Functional Design

Smart Guard

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Abbreviation

OLED: Organic Light Emitting Diode

GPS: Global Positioning System

UI: User Interface

ACS: Applied Computer Science

EIE: Electrical Information Engineering

OOP: Object Oriented Programming

I2C: Inter-Integrated Circuit

Glossary

OLED: A type of display.

UI: The point of interaction between a user and a computer program, typically through graphical elements such as buttons, menus, and icons.

OOP: A programming paradigm based on the concept of "objects," which can have data and code to manipulate that data.

I2C: Is a synchronous, multi-master/multi-slave (controller/target), single-ended, serial communication bus

UART: Universal Asynchronous Receiver-Transmitter - A hardware component used for serial communication, allowing data to be transmitted and received asynchronously.

PWM: Pulse Width Modulation - is any method of representing a signal as a rectangular wave with a varying duty cycle (and for some methods also a varying period).

Azure: Microsoft Azure - A cloud computing service provided by Microsoft, offering a variety of services including computing, storage, networking, and more.

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1 Introduction

1.1 Description

This is the functional design document of Safeguard's Personal Safety Device for individuals with epilepsy and a Medication Reminder System application. The goal of this document is to outline how the system should work and what it should do, describing all the features and functions of the Personal Safety Device and the Medication Reminder System. It is also essential to make sure that that the final product is clear and meets the needs and the expectations of users.

1.2 Goal of this document

This document is structured to provide a full design description of the functionality of this project, starting up with **analysis of the requirements** where functional and technical requirements are analyzed thoroughly, moving to the **concept principles** where alternative concepts, comparison between concept principles, and choice of the most promising concepts are considered. At the end an **elaboration of the chosen concept** to design functionally will be addressed with a clear overview of different concepts mechanically, electrically, electronically, and in software. At the end, a clear integration process with all different concepts will be explained.

2 Analysis of requirements

2.1 Medication Schedule Management

- **Requirement:** The system enables users to manage medication schedules, allowing customization for times, frequencies, and medication types.
- **Analysis:** This necessitates a user interface that is intuitive and can handle complex input without overwhelming the user. Technically, a database with the capability to store varied schedules and a logic layer to process and present these schedules are needed.

2.2 Reminder Notifications

- **Requirement:** Users receive reminders through phone, email, or SMS, containing specific information about their medication schedules.
- **Analysis:** A multi-channel notification system must be implemented, capable of generating personalized messages based on user settings and medication data. This involves integrating with external services for SMS and email delivery, and an in-app notification system.

2.3 Emergency Activation and Fall Detection

- **Requirement:** The system must include a panic button and be capable of detecting falls, distinguishing them from normal activity.
- **Analysis:** Hardware capable of sensing abnormal movements and a software algorithm to interpret these movements as falls or emergencies are needed. The system must instantly initiate predefined emergency protocols upon activation or fall detection.

2.4 Location Tracking

- **Requirement:** Real-time tracking of the user's location using location tracking technology, with data relayed to chosen contacts or a monitoring service.
- **Analysis:** Incorporation of a location tracking module into the device, along with software to process location data and send it securely to the necessary contacts or services. Ensures accuracy and timeliness in emergency situations.

2.5 System Architecture

- **Requirement:** A modular system including a mobile application, backend system, communication module, and hardware components.
- **Analysis:** This structure demands a clear separation of concerns among components, ensuring robust data flow and interaction. The mobile application must offer a user-friendly interface, the backend system handles data and logic processing, the communication module manages notifications and alerts, and hardware components support sensing and action functionalities.

3 Concept principals

The conceptual design principles for the Automated Medication Reminder System and Personal Safety Device are fundamentally rooted in the "Must Have" criteria derived from our project's MoSCoW prioritization. These principles guide the development and design framework, ensuring that the final product not only meets but exceeds the essential requirements for functionality, usability, and reliability.

Core Design Principles

Functionality and Reliability:

Reliable Safety Device: The core of our design is predicated on the integration of an ESP32 microcontroller, ensuring a reliable foundation for the safety device. This encompasses a dependable emergency alert system, precise fall detection capabilities, and an effective panic button feature.

Wearable Design: The device is conceptualized as wearable technology, emphasizing comfort, ease of use, and continuous wearability to ensure user safety and medication adherence.

Communication and Alert Systems:

Emergency Alerts and Location Sharing: Incorporating location tracking system and emergency alert functionalities to rapidly notify contacts or services. This principle ensures that in an emergency, users are given swift aid.

Notification System: A pivotal aspect of our design involves the user-friendly mobile app interface, facilitating straightforward medication schedule setups and prompt reminder notifications directly to the user's phone.

User Experience:

Intuitive Mobile Application: The design emphasizes a seamless user experience through a mobile application tailored for ease of setting medication reminders, understanding the importance of user engagement and adherence to medication schedules.

Hardware Integration:

Essential Components: Adhering to our MoSCoW must-haves, the design integrates critical hardware components such as a display for user interaction, a battery ensuring device longevity, radio components for communication, and location tracking system for accurate location tracking. Each element is chosen for its role in enhancing device functionality and user safety.

Guiding Design Considerations

User-Centric Design: Every aspect of the device and application is designed with the user in mind, from the wearability of the device to the interface of the mobile app. This principle ensures that technology serves the user, not the other way around.

Reliability and Safety: Given the device's role in critical safety and health management scenarios, reliability is paramount. This includes not only the physical reliability of the device but also the dependability of its software systems.

Simplicity and Accessibility: The design prioritizes simplicity in user interaction, making technology accessible to users of all ages and tech-savviness levels. This includes easy setup processes, straightforward medication scheduling, and one-touch emergency alerts.

3.1 Alternative concepts

	CONCEPT 1	CONCEPT 2	CONCEPT 3
DISPLAY	IPS-TFT	OLED	E-Ink
BATTERY	LiPo 550mah	Button cell 6mah	
RADIO (bluetooth, wifi, LTE, etc)	LoRa	Wi-Fi	Bluetooth LE
LOCATION DETECTION	Integrated GPS	Location via phone	Mesh network
FALL DETECTION SENSORS	Accelerometer	Gyro Sensor	Accelerometer&Gyro
Processing platform	Microcontroller	FPGA	PLC
Vibration Module	Coin vibration	linear resonant A	Vibration Motor
Sound Module	Buzzer Piezo	Piezoelectric Buzzers	Speaker
Charging methods	USB Charging	Wireless Charging	Replacable Batterry
Central server	Microsoft Azure	Raspberry Pi	Laptop/Pc

Figure 1 - Table of concepts.

Concept 1:

- Display: OLED
- Battery: LiPo 550mAh
- Radio: WiFi
- Location Detection: Integrated GPS
- Fall Detection Sensors: Accelerometer and Gyroscope
- Processing Platform: Microcontroller
- Vibration Module: Vibration Motor
- Sound Module: Buzzer Piezo
- Charging Methods: USB Charging
- Central Server: Microsoft Azure

Concept 2:

- Display: IPS-TFT
- Battery: Button Cell 6mAh
- Radio: Bluetooth LE
- Location Detection: Via Phone
- Fall Detection Sensors: Accelerometer and Gyroscope
- Processing Platform: Microcontroller
- Vibration Module: Vibration Motor
- Sound Module: Speaker
- Charging Methods: USB Charging
- Central Server: Raspberry Pi

Concept 3:

1- Display: OLED
2- Battery: LiPo 550mAh
3- Radio: LoRaWAN
4- Location Detection: Integrated GPS
5- Fall Detection Sensors: Accelerometer and Gyroscope
6- Processing Platform: Microcontroller
7- Vibration Module: Vibration Motor
8- Sound Module: Speaker
9- Charging Methods: Replaceable Battery
10- Central Server: Laptop/PC

3.2 Comparison of Concepts

Selection of Most Important Criteria

- Accuracy
- Cost
- Weight
- Battery Life
- Complexity

Table for comparison

	CONCEPT 1	CONCEPT 2	CONCEPT 3	WEIGHTS
SIZE	+++	+	--	10%
COST	++++	+	-	15%
WEIGHT	+-	-	---	20%
ACCURACY	+++	+	-	25%
BATTERY LIFE	-	+	+	20%
COMPLEXITY	++	-	--	10%

Figure 2 - Concepts comparison.

Display	Cost	Durability	Efficcency
IPS TFT	<	<	<
OLED	<<	<	<<
E-Ink	<<<	<	<<<

Battery	Cost	Durability	Capacity
LiPo	<<	<	<<<<
Button Cell	<	<<	<

Radio	Range	Bandwidth	Connection Time
LORA	<<<<	<	<
WIFI	<<	<<<	<<<<
BT LE	<	<<	<<<<

Location Detection	Cost	Accuracy	Effiecency
GPS	<<<	<<<	<<<
Phone Link	<	<<<	<<<<
Mesh	<<<	<	<<

Fall Detection	Cost	Accuracy	Effiecency
Acceleromet	<	<<<	<<
Gyroscope	<	<<	<<
Accelerometer & gyro	<<<	<<<<	<<<

Processing Platform	Cost	Speed	Effiecency
Microcontr	<	<<	<<<<
FPGA	<<<<	<<<	<
PLC	<<<	<<<<	<<

Alarm	Cost	Attetion	Noise
Coin	<	<	<<
Linear	<	<<<	<
Motor	<<	<<<	<<

Sound	Cost	Attetion	Noise
Piezeo	<	<	<<<
Speaker	<<	<<<	<<

Figure 3 - Concepts comparison 1.

Charging	Cost	Durability	Efficiency
USB	<	<<<	<<<<
Wireless	<<<	<<<<	<<
Replacable	<<	<<	<

Server	Cost	Scailabilty	Responcetime
Pi	<<	<<	<<
Azure	<<<	<<	<
Pc	<<<	<<<	<<<<

Figure 4 - Concepts comparison 2.

Display:

- Concept 1 and Concept 3 both have OLED displays. Concept 2 uses IPS-TFT, which might provide better visibility in bright conditions but could consume more power compared to OLED.

Battery:

- Concept 1 and Concept 3 both use LiPo batteries with a higher capacity (550mAh), providing longer battery life compared to the smaller Button Cell battery (6mAh) used in Concept 2.

Radio:

- Concept 1 uses WiFi offering relatively high bandwidth and faster data transmission speeds within the range of a WiFi network.
- Concept 2 uses Bluetooth LE offering low power consumption and compatibility with mobile devices.
- Concept 3 uses LoRaWAN a wireless communication technology optimized for long-range transmission with low power consumption.

Location Detection:

- Concept 1 and Concept 3 use integrated GPS for location detection, providing accurate positioning.
- Concept 2 relies on location detection via phone, which may not be so accurate.

Fall Detection Sensors:

- All concepts use accelerometers and gyroscopes for fall detection, which is more accurate than using only accelerometer or gyroscope.

Central Server:

- Concept 1 uses Microsoft Azure, Concept 2 uses Raspberry Pi, and Concept 3 uses a Laptop/PC. Microsoft Azure offers higher scalability, and reliability compared to Raspberry Pi or the Laptop/PC.

3.3 Concept Choice

As can be seen in the alternate concept table (Figure 1), certain components have been highlighted in red, these components are going to be used in the final concept, these components where selected based on the results from the comparison table (Figure 2). As seen in Figure 2, the most promising base concept was Concept 1, made practical by swapping components from other concepts.

4 Elaboration of functional design

4.1 Overview of design

This concept design is a personal handheld watch for people with seizures. The system uses technologies including an OLED display, LiPo battery, Wi-Fi connectivity, GPS for location detection, accelerometer & gyro for fall detection, microcontroller for processing, vibration motor, buzzer piezo for alerts, USB charging module, and cloud server Microsoft Azure with a Microsoft SQL Server database.

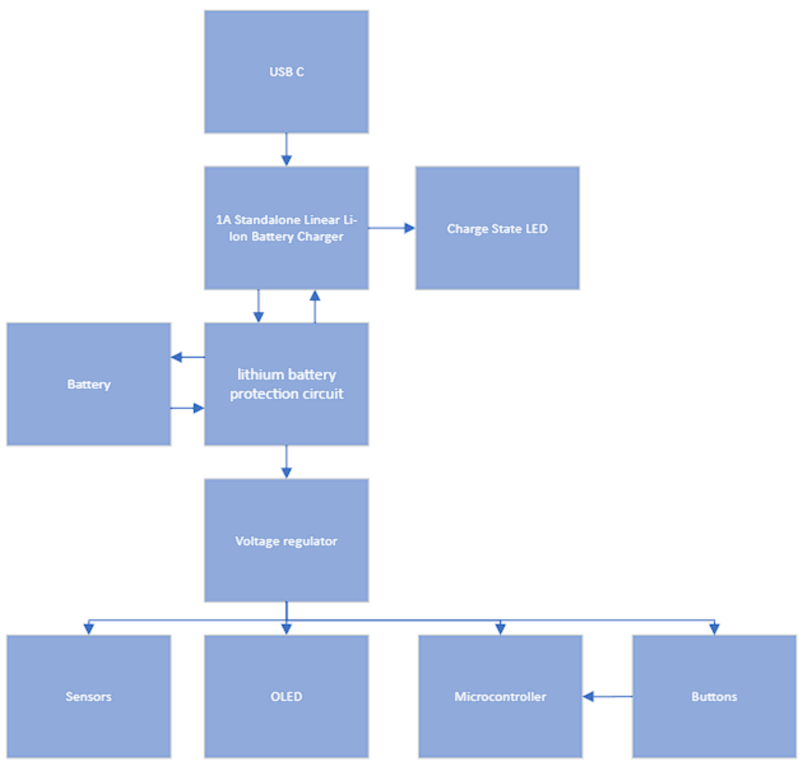

Figure 5 - Power supply block diagram.

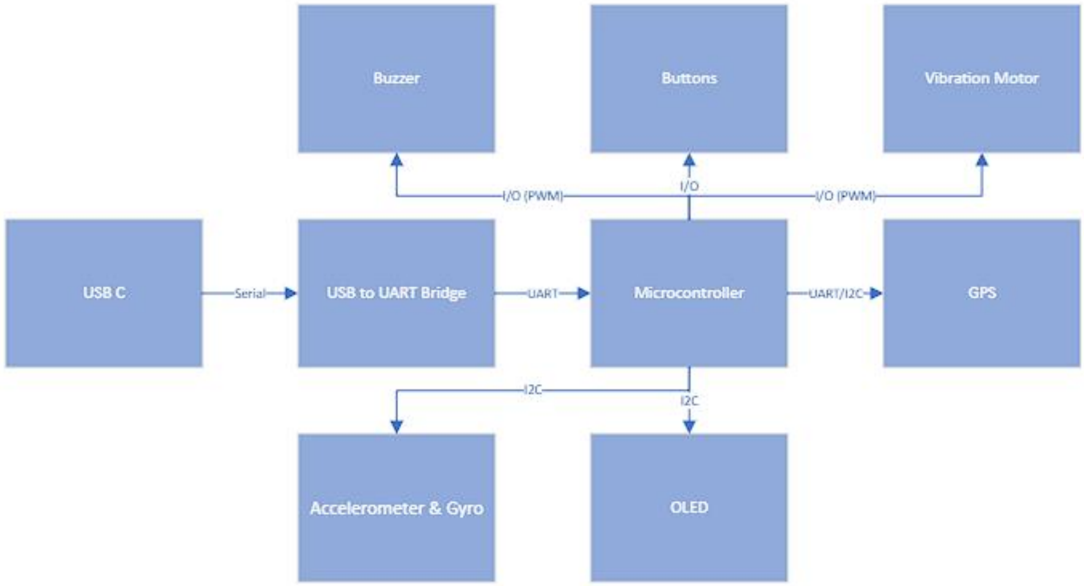

Figure 6 - Electronic functional block diagram.

4.2 Elaboration of design

4.2.1 Mechanical

The mechanical design of the smartwatch for the Personal Safety Device and Personal Medication Reminder System plays a crucial role in ensuring its functionality, comfort, and usability for epileptic patients. This chapter focuses on the positioning and relationships of major components. Where this stage involves dynamical and/or thermal calculations to ensure optimal performance and durability.

4.2.1.1 Mechanical Layout

The mechanical layout of the smartwatch includes the positioning and interaction of critical components, considering factors such as mass distribution, structural strength, and thermal management. Key components include:

Frames: The frame of the smartwatch serves as the structural backbone, providing support for internal components and ensuring overall robustness. It undergoes analysis for mass distribution, strength, and stiffness to withstand daily wear and potential impacts. Eigenfrequency analysis is conducted to find and mitigate resonance issues that could affect performance.

Mechanisms and Guidance: Mechanisms such as buttons, sensors, require precise guidance and support to function effectively. Stiffness analysis is performed to ensure that the mechanisms operate smoothly without excessive play or resistance. Disturbance forces generated during operation are evaluated to minimize their impact on device functionality and user experience.

Drives: The drive system of the smartwatch is a critical component that ensures the smooth operation of various functions such as vibration alerts and display operation. This section outlines the key aspects of the drive system, including dimensioning, transmissions, and flexibilities. Below are some key aspects of the drive system:

Dimensioning: Dimensioning involves determining the proper size and specifications of drive components to meet the system requirements of the smartwatch. Factors such as power consumption, and space constraints are carefully considered during the dimensioning process. By accurately dimensioning the drive components, optimal performance and energy efficiency can be achieved while minimizing unnecessary bulk and weight.

Flexibilities:

Flexibility analysis is conducted to assess the structural flexibility of the drive system components and identify potential points of failure under different operating conditions. This involves analysing the stiffness of individual components and their interconnections to ensure stability. By finding and addressing potential sources of flexibility, the reliability and durability of the drive system can be enhanced, minimizing the risk of mechanical failures or malfunctions.

4.2.1.2 Material Selection and Thermal Management

Material selection is a critical aspect of the mechanical design, with a focus on durability, weight optimization, and thermal conductivity. Components are constructed from materials such as lightweight to minimize mass while maintaining structural integrity. Thermal management strategies, including heat sinks and thermal insulation, are implemented to dissipate heat generated by internal components and ensure optimal operating temperatures.

4.2.2 Electrical

The electrical design phase is integral to the development of the smartwatch, focusing on creating an efficient layout of electrical modules and establishing interconnections at the wiring level. This section focuses on key considerations regarding power supply and amplification within the smartwatch.

Supply: Power and Amplifiers

Power supply management is crucial to ensure the seamless operation of the smartwatch's electrical components. This involves selecting appropriate power sources, such as batteries or rechargeable cells, capable of providing sufficient voltage and current to drive various functionalities while considering energy efficiency and longevity.

Amplifiers are essential components within the electrical system, tasked with boosting signals to ensure accurate and reliable transmission of data and commands. Whether it's amplifying signals from sensors or enhancing audio output for alerts and notifications, the design of amplifiers must align with the specific requirements of the smartwatch's functionalities.

In the electrical layout, careful attention is paid to the placement and routing of power lines and signal paths to minimize interference and optimize performance. Moreover, provisions are made for voltage regulation, filtering, and protection mechanisms to safeguard sensitive components from voltage fluctuations, noise, and overcurrent conditions.

In conclusion, addressing power supply and amplifier design within the electrical layout, the smartwatch can achieve optimal performance, efficiency, and reliability, meeting the diverse needs of its users while ensuring seamless operation in various environments and conditions.

4.2.3 Electronic

The Microcontroller will be programmed through the USB C port, because of this there needs to be a conversion between USB and UART, that is handled thought the USB-UART Bridge, from there the microcontroller can communicate to a computer directly, the microcontroller will make use of I2C to communicate to the sensors and display, the GPS module may use either UART or I2C it depends on the module chosen. Both the Buzzer and Vibration motor will be connected to GPIO with PWM capabilities, allowing for better control over pitch and noticeability. The buttons will be connected directly to any available GPIO as they have no specific requirements or standards to adhere to.

4.2.4 Software

4.2.4.1 Software functions algorithms:

In the following diagram the algorithms for the main functions of the personal safety watch will be explained. Also, important Libraries or dependencies will be shown.

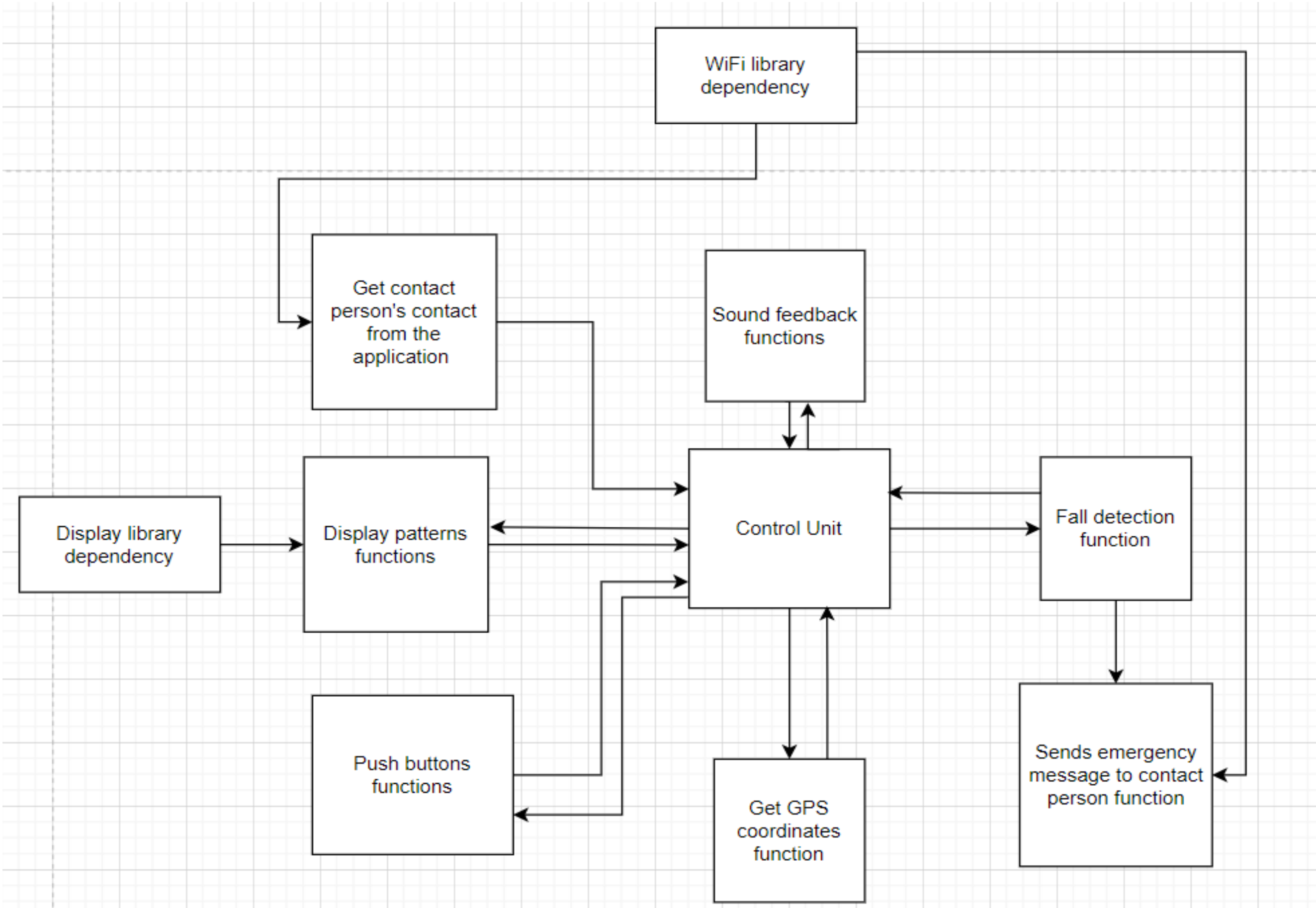

Figure 8 - Functional algorithms.

4.2.4.2 Architecture Diagram with modules and interface

The following diagram shows an explanation of the modules and interfaces.

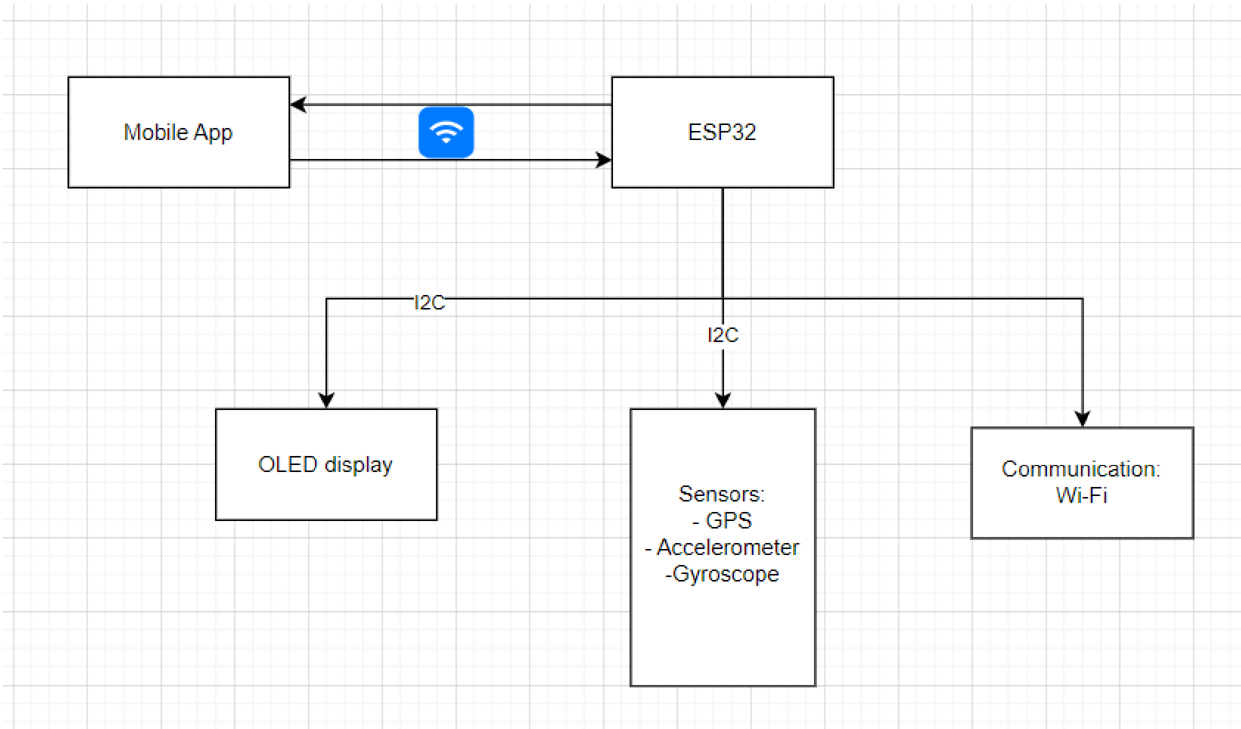

Figure 10 - Architecture Diagram.

The communication between the ESP32 and the Mobile application will be through Wi-Fi, this is mainly for inserting or editing contact person.

The communication between the microcontroller and the display and the sensors module will be through I2C.

The following image is a simple sketch drawing of the system.

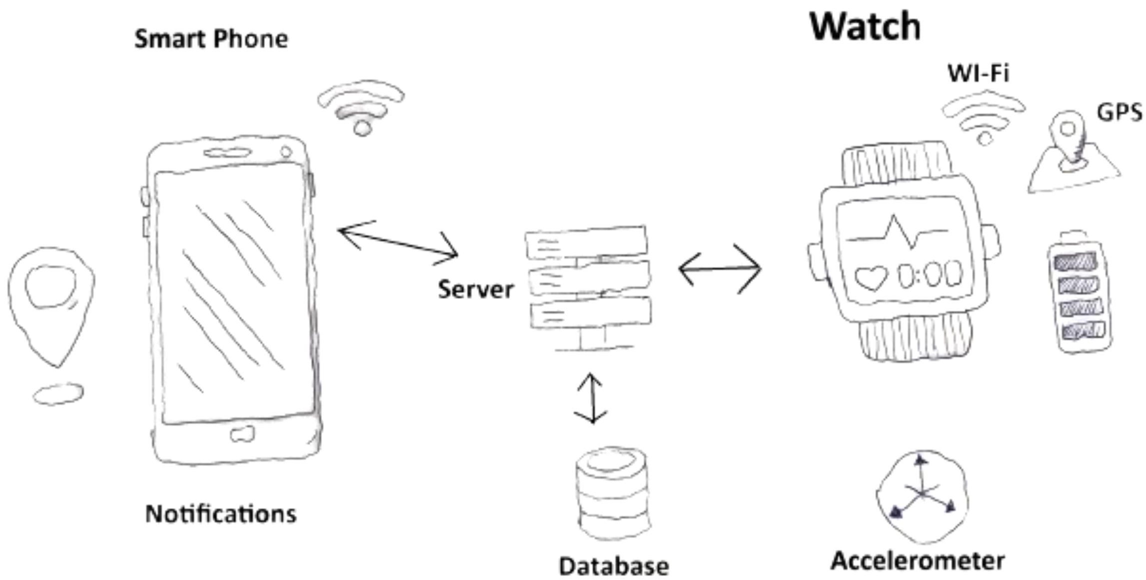

Figure 11 - Concept Sketch.

4.2.4.3 System states plus state transition diagram.

The following image explains the system state diagram.

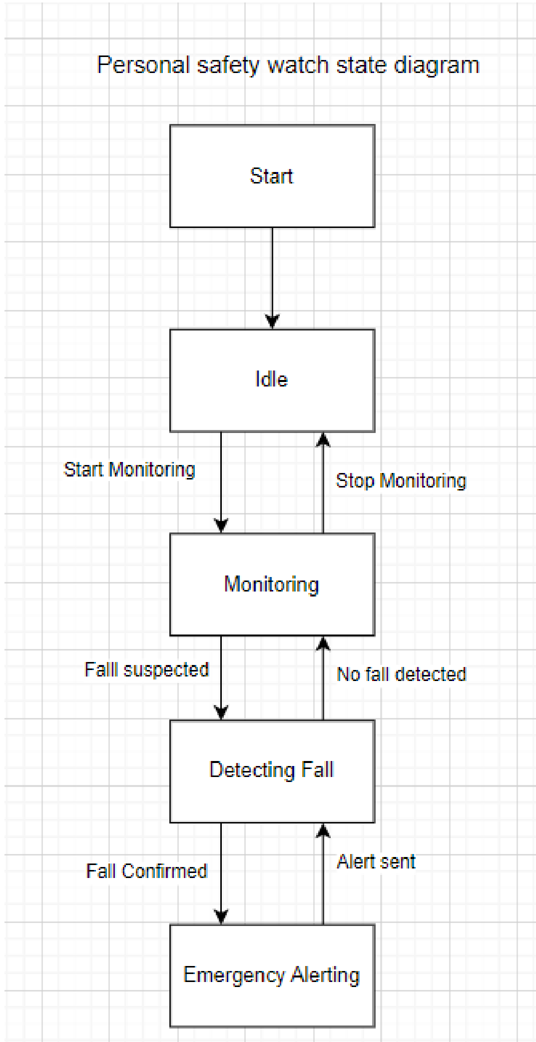

Figure 120 - State transition.

The following diagrams will explain the state transition in the system.

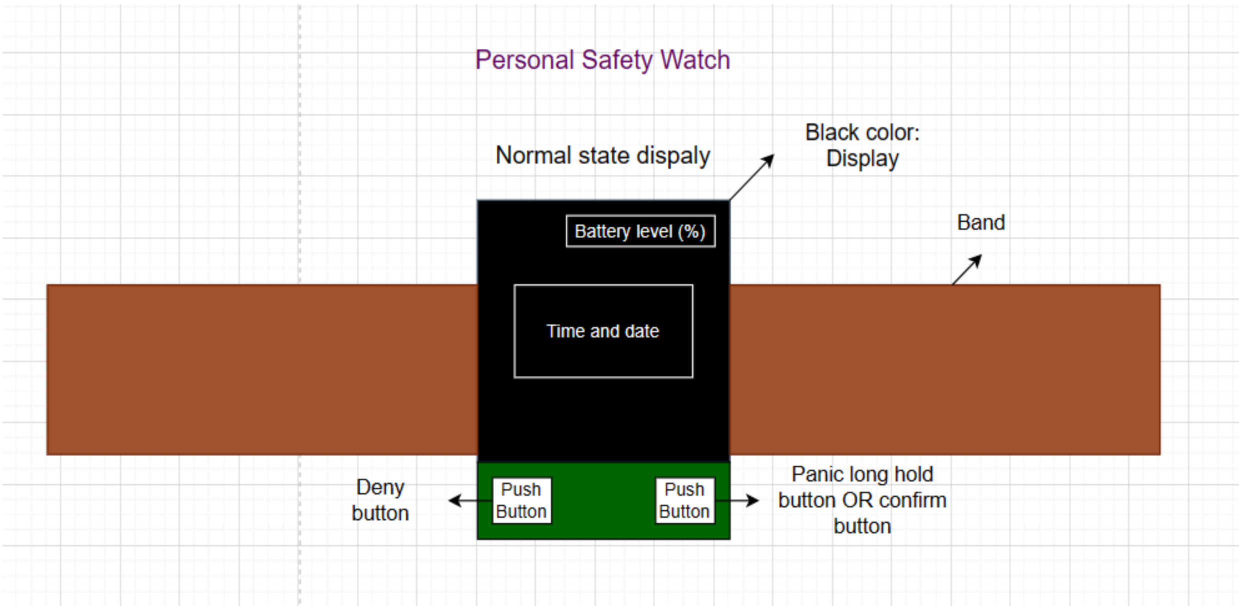

Figure 131 - Safety watch normal state.

The previous image shows the personal safety watch in the normal state, where it shows the display that will show the battery life, the time and date.

A long hold panic push button is also shown for cases where the user feels in trouble and needs help.

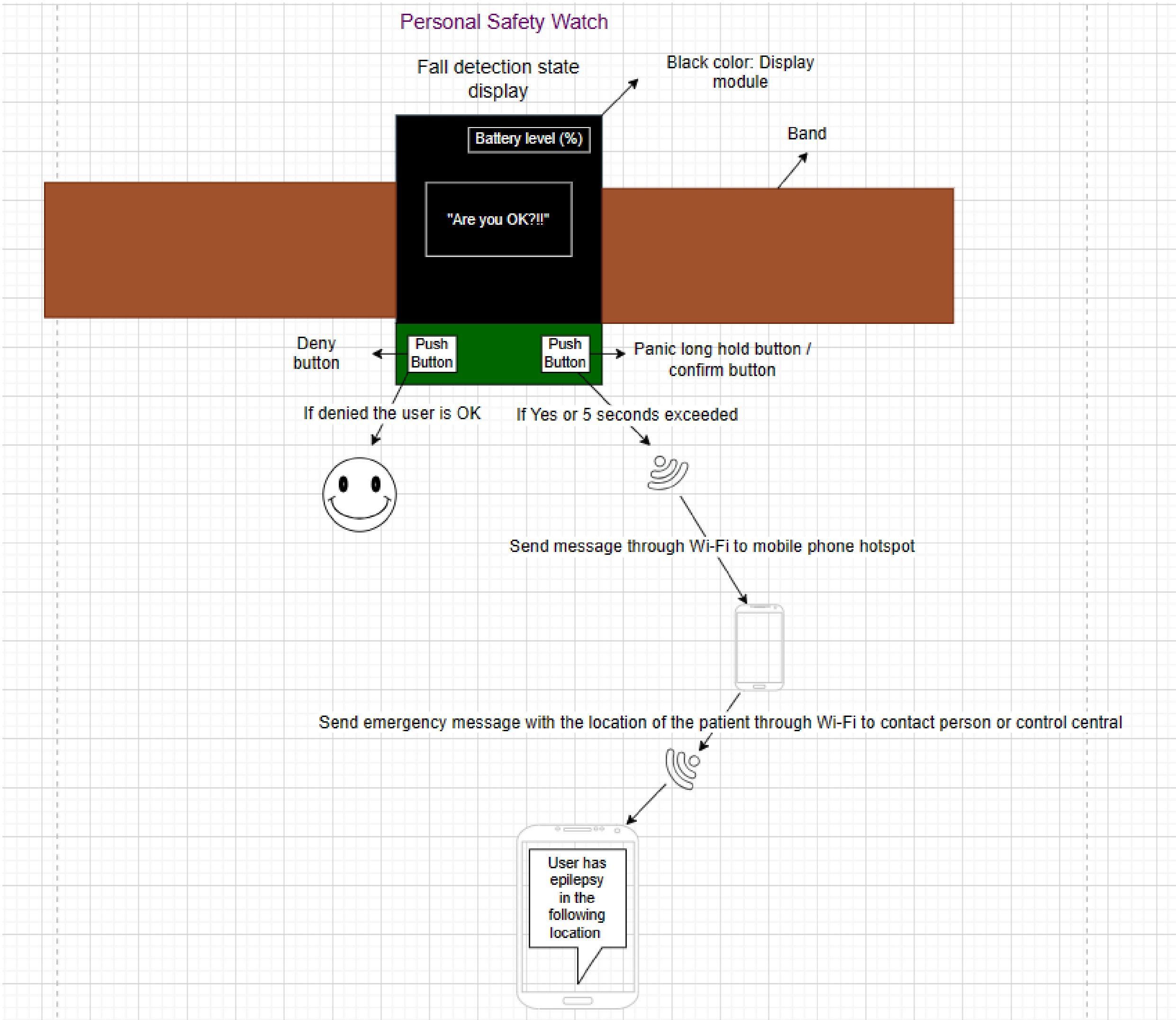

Figure 14- Personal safety watch in emergency state.

The previous image shows the personal safety watch in emergency state. If a fall is detected a notification in the watch's display will show up as shown in the image "Are you OK?". If the deny button is pressed, then the user is ok.

Otherwise, within approximately 5 seconds if the user did not react to the notification. Then an emergency signal with the location will be sent from the microcontroller to the user's mobile hotspot, which will be sent to the contact person or the control centre.

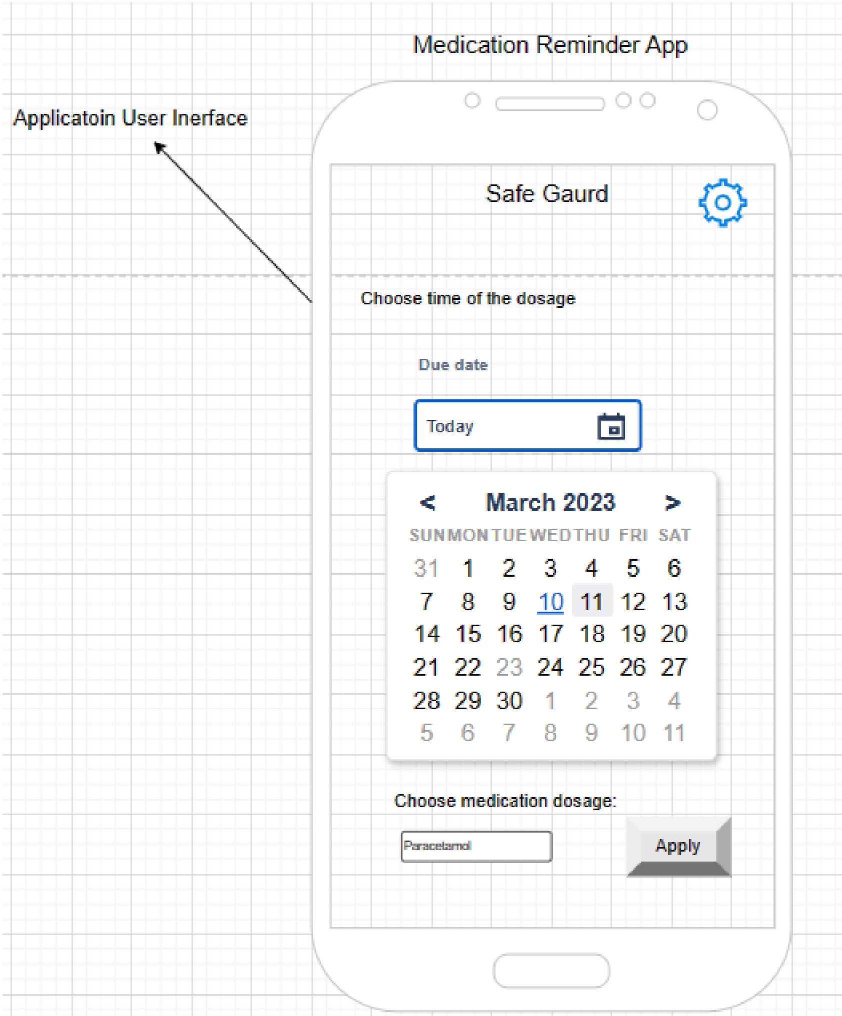

Figure 15 - Medication reminder application.

The previous image explains how the application user interface will look like. The user will be able to input a date, time, and dosage. And can change the setting for his preference, for instance changing the UI theme to dark mode and insert or change an emergency number to the personal safety device.

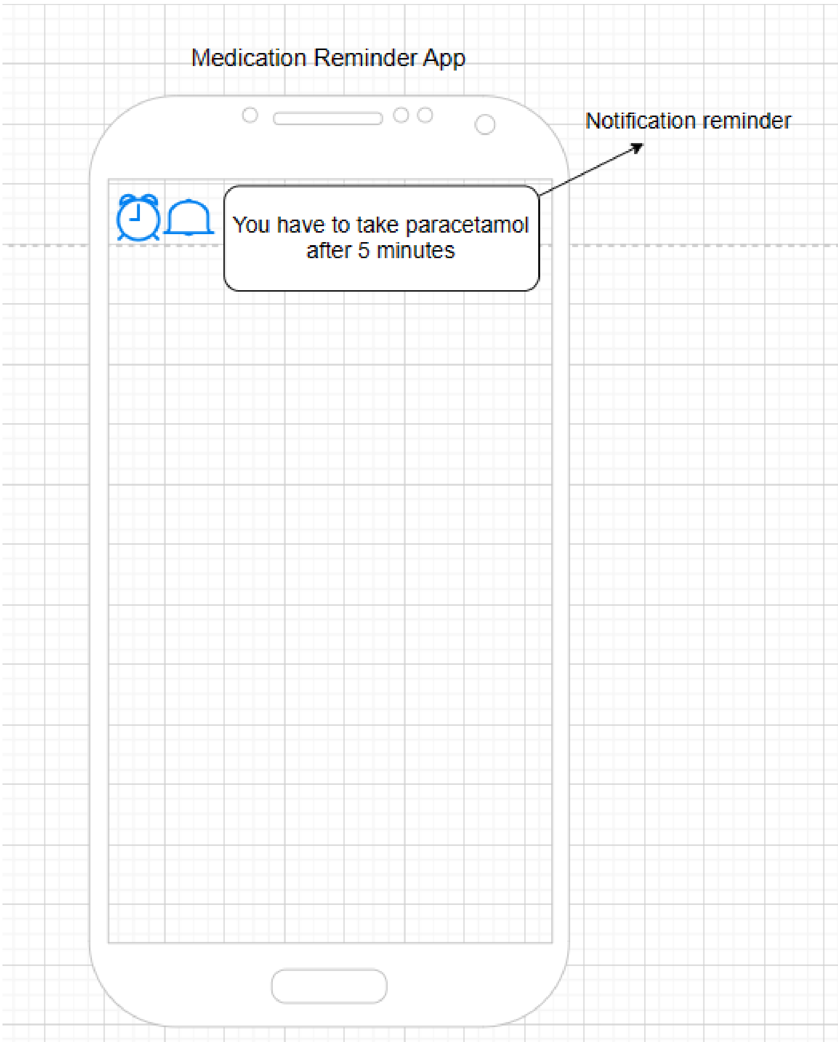

Figure 14 - Medication system mobile notification state.

The previous image clarifies that after the user has set the date, time, and the dosage of the modification. A mobile notification will be sent to him or her 5 minutes before the dosage intake.

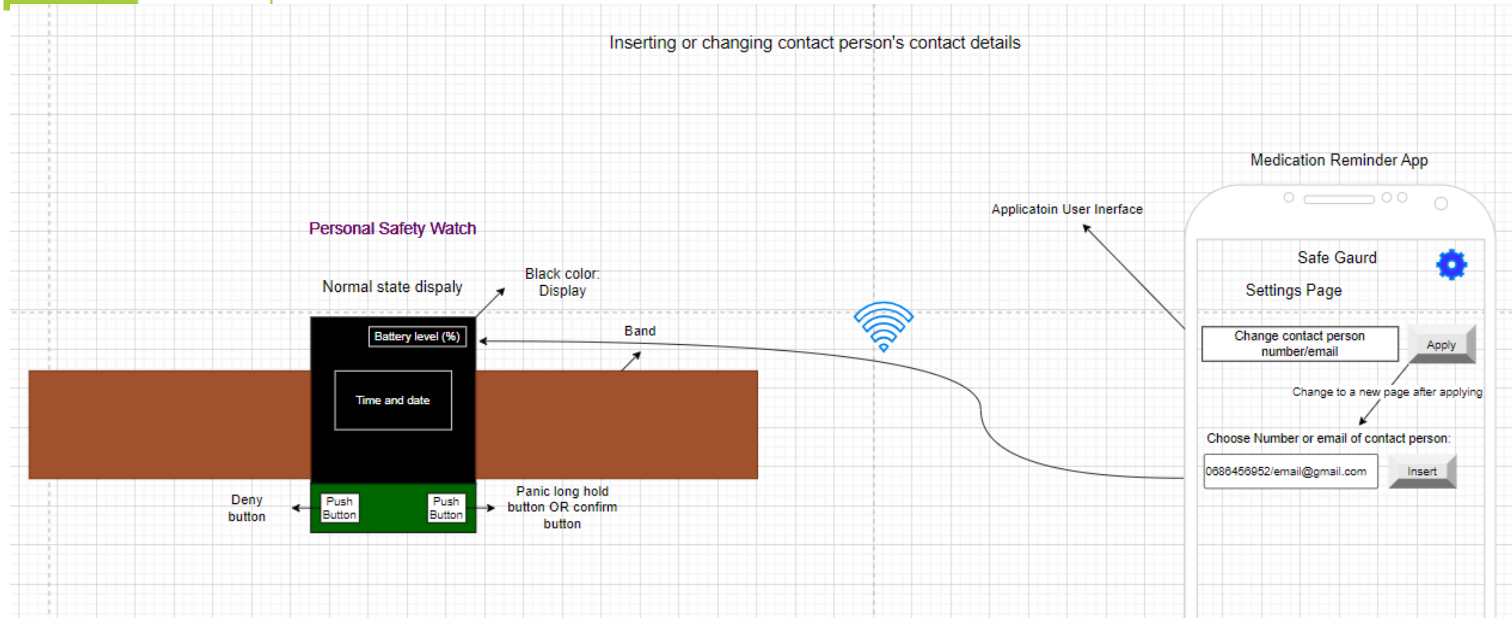

Figure 16 - Inserting a contact person and sending it to esp32.

In the previous image the functionality of inserting or changing a contact person number or mail is explained simply. The user will be able to change the contact person's contacts wirelessly using Smart Guard's Application.

4.2.4.4 Programming language and environment.

C/C++ are the main language/s to program the microcontroller and modules.

Arduino IDE will be the main Integrates development environment.

4.3 Functional design integration

The functional design integration involves how sections like, safety, speed, accuracy, cost, and maintenance can impact the overall functional design.

Safety: Safety is crucial in a system for people with seizures. The overall safety of this system should include features such as fall detection (accelerometer & gyro), panic button, and location tracking (GPS). The panic button should be as a safety feature for backup if the fall detection algorithm fails.

Speed: The speed of the overall system should be quick and responsive to alert the user when to take his/her medication accurately, contact the emergency contact as soon as a fall has been detected, and sending the exact location as fast as it happens.

Accuracy: The overall functional system should accurately send medication reminders at the exact same time the user has set them, precise GPS tracking, and accurate fall detection algorithm.

Cost: The overall system should not be costly without the cost of quality.

Maintenance: The overall functional system should have software updates and should have a chargeable battery. It should also give the user instructions on the app such as a help section.

5 Conclusion

To conclude, the device the chosen concept will have all the required features for to help individuals with seizures.

1- Display – OLED: an OLED screen was chosen for its simplicity, its low power consumption, and its great display.
2- Battery – LiPo 550 mAh: the lithium polymer battery was chosen for its good battery and life, weight, and size.
3- WIFI & GPS: an integrated WIFI and GPS module was chosen, so that the device can communicate with the server and provide accurate location of the user.
4- Processing unit – Microcontroller: A microcontroller was chosen as the brains of the device to communicate with all the components in the watch as it is simple and small.
5- Vibration Module – Vibration Motor: It was chosen for its small size and weight to provide the user with feedback.
6- Sound Module – Buzzer Piezo: It is used to give the user sound feedback when there are alerts. It was chosen for its size, weight, and cheap cost.
7- Charging Module – USB Cable: It was chosen as it will be easy for the user to just charge the watch instead of having to change batteries.

Limitations:

Some limitations that are going to be faced are the following:

- Some components cost a lot such as, OLED and Vibration module.
- Creating the overall system is going to be a complex task.
- Some components such as, the OLED display consume lots of power.

6 Appendix