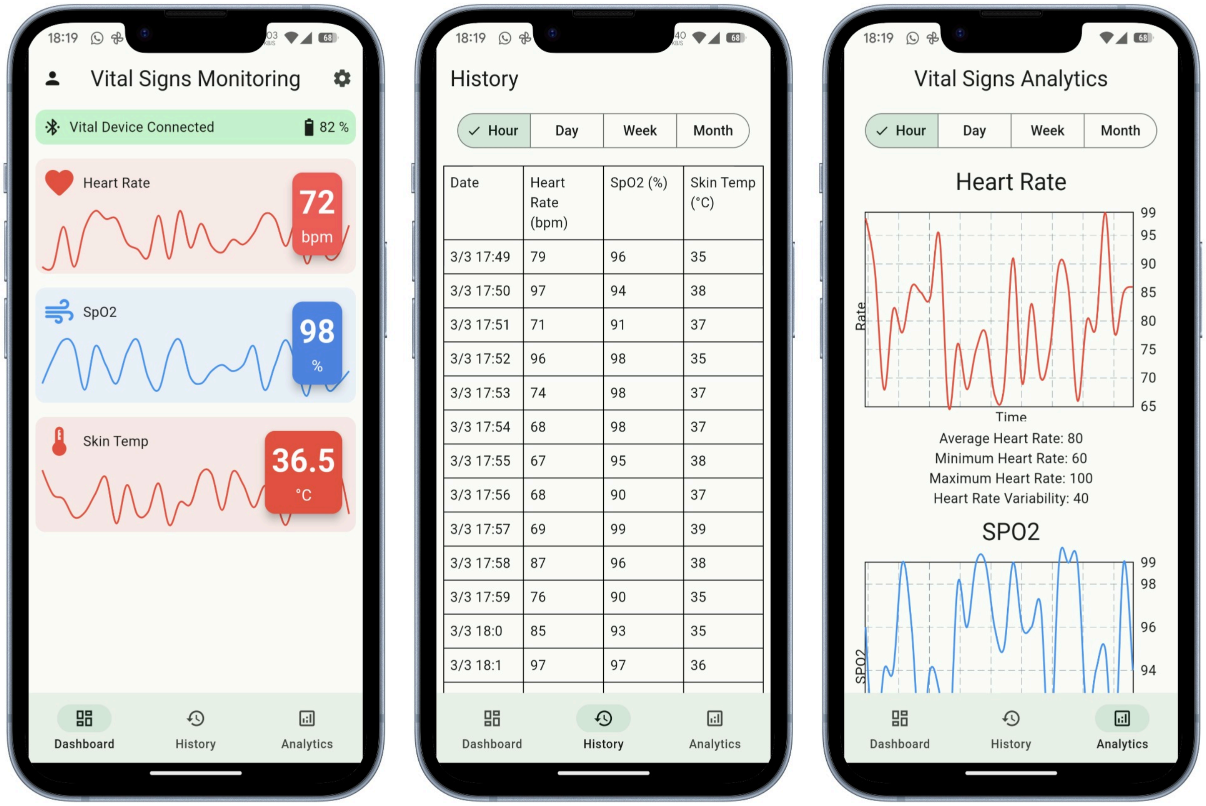
6.6. The App

We are developing a smartphone app that connects with Vital Monitoring Device and receives the sensor data. The app is built in Flutter Framework and supports both Android and IOS Platforms. The app can show live sensor data in real time, and access pass sensor data and analytics data. The app will notify when readings of certain parameters go beyond the threshold limit.

6.6.1. App Features

- Real time Sensor Data Monitoring
- Access Past Sensor Readings
- Alerts when readings reach at critical point
- Cloud Sync

6.6.2. App User Interface (UI)



6.7. Future Scope

The future scope of a project outlines potential advancements and areas for further development. It showcases the vision for how the project can evolve and address future needs.

Here's a future scope for my project: The band will shrink to a comfortable 3cm x 3cm approx. size using a miniaturized MCU and flexible PCB. We'll explore advanced monitoring like sleep and integrate AI for deeper health insights

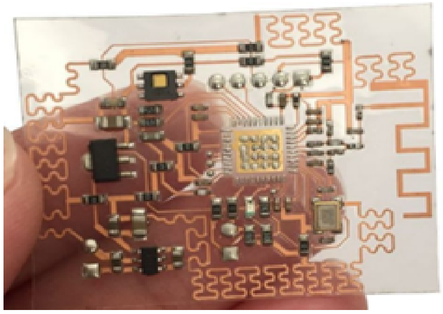
7.1 Miniaturization with Microcontroller Unit (MCU):

- **Explore Microcontroller (MCU) Options:** Transition from a full microcontroller to a more compact MCU unit. Research low-power, miniaturized MCUs suitable for vital sign monitoring applications. Examples include STM32L series, TI MSP430 series or consider custom Application Specific Integrated Circuits (ASICs) for ultimate size reduction.

- **Component Selection:** Prioritize smaller SMD (Surface Mount Device) components for all other necessary electronics like sensors, communication modules etc. This will significantly reduce the overall footprint of the band.
- **Optimization of PCB Layout:** Employ high-density interconnect techniques during PCB design to maximize space utilization within the approx. 3cm x 3cm constraint.

7.2 Flexible PCB Integration:

- **Selection of Flexible Substrate:** Choose a biocompatible and flexible substrate material for the PCB. Polyimide (PI) is a common choice due to its durability, flexibility, and high-temperature tolerance.
- **Design for Flexing:** Design the PCB layout with considerations for flexing. Minimize stress on components and solder joints by incorporating strain relief features and optimizing component placement.
- **Manufacturing Considerations:** Partner with a PCB manufacturer experienced in working with flexible substrates. Flex PCBs often require specialized manufacturing techniques.



Additional Considerations:

- **Power Source Miniaturization:** Exploring alternative power sources like thin-film batteries or energy harvesting techniques to reduce the overall size of the band.
- **Maintaining Functionality:** Ensure that miniaturization and using a smaller MCU does not compromise the core functionalities of vital sign monitoring.

8. Bill Of Materials

Item Name	Quantity	Approximate Cost	Probable Vendor
Heart Rate and Pulse Oximeter Sensor Module	2	3000	Robu
Microcontroller	2	2500	Robu
PCB Manufacturing	-	15000	JLC or PCB Way
Battery	2	2500	Electronics Components
Bluetooth Low Energy (BLE) Pass-through Module	2	1500	Robu
3D printing filament	1	800	Amazon
Material for body of Band	-	2500	From Multiple vendors
Temperature Sensor	2	1000	Zbotic
Miscellaneous	-	1200	-