UNIVERSITY OF WATERLOO

RescueTouch Emergency System

Design Document

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1. Introduction

1.1 Background

Emergency services are often difficult to access for people with disabilities, especially in urgent situations where fast communication is critical. Present systems use verbal communication or a complicated interface, which is a barrier for those with mobility, speech, or cognitive impairments. Around 1.3 billion people experience significant disabilities. Many of these individuals face difficulties when trying to contact emergency services, as the primary method is through voice call. In Europe alone, 80 million people with disabilities face such challenges, and while some countries offer alternatives like SMS or video calls, access remains unequal, leaving many vulnerable in emergencies.

1.2 Project Purpose

This project aims to create a system that allows users to quickly communicate essential information, such as name, address, and health care details, to first responders through a simple task like pressing a button or entering a number. This ensures timely assistance for people who may struggle with traditional emergency communication methods. Focusing on user-friendly interface with easy controls and ensures accurate and rapid transmission of vital information.

2. Needs Assessment

2.1 Client/Customer Definition

2.1.1 Demographic

The client for this project is the Deaf-Blind community. A unique population characterized by their dual sensory impairment, which significantly affects both hearing and vision. This combination of impairments impacts nearly every aspect of their daily lives, making basic communication, independent navigation, and access to services difficult [7]. Many Deaf-Blind individuals rely on specialized tools like Braille, screen readers, or tactile signing to interact with their surroundings and the people around them. However, even with these tools, they face immense challenges in activities, such as using public transportation, accessing healthcare, or receiving emergency alerts. The problem extends into public safety, as the inability to respond to visual or auditory alerts leaves this community particularly vulnerable during emergencies, where immediate action is required for safety and survival.

The Deaf-Blind community in Toronto represents a significant portion of the overall Deaf-Blind population in Ontario. While precise figures are challenging to determine, it's estimated that approximately 80,000 to 90,000 individuals with varying degrees of dual sensory impairment reside in the Greater Toronto Area. This estimate is based on the concentration of specialized services and support systems in urban centers, particularly in Toronto [44].

Organizations like the CADB have long advocated for the development of improved accessibility features in public infrastructure and emergency response systems. They emphasize the importance of solutions that accommodate the specific needs of Deaf-Blind individuals, particularly in critical situations where timely access to emergency services is vital [7]. This project aims to address the identified gap by creating an emergency call system designed to serve the Deaf-Blind community effectively. By focusing on tactile and haptic feedback mechanisms, this system will enable users to quickly communicate essential information, such as personal identification and health details, to emergency responders.

2.1.2 Geographic

Urban concentration is a significant geographic attribute for the Deaf-Blind community in Canada, particularly in Ontario. This concentration is evident through the distribution of services and support systems in major urban centers:

1. Toronto stands out as a primary hub for Deaf-Blind services. The Canadian Helen Keller Centre (CHKC) operates a 16-unit accessible apartment building in the Willowdale neighborhood and plans to open a 56-unit building in the Etobicoke-Lakeshore region by 2025 [40].
   This expansion indicates a growing demand for specialized housing in urban areas.
2. DeafBlind Ontario Services, one of the largest service providers for people with sensory loss in Ontario, has a significant presence in urban centers. They operate multiple supported living homes in cities such as London (3 homes), Oshawa (2 homes), and Peterborough (5 homes) [41]. This distribution suggests a higher concentration of Deaf-Blind individuals in these urban areas.
3. The concentration of services in cities like Toronto, Ottawa, and London reflects the tendency for individuals with specialized needs to gravitate towards urban centers where support is more readily available. This is particularly crucial for the Deaf-Blind community, who rely heavily on specialized services for daily living and communication [42].
4. Urban areas also offer better access to public transportation and healthcare facilities, which are essential for the independence and well-being of Deaf-Blind individuals. Cities like Toronto, with extensive public transit systems, provide greater mobility options for this community [43].

This urban concentration is not just about population distribution but also about the accessibility of critical services and support systems that are more prevalent in city environments.

Proximity to emergency services is a crucial geographic attribute for the Deaf-Blind community, particularly in urban areas of Canada. This factor significantly impacts the effectiveness of emergency response for this vulnerable population. In major urban centers, emergency services are typically more densely distributed, providing faster response times. For instance, Toronto has numerous fire stations strategically located throughout the city to ensure rapid response [45]. This distribution is particularly beneficial for the Deaf-Blind community, who may face challenges in communicating their emergency needs quickly. The concentration of specialized medical facilities in urban areas is also advantageous. Toronto hosts the Canadian Helen Keller Centre, which provides critical services and housing for individuals with dual sensory loss [40] . This proximity allows for quicker access to specialized care during emergencies. Urban areas often have more advanced emergency alert systems. For example, Toronto's Emergency Management Office has implemented a multi-channel emergency notification system that includes methods suitable for Deaf-Blind individuals, such as text-based alerts [46]. This system's effectiveness is enhanced by the dense urban infrastructure, allowing for better coverage and faster dissemination of critical information. The clustering of Deaf-Blind support services near emergency response infrastructure in cities facilitates better coordination during crises. Organizations like DeafBlind Ontario Services operate multiple supported living homes in urban areas that are typically well-served by local emergency services [44]. This proximity allows for more frequent and accessible training sessions aimed at enhancing the community's overall emergency readiness [47] . While this urban-centric distribution of emergency services benefits many Deaf-Blind individuals, it also highlights potential vulnerabilities for those living in less densely populated areas, where such services may be less readily available or accessible.

2.1.3 Economic

The economic situation of the Deaf-Blind community in Toronto presents distinct challenges that impact their quality of life and access to essential services. Here are key aspects of their economic attributes:

Deaf-Blind individuals often face significant barriers to employment. In Toronto, these barriers include limited job opportunities, lack of accessible workplaces, and insufficient training programs tailored to their unique needs. Many Deaf-Blind individuals are underemployed or unemployed, which can lead to economic instability. Organizations like the Canadian Helen Keller Centre (CHKC) provide training and support aimed at enhancing employability, but the overall employment rate for those with dual sensory impairments remains low compared to the general population [40]. The employment situation for Deaf-Blind individuals in Toronto reflects broader trends observed in Canada. According to a survey conducted by the Canadian Association of the Deaf, only 20% of Deaf Canadians are fully employed, while 42% are under-employed, and 38% are unemployed [49]. These statistics, while not specific to Toronto or the Deaf-Blind community, suggest a significant employment gap that likely extends to those with dual sensory impairments.

Due to the challenges in securing stable employment, many Deaf-Blind individuals rely on social assistance programs. In Toronto, programs such as Ontario Disability Support Program (ODSP) provide financial support, but these benefits often fall short of covering the higher living costs associated with disability-related expenses. This reliance on social security can contribute to a cycle of poverty and economic exclusion within the Deaf-Blind community [48]. Living with dual sensory impairments incurs additional costs that can strain financial resources. Deaf-Blind individuals often require specialized tools and services—such as intervenor services—which can be expensive. For instance, the CNIB Deafblind Community Services offers emergency intervention services that are crucial for navigating daily life and emergencies, but accessing these services may not always be financially feasible for all individuals [48].

Housing is another critical economic factor for the Deaf-Blind community in Toronto. The Canadian Helen Keller Centre operates affordable housing units specifically designed for individuals who are Deaf-Blind, yet demand often exceeds supply. As Toronto's housing market becomes increasingly competitive and expensive, finding suitable and affordable accommodations remains a significant challenge for this community [40].

Overall, the combination of employment difficulties, dependence on social support, additional living costs, and housing challenges contributes to a broader pattern of economic exclusion for Deaf-Blind individuals in Toronto. This situation underscores the need for targeted interventions that address these specific economic barriers and promote greater independence and quality of life within this community.

2.1.4 Challenges Faced

Deaf-Blind individuals face many barriers in accessing emergency services, primarily due to the absence of communication systems that account for their dual sensory impairments. The current emergency infrastructure in Canada, which is heavily reliant on auditory and visual cues, renders it largely inaccessible for those who cannot hear or see. According to the Canadian Hearing Society (CHS), many Deaf-Blind individuals encounter situations where they are unable to verbally communicate with 911 operators [6]. As a result, operators often misinterpret these silent or incomplete calls as errors or misdials, leading to the premature termination of the call. This miscommunication can have dire consequences, especially in time-sensitive emergencies where swift access to help is critical. Additionally, the "Barrier-Free Emergency Communication Access and Alerting System Research Report" reveals that most alerting systems currently do not support alternative communication methods, such as text-based messaging or tactile alerts, which are vital for Deaf-Blind individuals to convey their needs during crises [6]. This critical gap leaves these individuals particularly vulnerable, unable to communicate effectively in life-threatening situations.

As highlighted by the World Health Organization (WHO), Deaf-Blind individuals often find themselves isolated, struggling to navigate a world that largely overlooks their specific needs [9]. They may lack the means to alert emergency services, further exposing their vulnerability in critical moments. Addressing this problem with a solution would drastically improve the lives of Deaf-Blind individuals. A comprehensive emergency communication system, specifically designed to support alternative communication, would allow these individuals to access emergency services with the same immediacy and effectiveness as any other member of society [8]. Integrating features such as text-based messaging, Braille interfaces, or haptic feedback systems into emergency alert infrastructure would ensure that Deaf-Blind individuals can transmit essential information—such as their location, health condition, or type of emergency—directly to first responders. This would not only empower the Deaf-Blind community by giving them a reliable method to seek assistance but also significantly enhance their safety and independence [8].

Moreover, communicating personal information and specific details, such as medical history or exact location, remains a significant challenge. Given the limitations in visual and auditory communication channels, there is a high likelihood of miscommunication or omitted details, which can lead to inappropriate response measures by emergency personnel. Therefore, a reliable system that supports personalized information input and allows for quick transmission of critical details in a format accessible to the Deaf-Blind community is essential. This would not only enhance safety but also increase the efficacy and relevance of emergency responses. Research underscores the importance of tailored emergency devices that are built with the sensory needs of users in mind, reinforcing the necessity of integrating accessible input and feedback systems into emergency devices [6].

2.2 Competitive Landscape

2.2.1 Teletype Device

A TTY or Teletype device is something used by deaf people to communicate with others via typed messages. Typically, the deaf person has to call a relay center, where the operator answers using a TTY. The deaf person then types out who/where they are trying to reach, and the operator acts as a middleman to communicate between both parties [36]. In this situation however, emergency services are "[required to] have TTY capabilities" [35]. This means that a deaf person can use their TTY to communicate with emergency services. Using a braille keyboard, a blind and deaf person is able to communicate their situation to 911, thus addressing the challenge of communicating information to 911 [37]. However, this system has huge shortcomings. First, the blind and deaf person will only be able to send a message to 911 but will not be able to see the response. This means that if the 911 operator needs more information, they will not be able to get it. This relies on the blind and deaf person to relay all of the relevant information in one interaction. Second, the TTY is not as small as a mobile phone. If the blind and deaf person is the one in an emergency, they would have to be able to move to their TTY to access it and send a message. If they happen to be incapacitated or away from home, this method is not usable.

2.2.2 Careterak

The company Careterak makes a device that is wearable like a necklace. There is a button on the device that will automatically connect you to 911 or a family member, and will also send our location to them. It will also automatically trigger if you fall. This device is primarily meant to be used by old people since it allows them to communicate via voice to emergency contracts or operators. However, this device can be used by the deaf-blind community to immediately send their location to emergency services. The button is easily accessible and is easy for anyone wearing the necklace to find. This addresses the challenge that deaf-blind people have with physically being able to contact 911 since the button is easy to find. [38] There are several drawbacks though. First is that there is no way to communicate further beyond gps location with emergency services. Since most if not all deaf-blind people will not be able to speak properly, they will not be able to utilize the communication that the device provides. Secondly, many 911 operators may not realize that the person making sounds needs help. They may think that someone is intentionally making a prank call. This is a major drawback.

2.2.3 Lorm Glove

In Germany, a device called the "Lorm Glove" allows deaf-blind individuals to control a mobile device using a glove. The glove works on the "lorm" alphabet, which is a system of hand contact communication similar to sign language, but relying on touch rather than sight. The glove uses actuators and sensors to allow the deaf-blind individual to both send messages (via sensing their lorm actions) and receive messages (via conveying messages using lorm signals created by actuators) [39]. This is useful since 911 typically has the ability to receive texts [35]. Using the lorm glove, the individual can send and receive texts from 911 to convey their situation and can also provide more information as needed. This addresses the challenge of communication with emergency services. This solution is the most promising, but has some drawbacks. The main drawback is that this seems to be a device in prototype, since it doesn't seem to be widespread. This means that it is difficult for most people to get their hands on and may not be fully developed yet. Another drawback is that it requires two hands to use, so if the individual cannot use a hand, the glove is not usable.

2.3 Requirement Specification

2.3.1 Functional Requirements

The emergency call system for the Deaf-Blind community is designed with several functional requirements that ensure effectiveness and reliability. First, the system must communicate user details, including name, address, and healthcare information, within 120 seconds of triggering. This requirement is quantifiably defined within a range of 0 to 120 seconds (unit: seconds) and is achievable with current technology in emergency communication, ensuring timely responses in critical situations [28]. Additionally, the system must ensure at least a 90% successful transmission rate between STM32 boards, with a quantifiable range of 90% to 100% (unit: percentage). This level of reliability is essential for effective emergency communication and can be measured through test runs and communication logs, as supported by established communication protocols [6].

The system must also support input methods such as button presses or number entry requiring no more than 2 Newtons of force to activate. This specification, ranging from 1.7 to 2 Newtons (unit: Newtons), aligns with ergonomic standards and is critical for users with limited dexterity [18]. Furthermore, the system must transmit data reliably over a range of at least 10 meters in typical indoor environments, with a quantifiable range of 10 to 30 meters (unit: meters). This requirement is necessary for practical scenarios where users may need to communicate from a distance and is supported by studies in wireless communication [21].

An additional functional requirement is that the system must provide haptic feedback to the user upon successful transmission of their emergency information, ensuring they receive confirmation without relying on visual or auditory cues. This haptic feedback must occur within 5 seconds of the transmission being completed, with a quantifiable range of 0 to 5 second (unit: seconds). This feedback mechanism is essential for user assurance and can be measured through simple timing methods. The requirement aligns with best practices in assistive technology design, emphasizing the need for multi-sensory feedback [29].

2.3.2 Technical Requirements

The emergency call system incorporates several key technical requirements essential for its functionality. First, the system must utilize communication protocols between the STM32 boards that ensure low-latency communication, defined as a response time of less than 50 milliseconds (unit: milliseconds) for data transmission. This requirement is critical for ensuring that emergency communications are timely and efficient, as supported by studies indicating that low latency is essential for effective real-time communications [17].

Additionally, the system must demonstrate power efficiency, with a maximum power consumption of no more than 500 milliwatts (unit: milliwatts) during operation. This requirement, defined within a range of 0 to 500 milliwatts, is achievable using current energy-efficient components and is measurable with standard electrical testing equipment. Maintaining low power consumption is important for ensuring that the system remains operational during emergencies when power sources may be limited [30].

Furthermore, the system must be capable of processing and transmitting data quickly, with the requirement that it can handle a data throughput of at least 1 kilobyte per second (unit: kilobytes per second) during peak usage [30]. This quantifiable requirement, set within a range of 1 to 10 kilobytes per second, is appropriate for the needs of the Deaf-Blind community and can be tested using data transfer benchmarks. Ensuring adequate data throughput is crucial for transmitting user information promptly during emergencies [1].

Finally, the STM32 boards should seamlessly integrate with existing emergency response communication channels, requiring compatibility with standard communication protocols such as UART (Universal Asynchronous Receiver-Transmitter). This integration must adhere to the specifications outlined in relevant technical standards, which provide guidelines on communication compatibility [17].

2.3.3 Safety Requirements

The emergency call system must incorporate several critical safety requirements to enhance its reliability and user safety. Firstly, the system must be designed to prevent accidental false alerts, ensuring that emergency services are only contacted in real situations. The response time for this confirmation must be within 3 seconds (unit: seconds), allowing users to quickly cancel any unintentional alerts [29].

Additionally, the system must be resilient and function reliably under various conditions, including environmental factors such as extreme temperatures (ranging from -20°C to 50°C) and signal interference, to ensure it remains operational during emergencies. This temperature range is specified in degrees Celsius and is supported by guidelines from the World Health Organization [16], indicating that electronic devices should withstand these conditions for consistent performance. The system should also maintain operational capabilities despite signal interference, with a requirement for maintaining at least 80% communication effectiveness in environments with high electromagnetic interference (EMI), which can be measured through standardized testing protocols [6].

In summary, these additional technical requirements ensure that the emergency call system is robust, secure, and user-friendly, ultimately enhancing the safety and reliability of emergency communications for the Deaf-Blind community. Each requirement is quantifiably defined, feasible for a first-year engineering student, measurable, appropriate for the defined problem, and supported by credible references, reinforcing the project’s objectives.

3. Analysis

3.1 Design

The RescueTouch Emergency System is an innovative communication device designed specifically for Deaf-Blind individuals, enabling them to quickly and effectively alert emergency responders in critical situations. The system consists of two main components: a **User Device**, which the user activates with a simple button press, and a **Receiver Device** that receives the alert and communicates with emergency services. The system consists of two STM32 boards that communicate. The first board is equipped with four buttons and a servo, while the second board features an LCD display and a single button. Below, we explain how each component works together to ensure effective communication and assistance.

3.1.1 Assembly Process

To construct the Emergency Call System, begin by gathering all necessary components:

- 2 STM32 boards
- 1 LCD display
- 5 buttons (four for input on the first board and one for acknowledgment on the second
- 1 servo motor
- 23 wires
- 2 breadboards

1. Physical Assembly:
    - Connect the four buttons to digital input pins on the first STM32 board, with each button wired to trigger a different message. The servo should be connected to a PWM (Pulse Width Modulation) pin. On the second STM32 board, connect the LCD display and the acknowledgment button. Diagram below to clarify components connections for each board, refer to *figure 3.1.1.1 & 3.1.1.2*:

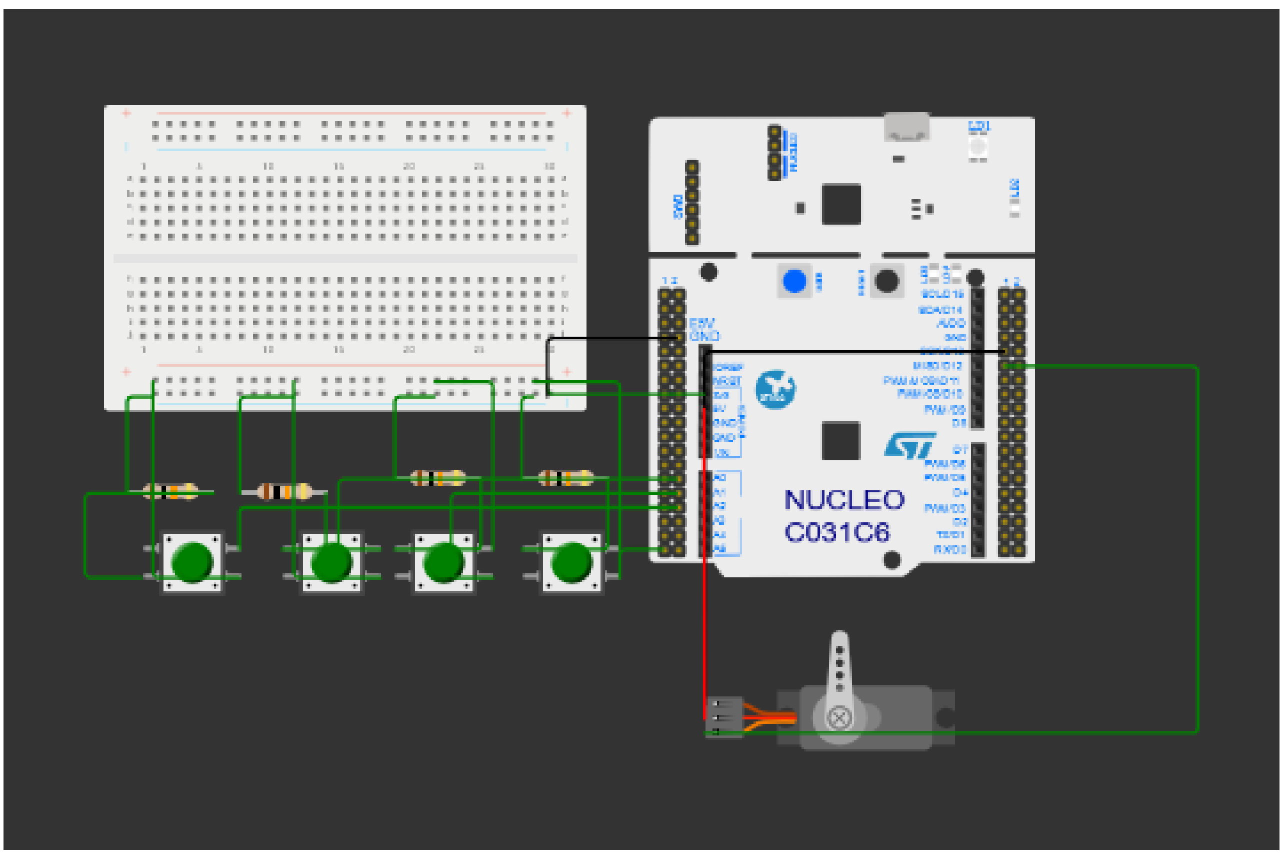

Figure 3.1.1.1: RescueTouch Emergency Device 3D Diagram (User)

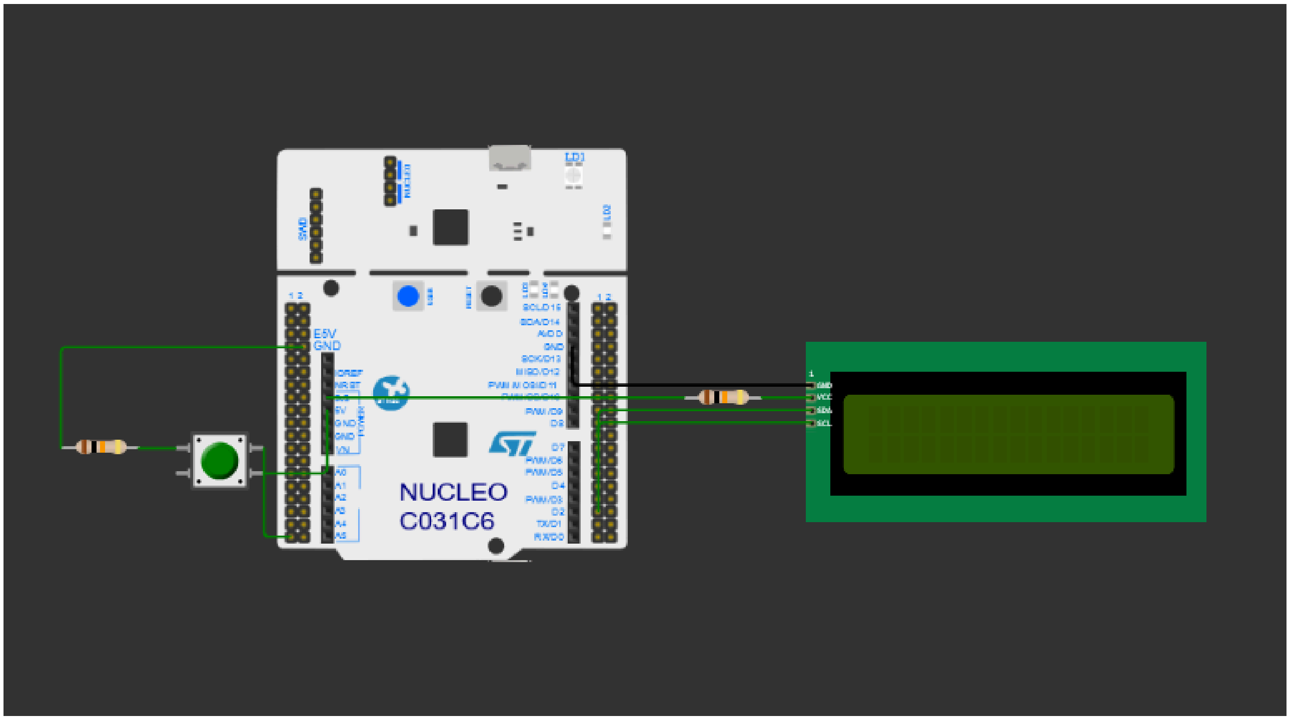

Figure 3.1.1.2: RescueTouch Emergency Device 3D Diagram (Emergency Service)

2. <u>Circuit Connections:</u>
    - Use jumper wires to connect all components according to the provided schematic diagram, refer to *figure 3.1.1.3*. Ensure that each connection is secure and double-check the wiring against the schematic to prevent short circuits or miscommunication between boards.

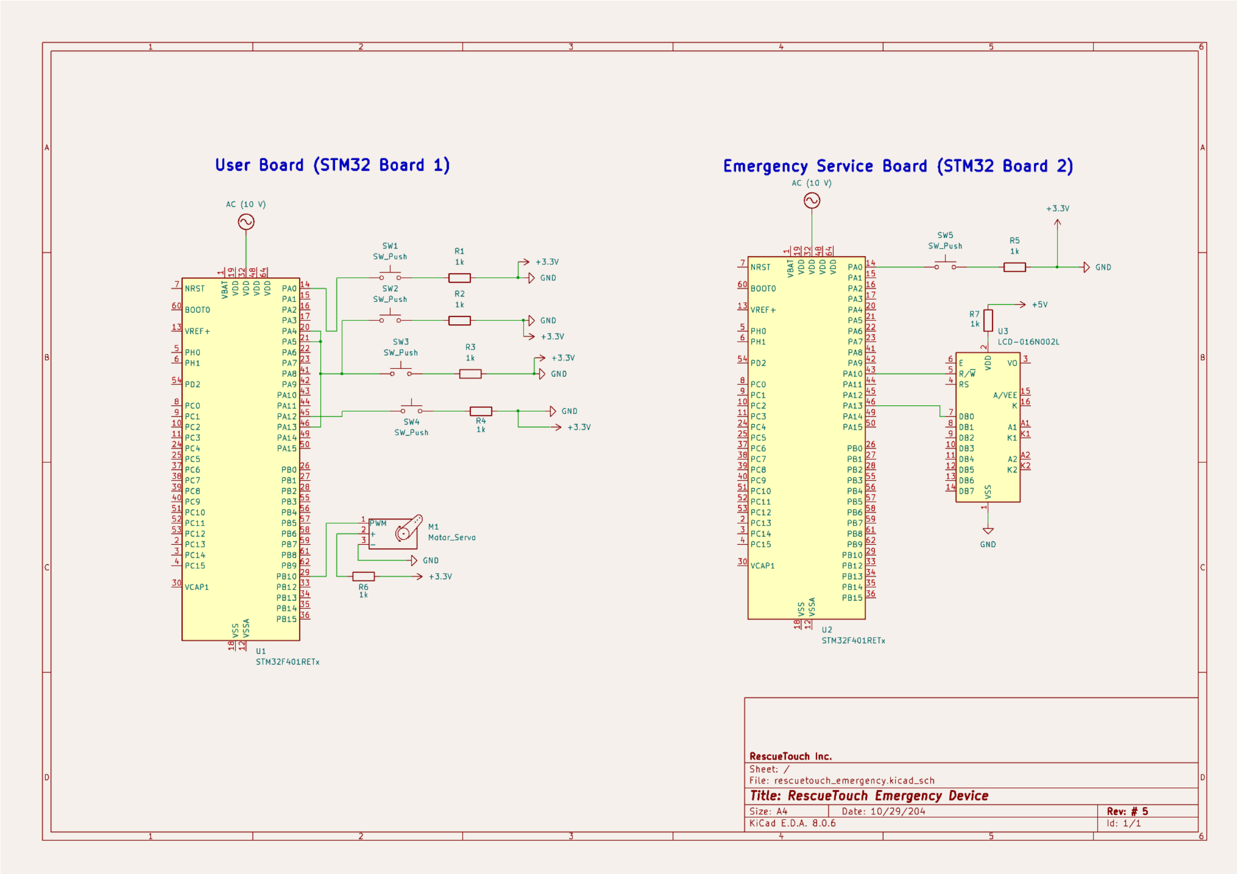

Figure 3.1.1.3: RescueTouch Emergency Device Schematic

3. <u>Programming:</u>
    - The program to handle button inputs, communication between the two boards, and the logic for activating the onboard LED and servo. Below is a simplified pseudo-code representation of how the system functions:

// First STM32 Board (User Board)

Initialize buttons, servo, and wireless communication

While true:

For each button:

If button pressed:

Send message corresponding to the button to the second board

Turn on LED

Wait for acknowledgment from the second board

If acknowledgment received:

Activate servo

Turn off LED

// Second STM32 Board (Emergency Service Board)

Initialize LCD and acknowledgment button, and wireless communication

While true:

If message received from the first board:

Display message on LCD

Turn on LED

If acknowledgment button pressed:

Send acknowledgment back to the first board

3.1.2 Implementation:

1. <u>Power On Both STM32 Boards:</u>
    - Connect each STM32 board to its dedicated power source (battery or USB power supply).
    - Verify that each board's power indicator LED is on, confirming power is correctly supplied to both devices. Ensure they are positioned within close proximity to optimize wireless connectivity.
2. <u>Set Up the First STM32 Board (User Device):</u>
    - **Buttons**: Verify that each of the four buttons on the first board is securely in place and responsive to light pressure. These buttons allow the user to signal for help or communicate specific information.
    - **Servo Motor**: Make sure the servo motor is firmly attached and able to rotate freely. This motor provides feedback to the user, so it must be calibrated to move when a message is acknowledged by the second board.
3. <u>Prepare the Second STM32 Board (Receiver Device):</u>
    - **LCD Display**: Turn on the second board and check that the LCD display powers up and shows a ready or standby screen. This display will show incoming messages from the user device.
    - **Acknowledgment Button**: Press the acknowledgment button to ensure it responds and is not obstructed. This button will send a response signal back to the first board.
4. <u>Test the Wireless Message Transmission:</u>
    - **Press a Button on the First Board**: Select one of the four buttons on the first board and press it. This action should send a wireless signal to the second board.

    - **Monitor the Second Board for Message Receipt**: After pressing a button on the first board, observe the LCD display on the second board. The LCD should display a message corresponding to the button pressed, indicating successful communication.
5. <u>Check LED Confirmation on the Receiver Device:</u>
    - Upon receiving the message, the LED on the second board should light up to indicate that the alert was received. This visual signal is crucial for confirming message receipt on the receiving end.
6. <u>Acknowledge the Alert on the Second Board:</u>
    - After confirming the message on the second board's display, press the acknowledgment button on this board. This button press should trigger a signal back to the first board.
7. <u>Servo Motor Feedback on the First Board:</u>
    - After pressing the acknowledgment button on the second board, check that the servo motor on the first board activates briefly. This servo movement is a tactile signal for the user, informing them that their alert has been acknowledged and help is on the way.
8. <u>Monitor System Performance:</u>
    - Observe the speed of communication and the responsiveness of each component. Delays in communication or unresponsive buttons may require code adjustments or closer board positioning.
    - Address any issues by referring to the programming code to check for connectivity errors, wireless interference, or misconfigured settings.

3.1.3 Operate:

1. Powering On and Positioning
    - **Power On**: Ensure both STM32 boards are powered. The system relies on both boards being active and nearby each other for reliable communication.
    - **Check Placement**: Place the boards within a reasonable range, ideally close enough for uninterrupted wireless transmission.
2. Using the Emergency Buttons
    - **Button Press**: On the first board, there are four distinct buttons, each pre-set with a unique emergency message.
        - Example Messages:
            - Button 1: "Help needed!"
            - Button 2: "Medical assistance required!"
    - **Transmitting Message**: When the user presses a button, the first board sends a wireless signal to the second board. This triggers the emergency message to transmit.
3. Receiving the Message (Responder's Board)
    - **LCD Display**: On the second board, the received message will appear on the LCD screen. This allows the responder to read the emergency request.

- **LED Confirmation**: An LED light on the second board turns on, indicating that the message has been received.

4. Acknowledgment by Responder
   - **Acknowledgment Button**: The responder can press the acknowledgment button on the second board. This sends a confirmation back to the user's board.
   - **Servo Activation**: Upon receiving the acknowledgment, the first board activates a servo motor, giving a physical signal to the user that help is on the way.
5. Maintenance and Routine Checks
   - **Check Battery Levels**: Regularly check battery levels for both STM32 boards to prevent unexpected shutdowns.
   - **Inspect Components**: Verify that all buttons, the LED, and the LCD display function correctly.
   - **Troubleshooting**: If there are any issues (like delayed message transmission or unresponsive buttons), refer to the troubleshooting guide in the documentation for quick fixes.

3.1.4 Requirements:

The design of the emergency call system effectively addresses the first functional requirement of communicating user details, including name, address, and healthcare information, within 120 seconds of activation. This capability is facilitated by the robust processing power of the STM32 microcontroller, which allows for rapid data processing and transmission [54]. Furthermore, the design includes a streamlined user interface that minimizes the time required for activation, enabling users to initiate communication effortlessly. By leveraging existing technology and adhering to established communication protocols, the system not only meets the requirement of transmitting essential user information within the specified timeframe but also enhances the overall reliability of emergency responses for the Deaf-Blind community.

The design of the emergency call system also successfully meets the requirement of supporting input methods, such as button presses, that requires no more than 2 Newtons of force to activate. This consideration is essential for users with limited dexterity, ensuring that the system is accessible and easy to use. The implementation of a tactile button that operates within the specified force range of 1.7 to 2 Newtons aligns with ergonomic standards, allowing users to activate the system without unnecessary strain or difficulty [18]. Moreover, the design incorporates reliable wireless communication that enables data transmission over a distance of at least 10 meters, with capabilities extending up to 30 meters in typical indoor environments [21].

The design of the emergency call system also effectively addresses the requirement for haptic feedback, which is crucial for providing users with confirmation of successful transmission of their emergency information. This feedback mechanism ensures that Deaf-Blind users receive immediate tactile reassurance, allowing them to know their signal has been sent without needing to rely on visual or auditory cues. The system is designed to deliver this haptic feedback within a strict time frame of 5 seconds after the transmission is completed, aligning with the specified quantifiable range of 0 to 5 seconds.This prompt response is essential for user confidence during emergency situations, as it allows individuals to remain informed about the status of their communication. By integrating haptic feedback, the system not only meets functional requirements but also enhances its usability and effectiveness for the Deaf-Blind community.

The emergency call system successfully incorporates several key technical requirements that are crucial for its overall functionality, particularly the use of communication protocols between the STM32 boards designed to ensure low-latency communication. This requirement mandates a response time of less than 50 milliseconds for data transmission, which is vital for facilitating timely and efficient emergency communications [54]. By implementing optimized communication protocols that prioritize speed and efficiency, the system not only meets this critical technical requirement but also reinforces its commitment to delivering prompt assistance to users.

The emergency call system also emphasizes power efficiency, necessitating a maximum power consumption of no more than 500 milliwatts during operation. This requirement, defined within a range of 0 to 500 milliwatts, is not only achievable through the use of current energy-efficient components but can also be accurately measured with standard electrical testing equipment. Maintaining low power consumption is particularly vital for ensuring the system remains operational during emergencies when power sources may be limited, thereby reinforcing its reliability for users in critical situations, the system must handle data processing and transmission swiftly, with a requirement to achieve a minimum data throughput of at least 1 kilobyte per second during peak usage, defined within a range of 1 to 10 kilobytes per second [54]. This quantifiable requirement is tailored to meet the specific needs of the Deaf-Blind community and can be assessed through data transfer benchmarks, ensuring timely transmission of user information during emergencies. The emergency call system not only guarantees efficiency and reliability but also enhances the overall effectiveness of emergency communications for the Deaf-Blind community.

Furthermore, the system must demonstrate resilience and reliable functionality under varying environmental conditions. It is designed to operate effectively across a temperature range of -20°C to 50°C, supported by guidelines from the World Health Organization, which indicate that electronic devices should withstand such conditions for consistent performance. Additionally, the system maintains operational capabilities despite signal interference, requiring at least 80% communication effectiveness in environments with high electromagnetic interference (EMI). This aspect can be assessed through standardized testing protocols, ensuring that the system remains operational during emergencies regardless of external factors. By meeting these safety requirements, the emergency call system not only protects users but also enhances the overall reliability of emergency communications for the Deaf-Blind community.

3.1.5 Alternatives:

The development of the RescueTouch Emergency System included a rigorous evaluation of various technical solutions to determine the most reliable and accessible communication method for the Deaf-Blind community. One alternative was the use of smartphone applications with voice recognition, which offer customizable interfaces but rely heavily on visual and auditory cues, making them unsuitable for Deaf-Blind users who struggle with screen-based interactions and auditory notifications [50]. Studies have demonstrated that tactile communication methods are more effective, providing intuitive interactions that enable users to alert emergency services quickly and with minimal cognitive effort [50]. Consequently, while smartphone apps serve many users, they fail to address the specific needs of the Deaf-Blind population, emphasizing the necessity for a tactile-focused design in the RescueTouch system.

Bluetooth technology was also evaluated but ultimately deemed unsuitable due to potential connectivity issues in crowded urban settings where signal interference is prevalent. Bluetooth often struggles to maintain stable connections under these conditions, which could undermine the system's reliability in emergencies [51]. Research has shown that low-power radio frequency (RF) systems offer greater stability and range, making them a preferable choice for emergency communication over distances up to 30 meters [52]. Accordingly, the RescueTouch system leverages STM32 boards with a specialized wireless protocol to ensure high transmission success rates, meeting the 90% reliability standard critical for emergency situations.

Another alternative solution for Deaf-Blind individuals to access emergency services was a wearable device equipped with GPS and haptic feedback features, designed to connect directly with emergency responders [53]. This device could operate independently of smartphones, reducing reliance on visual or auditory interfaces by using tactile vibrations to guide users through an emergency alert process. For example, the user could press a dedicated button on the wearable to activate an emergency signal, transmitting their real-time location and pre-programmed personal information to emergency services [53]. However, using the STM32-based solution provides a more robust and reliable communication pathway by offering low-latency and highly stable connectivity, essential for emergency situations where quick response is critical. Unlike wearable devices, the STM32 setup allows for customizable and adaptable inputs, including tactile buttons that require minimal dexterity, making it especially accessible for Deaf-Blind users [54]. Additionally, the STM32 system integrates seamlessly with other emergency communication protocols, ensuring compatibility and enhancing the overall effectiveness and reach of emergency assistance.

The decision to use STM32 boards for the RescueTouch system is also supported by their high processing speed, low power consumption, and compatibility with communication protocols that can perform in crowded urban environments [54]. The STM32 board's ability to support low-power RF communication aligns with industry standards, ensuring effective performance within a 30-meter range [54]. Furthermore, the board's adaptability allows the RescueTouch system to adhere to ergonomic design principles, making the device intuitive and easy to use for individuals with limited dexterity.

In summary, the RescueTouch Emergency System was designed with an STM32 board at its core, enabling it to meet the specific requirements of the Deaf-Blind community. The system's button-based activation minimizes cognitive load, adheres to ergonomic standards, and enhances user accessibility, ensuring quick and reliable emergency communication. By integrating tactile, low-latency, and energy-efficient components, the system addresses the distinct needs of its users and supports the Deaf-Blind community in emergency situations.

3.2 Scientific and Mathematical Principles

3.2.1 Ohm's Law

The design of the emergency call system for Deaf-Blind individuals will primarily exploit several scientific and engineering principles to ensure optimal performance and reliability. First, Ohm's Law plays a crucial role in the electrical design of the system. This law states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance, as expressed by the equation [19]:

$$V = I \times R$$

By applying Ohm's Law, we can accurately select resistor values for various components, such as LEDs, haptic feedback devices, and transducers, to ensure they operate within safe current limits. This careful management of electrical parameters not only enhances component longevity but also prevents overheating, which is critical in emergency scenarios where system reliability is paramount. Furthermore, understanding the relationship between voltage, current, and resistance enables us to design circuits that can efficiently power all system elements without risking damage or failure during operation.

By employing these scientific principles—Ohm's Law for circuit design for effective communication—the emergency call system will be well-equipped to provide a reliable, efficient, and safe means of communication for Deaf-Blind individuals. This comprehensive approach ultimately contributes to enhancing their independence and safety in emergency situations, bridging a significant gap in current emergency response systems.

Application:

Using Ohm's Law, we can calculate the current for each component in the system based on the voltage and resistance values. The formula used for these calculations is:

$I = V / R$

where I is the current (in Amperes), V is the voltage (in Volts), and R is the resistance (in Ohms).

1. LCD Current

- Voltage: $V_{LCD} = 5$ V
- Resistance: $R_{LCD} = 1000\ \Omega$

Calculation:

$I_{LCD} = V_{LCD} / R_{LCD} = 5\text{ V} / 1000\ \Omega = 0.005\text{ A}$ (5 mA)

2. Servo Current

- Voltage: $V_{SERVO} = 5$ V
- Resistance: $R_{SERVO} = 1000\ \Omega$

Calculation:

$I_{SERVO} = V_{SERVO} / R_{SERVO} = 5\text{ V} / 1000\ \Omega = 0.005\text{ A}$ (5 mA)

3. Button Current (per button)

- Voltage: $V_{BUTTON} = 3.3$ V
- Resistance: $R_{BUTTON} = 1000\ \Omega$

Calculation:

$I_{BUTTON} = V_{BUTTON} / R_{BUTTON} = 3.3\text{ V} / 1000\ \Omega = 0.0033\text{ A}$ (3.3 mA)

4. Total Current for 4 Buttons

Calculation:

$I_{TOTAL\ BUTTON} = 4 \times I_{BUTTON} = 4 \times 0.0033\text{ A} = 0.0132\text{ A}$ (13.2 mA)

Summary of Currents

- LCD Current: 5 mA
- Servo Current: 5 mA
- Single Button Current: 3.3 mA
- Total Current for 4 Buttons: 13.2 mA

These calculations provide essential insight into the power requirements of each component, ensuring that the system operates efficiently and within safe limits while optimizing overall performance.

3.2.2 Power Formula in Circuit Designs

The power formula, defined as, $P = VI$, where P is power in watts, V is voltage in volts, and I is current in amperes, is fundamental to the design and analysis of electrical circuits within the emergency call system [55]. Understanding how to calculate power is crucial for ensuring that each component operates within its specified limits, preventing damage and maintaining system reliability. For instance, when designing the power supply for the system, we can determine the total power required by summing the individual power ratings of all components, such as the Nucleo-64 STM32F401RE unit, LCD display, and servo motor. By calculating the power requirements for each component, we can also make informed decisions about the type and size of the battery needed to meet the total power consumption without exceeding the design limit of 30W. This ensures that the system operates efficiently under maximum load conditions.

Additionally, applying the power formula allows us to evaluate the efficiency of different components, enabling us to select alternatives that minimize energy consumption, such as low-power versions of sensors or actuators. This is particularly important in our design, as the system must not only meet power specifications but also adhere to energy storage limits of 500mJ, ensuring that we do not compromise user safety in emergencies. Furthermore, understanding the power distribution across the system enhances our ability to diagnose potential issues, such as identifying components that may draw excessive current, leading to overheating or system failure. Ultimately, this comprehensive approach to power management ensures that the emergency call system remains functional and dependable during critical situations, significantly enhancing its effectiveness in providing timely assistance to Deaf-Blind individuals and bridging the communication gap they face during emergencies [55].

Application:

Transmitter Power Calculations:

- Nucleo-64 STM32F401RE:

Typical current draw is around 80mA at 3.3V.

$$P_{STM32} = V \times I = 3.3\,V \times 0.08A = 0.264\,W$$

- Miniature Pushbuttons:
  These consume negligible power as they only act as a momentary switch.

- Servo Motor (SPRINGRC, SM-S2309S):
  Operating voltage: 5V, typical current: 500mA.

$$P_{SERVO} = V \times I = 5\,V \times 0.5A = 2.5\,W$$

- Resistors:
  Power dissipated across resistors depends on resistance values, which are to be determined. Typically, they will contribute minimal power consumption.

Total estimated power for the Transmitter:

$$P_{TRANSMITTER} = 0.264\,W + 2.5\,W = 2.764\,W$$

Receiver Power Calculations:

- LCD 16x2 Display:

Typical operating voltage: 5V, current draw: around 15mA.

$$P_{LCD} = V \times I = 5\,V \times 0.015A = 0.075\,W$$

- Miniature Pushbutton:

Negligible power consumption as it only functions as a switch.

- Resistors:

Minimal power consumption similar to those in the transmitter.

Total estimated power for the Receiver:

$$P_{RECIEVER} = 0.08\ W + 0.3\ W = 0.38\ W$$

Total Power Consumption:
Combining both the transmitter and receiver:

$$P_{TOTAL} = 2.8\ W + 0.38\ W = 3.18\ W$$

This total power consumption is well within the 30W limit.

3.2.3 Functions & Graphs

Incorporating functions and graphs into the design of the emergency call system enhances our ability to model, analyze, and optimize its performance under various conditions. Graphical representations allow for a detailed assessment of key parameters such as the different materials used affecting durability and strength.

3D Printing Material Properties

When considering the enclosure for our device, the choice of 3D printing materials significantly influences its strength and durability, which are critical for the performance of the RescueTouch Emergency System. A graph comparing the mechanical properties of various plastics (like PLA, ABS, and PETG) can provide insights into how these materials can withstand physical stress and environmental factors. Understanding the strength and resilience of these materials will guide our selection process to ensure that the enclosure can protect the internal components effectively while maintaining reliable wireless communication between the STM32 boards.

Benefits:

- **Strength and Resilience**: Choosing the right material enhances the enclosure's ability to withstand impacts, drops, and everyday wear and tear, ensuring the device remains operational during critical emergencies.
- **Environmental Protection**: A durable material protects the device from external factors such as moisture, dust, and chemicals, ensuring longevity and reliability in various situations.

Application:

Common 3D Printing Materials

1. **PLA (Polylactic Acid)**

- **Strength**: Moderate; while it has good rigidity, it can be brittle and may crack under stress.
- **Durability**: Biodegradable and not suitable for long-term outdoor use; softens at lower temperatures (around 60°C).
- **Applications**: Best for low-stress applications where a rigid structure is needed, but not ideal for environments requiring high durability.

2. **ABS (Acrylonitrile Butadiene Styrene)**
   - **Strength**: High impact resistance, making it suitable for durable enclosures that need to withstand stress.
   - **Durability**: More robust than PLA, with better temperature resistance (softens around 100°C), making it suitable for functional parts exposed to heat or physical impacts.
   - **Applications**: Ideal for parts requiring resilience and toughness, particularly in environments where physical integrity is crucial.
3. **PETG (Polyethylene Terephthalate Glycol-Modified)**
   - **Strength**: Exceptional layer adhesion and impact resistance, making it highly durable for various applications.
   - **Durability**: Offers higher temperature resistance than PLA (softens around 80°C) and better chemical resistance, ensuring the device remains functional in challenging conditions.
   - **Applications**: Excellent for applications needing both durability and the ability to withstand environmental stressors, making it a strong candidate for the enclosure.

Based on the strength and durability properties of the materials, **PETG** is recommended for the enclosure of the RescueTouch Emergency System for several compelling reasons [56]:

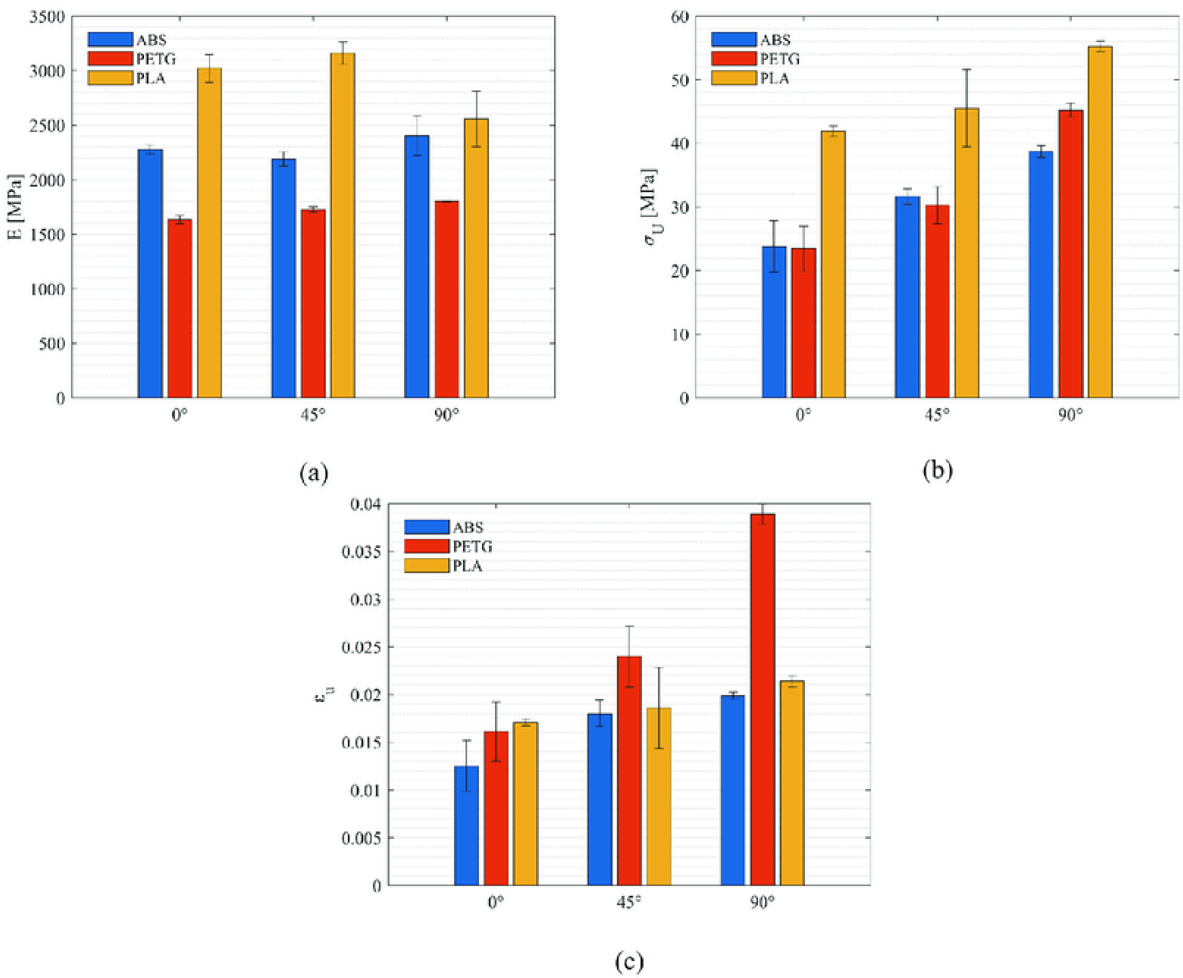

Figure 3.2.3.1 Durability between ABS, PETG, & PLA [56]

- **Impact Resistance**: PETG's high impact resistance ensures that the enclosure can withstand accidental drops and physical shocks, maintaining the integrity of the internal components.
- **Temperature Stability**: With a higher softening point than PLA, PETG is more suitable for varied operational environments, ensuring that the enclosure does not deform under heat.
- **Chemical Resistance**: PETG's resistance to various chemicals protects the device in emergency situations where exposure to different substances might occur.

In conclusion, selecting PETG as the 3D printing material for the RescueTouch Emergency System's enclosure will significantly enhance the device's strength and durability [56]. This material will ensure that the enclosure effectively protects the internal components while facilitating reliable wireless communication. By prioritizing material properties that contribute to the device's longevity and resilience, the design will adequately meet the needs of Deaf-Blind individuals in emergency situations, ensuring consistent performance when it matters most [56].

4. Manufacturing and Implementation Costs

4.1 Bill of Materials (BOM):
In developing the Emergency Call System for Deaf-Blind individuals, understanding the associated costs is crucial not only for budgeting but also for evaluating the overall feasibility and sustainability of the project. The following outlines the costs incurred for both the transmitter and receiver components, emphasizing the significance of each item beyond its dollar amount.

Transmitter Components:

1. **Nucleo-64 STM32F401RE Unit**: $39.54
   - **Significance**: This microcontroller serves as the core processing unit for the system, enabling real-time data handling and communication with emergency services. Its performance directly impacts the system's reliability and responsiveness.
2. **Miniature Push Buttons (4-5 units)**: $0.45 each ($2.70 total for 6)
   - **Significance**: These buttons allow users to initiate the emergency call, making them critical for user interaction. The choice of reliable buttons can enhance the device's usability and reduce the likelihood of failure during an emergency.
3. **Jumper Wires**: $2.10 for 20
   - **Significance**: Essential for establishing connections between components, quality jumper wires are necessary for ensuring stable electrical connections, which are vital for the overall performance of the system.
4. **Servo Motor**: $7.00
   - **Significance**: The servo motor can provide haptic feedback to alert users of a successful transmission or to indicate when the system is activated. This feedback is crucial for Deaf-Blind users to ensure they are aware that their alert has been sent.
5. **Resistors (1000 Ohms)**: Price $0.64 for 4
   - **Significance**: Resistors will be selected based on circuit requirements as the design progresses. They play a key role in managing current flow and protecting components from damage.
6. **Battery**: Price $5.67
   - **Significance**: The battery is essential for powering the entire system. Selecting an appropriate battery type and capacity is crucial to ensure adequate operation time and reliability in emergencies. (5V and 3W)

Receiver Components:

1. **LCD 16x2 Display**: $16.00
   - **Significance**: This display provides vital feedback to the user, such as system status and confirmations of calls sent. Clear visibility is important for ensuring the user can understand the device’s operation.
2. **Jumper Wires**: $2.10 for 20 (same as transmitter)
   - **Significance**: Reliable connections between components are equally important for the receiver side of the system.
3. **Miniature Push Button (1 unit)**: $0.45

- **Significance**: Similar to the transmitter, this button facilitates user interaction, allowing for easy control over the system.

4. **Resistors (1000 Ohms)**: Price $0.64 for 4
    - **Significance**: Like the transmitter, the resistors chosen will be critical to ensuring the proper functioning of the receiver components.
5. **Nucleo-64 STM32F401RE Unit**: $39.54 (same as transmitter)
    - **Significance**: The same microcontroller is used for processing in the receiver, highlighting its central role in the system.
6. **Battery**: Price $5.67
    - **Significance**: The battery's capacity and type are also crucial for the receiver's reliability and performance. (5V and 3W)

- **Transmitter Total**:
    - Nucleo-64: $39.54
    - Push Buttons: $2.70
    - Jumper Wires: $2.10
    - Servo Motor: $7.00
    - Resistors: $0.64
    - Battery: $5.67

Total for Transmitter: $84.65

- **Receiver Total**:
    - Nucleo-64: $39.54
    - Push Buttons: $0.45
    - Jumper Wires: $2.10
    - Resistors: $0.16
    - Battery: $5.67

Total for Receiver: $59.77

Grand Total: $144.42

While the exact costs of batteries and resistors are yet to be determined, this analysis highlights the critical nature of each component and its impact on the system's overall functionality and reliability. As the design process evolves, continued assessment of component costs and potential adjustments will be necessary to ensure that the project remains within budget while meeting the needs of Deaf-Blind individuals effectively.

4.2 Component Sourcing:
STM32 Board:

Manufactured and shipped from the ST manufacturing plant in Bouskoura, Morocco [57]. Delivered through various means of travel, which would result in an increase of carbon emissions. The total distance shipped to get to Waterloo is about 23690 km. All industries are taxed for their carbon emissions, this would be factored into the manufacturing costs for all sources.

Digikey:

While the Jumper Wires are a Sparkfun product, they have been ordered using Digikey[59]. Digikey outsources their products, Johnson electric ships for Digikey from Hong kong [58].

Sparkfun Electronics Products:

The Jumper Wires, Pushbuttons, Servo Motor, and the LCD Display are all manufactured or distributed by Sparkfun Electronics. The Servo is the only product manufactured by another company, which is SPRINGRC. Sparkfun parts are manufactured in Niwot, Colorado [60].

4.3 Installation Manual:

1. Introduction

The RescueTouch Emergency System is designed to assist Deaf-Blind individuals in emergency situations. This manual provides step-by-step instructions for installation and usage.

2. Components Required

- Nucleo-64 STM32F401RE Board
- Miniature Push Buttons (4-5)
- 1 Servo Motor
- 1 LCD 16x2 Display
- 1000 Ohm Resistors (as needed)
- USB Power Adapter (10V)
- Jumper Wires
- Battery

3. Installation Steps

3.1 Connect the Components

1. **Wiring the STM32 Board:**
    - Connect the STM32 board to the USB power adapter using jumper wires.
    - Use the 1000 ohm resistors to connect the push buttons to the GPIO pins on the STM32. (Refer to figure 4.3.1 & 4.3.2)
2. **Attach the LCD Display:**
    - Connect the LCD display to the STM32 using appropriate jumper wires.
    - Ensure the power and ground pins are correctly connected. (Refer to figure 4.3.1 & 4.3.2)
3. **Install the Servo Motor:**
    - Connect the servo motor to the STM32, ensuring that the signal, power, and ground pins are correctly wired. (Refer to figure 4.3.1 & 4.3.2)

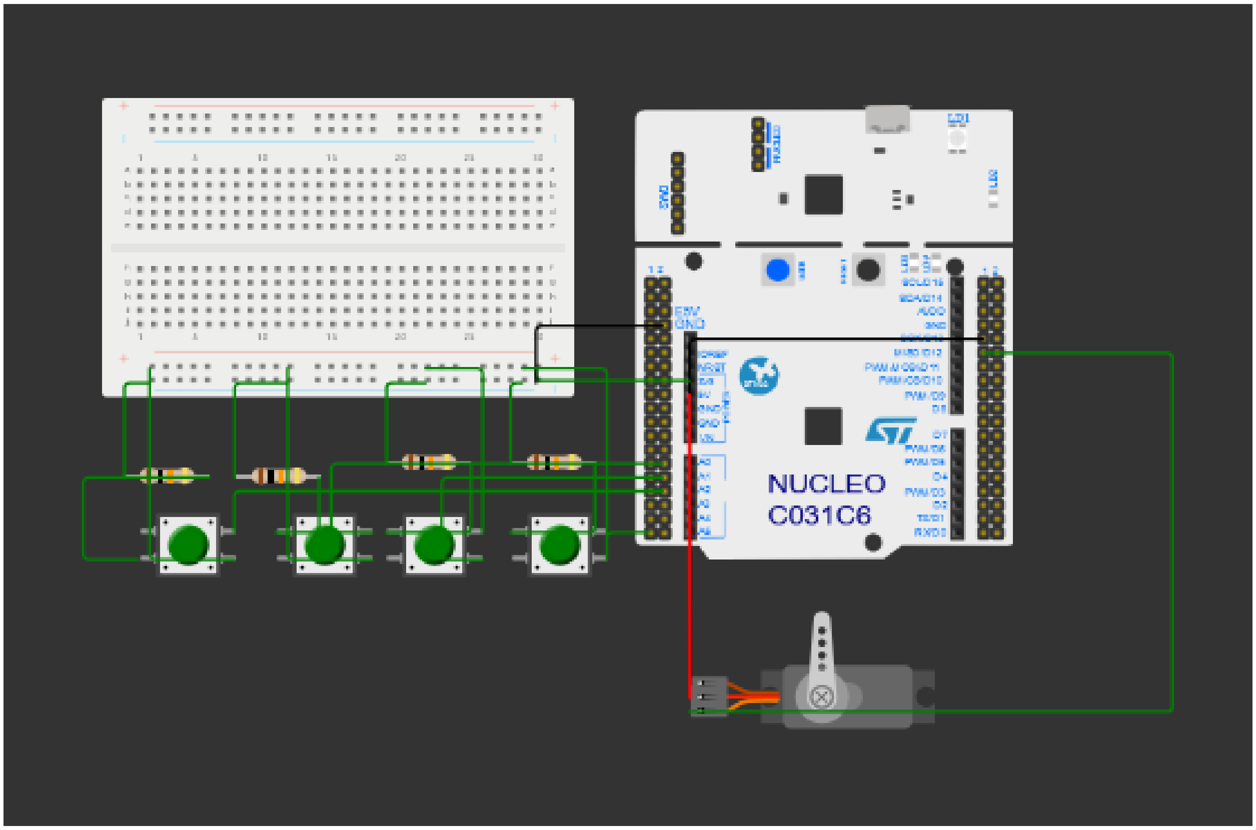

Figure 4.2.1: RescueTouch Emergency Device 3D Diagram (User)

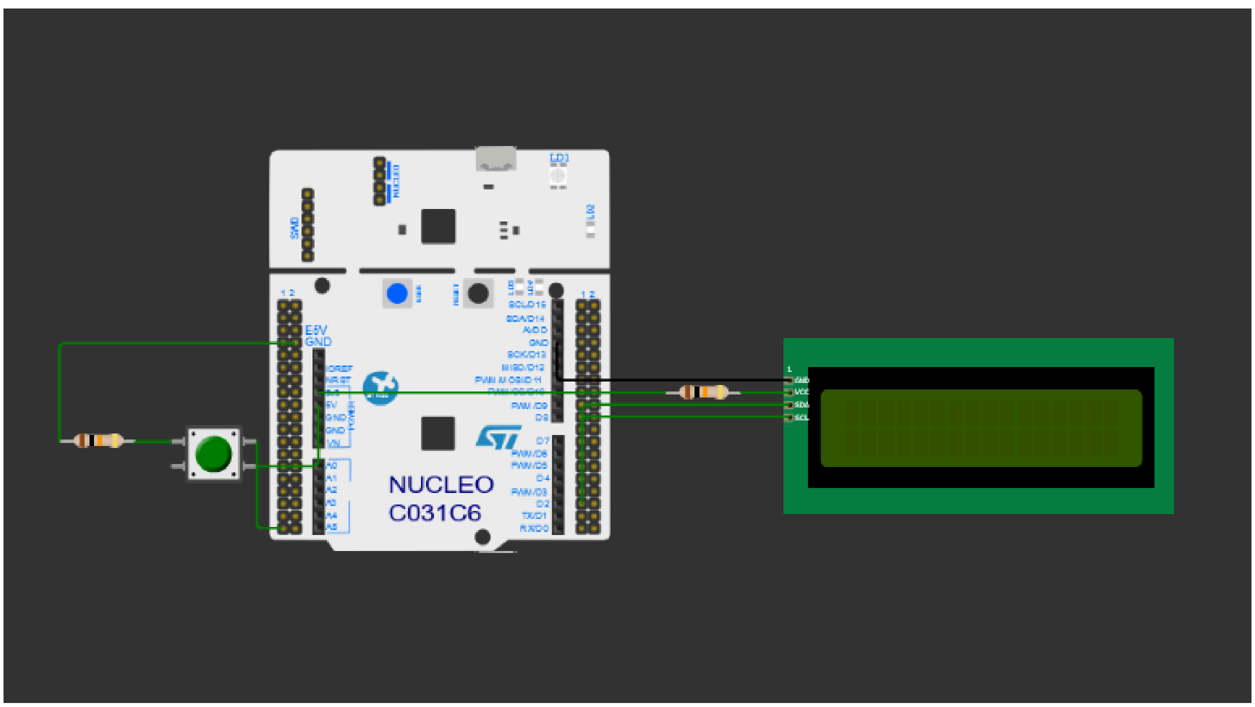

Figure 4.2.2: RescueTouch Emergency Device 3D Diagram (Emergency Service)

3.3 Power Up the System

- Plug the USB power adapter into a wall outlet and connect it to the STM32 board.
- Verify that all connections are secure.

4. Testing the System

4.1 Initial Test

1. Power on the system and observe the LCD display for startup messages.
2. Press each push button to ensure the system responds accordingly.

4.2 Functionality Check

- Ensure the servo motor activates as intended when the corresponding button is pressed.
- Confirm that emergency alerts are sent successfully via the wireless transmission module (if applicable).

5. Safety Precautions

- Avoid using the device in wet or humid environments to prevent electrical hazards.
- Handle all components with care to avoid damage or injury.

6. User Guide

6.1 Operating the System

- To send an emergency alert, press the designated push button.
- Observe the LCD display for feedback on the alert status.
- Follow any additional prompts displayed on the screen.

6.2 Maintenance

- Regularly check all connections and replace any damaged components.
- Keep the system clean and dry to ensure optimal performance.

5. Risks

5.1 Energy Analysis

5.1.1 Reference Standard

1. Identify Types of Energy Storage:
   - Electrical Energy: Stored in capacitors and batteries.
   - Chemical Energy: Stored in batteries (chemical reactions).
   - Mechanical Energy: Stored in springs or flywheels.
   - Thermal Energy: Stored in materials when heated.
2. Evaluate the Design:

- Power Supply: The design uses a USB connection from a wall adapter, providing a 10 V supply. The only energy storage component present in the system is the battery, which is essential for operation but does not indicate significant storage capacity if it's a standard lithium polymer battery designed for low-power applications.

1. IEEE 802.15.4:
    - This standard governs low-rate wireless personal area networks (LR-WPANs), which is relevant for our device which relies on wireless communication [17].
2. USB Power Delivery Specification:
    - This standard outlines how devices can communicate their power requirements, ensuring that our design complies with USB power specifications and protects against overcurrent conditions [62].
3. NIST SP 800-121 Rev. 1:
    - This publication provides guidelines for the security of wireless networks, which is essential if our design transmits sensitive information [61].

5.1.2 Energy Storage

The RescueTouch Emergency System is designed with specific power and energy limitations to ensure safety, reliability, and compliance with project standards. The project requirements are as follows:

- *Power Limit:* The system must not consume, transfer, discharge, or otherwise expend more than **30W** of power at any time during operation across any of the components. This encompasses all forms of energy.
- *Energy Limit:* The system must not store or contain more than **500 mJ** of energy at any given time. This includes all energy forms.

Analysis of Power Consumption:

To demonstrate compliance with these power and energy limits, an analysis of the individual components of the system is performed, ensuring that their combined power consumption remains within the specified limits.

1. Component Power Calculations
    a. Transmitter Unit
    - Nucleo-64 STM32F401RE Unit: Consumes 50 mA at 5V
        - Power Calculation
            - Power = Voltage x Current = 5 V x 0.05 A = 0.25 W
    - Miniature Push Buttons (5 buttons): Each button typically draws a negligible amount of power but can be considered as
        - Assuming each button draws about 5 mA at 5 V when pressed
        - Total power for Push Buttons
            - Power = 5 V x 0.005 A x 4 = 0.1 W
    - Servo Motor: Power consumption is 500 mA at 5 V
        - Power Calculation:
            - Power = 5 V x 0.02 A = 0.1 W

    b. Receiver Unit
    - LCD 16x2 Display: Consumes 20 mA at 5 V

        - Power Calculation:
            - Power = 5 V x 0.02 A = 0.1 W
    - Miniature Push Button (1 Button)
        - Power:
            - Power = 5 V x 0.005 A = 0.025 W
    - Nucleo-64 STM32F401RE Unit
        - Power = 0.25 W

2. Total Power Consumption

Summing the power consumption of all components gives the total power consumption of the system:

- Total Power = Transmitter Power + Receiver Power = (0.25 W + 0.1 W + 2.5 W) + (0.1 W + 0.025 W + 0.25 W) = 2.975 W

The total power consumption of the RescueTouch Emergency System is **2.975 W**, which is below the specified limit of 30 W. This demonstrates that the design adheres to the project power requirements.

To ensure that the RescueTouch Emergency System adheres to the limits for power and energy consumption. This includes analyzing the components of the system, quantifying the maximum total energy stored during operation, and demonstrating through scientific reasoning that the project does not exceed the limits.

Reference Standard Compliance:

- AC Power Adapter Marks:
    - The power supply used in the RescueTouch Emergency System is marked with the following specifications
        - Output Voltage: 10 V
        - Output Current: 1 A
        - In figure 5.1.1.1 you can see the AC adapter is attached to both STM32 Boards, supplying 10 V.

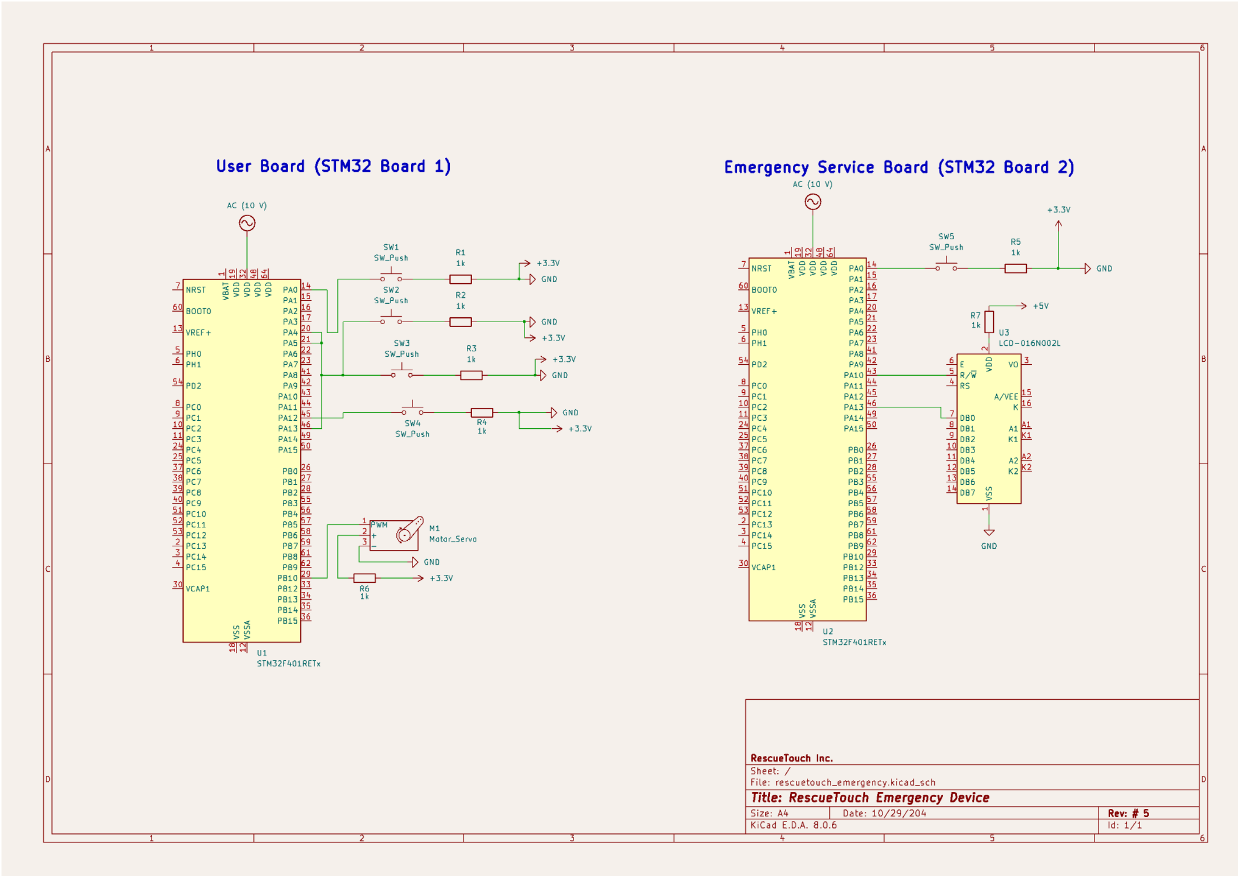

Figure 5.1.1.1: RescueTouch Emergency Device Schematic

This information shows that the power adapter conforms to typical standards for low-power electronic devices, ensuring that it can deliver the necessary voltage and current to operate the system efficiently.

The design of the RescueTouch Emergency System was analyzed to determine whether significant energy storage could occur in various forms, including electrical, chemical, and mechanical energy. Below is a breakdown of these analyses, including considerations of materials and geometries:

1. Electrical Energy Storage:
    - Component: LiPo Battery
        - Voltage: 3.7V
        - Capacity: 100mAh (0.1Ah)
    - Energy Calculation:
        - Energy (in mJ) = Voltage x Capacity (in Ah) x 1000 = 3.7 V x 0.1 Ah x 100 = 370 mJ.
    - Material and Geometry: The battery casing is typically made of lightweight plastic (e.g., polycarbonate), which does not significantly contribute to energy storage but ensures safety and durability. The cylindrical geometry of the battery allows for efficient packaging within the enclosure while providing adequate energy storage without exceeding limits.

2. Chemical Energy Storage:
    - The battery also stores chemical energy, which is released during operation. This is accounted for in the electrical energy storage analysis above, as the stored energy is effectively converted into electrical energy when the battery powers the system.
3. Mechanical Energy Storage:
    - Component: Servo Motor
    - Material: The servo motor typically comprises metals (for gears) and plastics (for the housing). The mechanical potential energy stored in the servo when not in motion is based on its position.
    - Geometry: The gear system inside the servo motor can store mechanical energy depending on the torque applied and the position of the motor. However, for the purpose of this design, the servo will primarily be in motion rather than storing significant energy in a static position.
    - Energy Consideration: When the servo is activated, it draws energy from the power supply, but the mechanical energy stored in the gears is minimal when the servo is not actuated, further ensuring that the overall energy storage remains low.

5.1.3 Maximum Energy

Based on the analyses above, the maximum total energy stored within the RescueTouch Emergency System under operation is calculated as follows:

Total Energy Stored = Electrical Energy + Mechanical Energy

- Given that the mechanical energy stored in the servo motor is negligible and the electrical energy is 370mJ, the total energy stored during operation is:

Total Energy Stored = 370 mJ

The analyses performed clearly indicate that the design of the RescueTouch Emergency System does not exceed the project limits for energy storage. The maximum electrical energy stored in the battery is 370mJ, which is below the 500mJ limit. The mechanical energy stored in the servo motor is minimal and does not contribute significantly to the total energy storage.

This thorough analysis, supported by reference standards and a consideration of materials and geometries, ensures that the design remains safe and reliable for the intended application while meeting the specifications required for the project.

5.2 Risk Analysis

5.2.1 Possible Risks from using the Device as Intended

While the RescueTouch Emergency System is designed with low power constraints to minimize safety and environmental risks, there are still potential negative consequences that could arise from its use, particularly if the device is utilized in unintended environments or situations.

1. **Environmental Risks:**

- **Improper Disposal**: If the device is disposed of improperly, it could contribute to electronic waste (e-waste) pollution. E-waste can release hazardous materials, such as heavy metals and chemicals, into the environment, potentially contaminating soil and water sources. For example, lithium-ion batteries can leak harmful substances if not recycled correctly, disrupt ecosystems, and pose health risks to nearby communities.
- **Littering Concerns**: If discarded carelessly, the device may become litter, leading to aesthetic pollution and environmental degradation. Plastic components from the device may take years to decompose, contributing to long-term environmental issues . Wildlife or become entangled in the discarded materials, leading to injury or death.

2. **Safety Risks:**
    - **Electrical Hazards**: While the device is designed to operate safely within specified voltage and current limits, using it in wet environments poses a significant risk. Water can create a conductive path, potentially leading to electrical leakage or short circuits. This could result in electric shock or burns for users or others nearby . It is essential tat the device is rated for use in such conditions or to provide adequate waterproofing.
    - **Component Damage**: Exposure to moisture, extreme temperatures, or physical impact could damage the device, affecting its functionality during emergencies. If the device fails when needed, it could compromise the safety of the user, particularly for Deaf-Blind individuals relying on it for emergency communication.
    - **User Injury**: In high-stress emergency situations, users may be handling the device in a rush or panic. If the device is not securely housed within a protective enclosure, it may become damaged or malfunction, which could lead to physical injuries if components break or if the user attempts to manipulate the device without proper knowledge of its operation .
3. **Limited AccessibilityUser Dependency:**
    - If the device is the sole means of communication in an emergency, users may become overly reliant on it. If the device fails or is not accessible due to environmental conditions, users may find themselves unable to seek help, leading to potentially life-threatening situations. It's crucial to encourage users to have multiple communication strategies in place for emergencies .

Although the RescueTouch System is designed to be safe and environmentally friendly within its intended usage parameters, there are still significant risks associated with improper use, disposal, and environmental conditions. Ensuring that users are educated about the device's limitations, proper handling, and disposal methods is vital to mitigating these risks. Additionally, incorporating robust environmental and safety considerations into the design process can further minimize potential negative impacts on users and the surrounding environment.

5.2.2 Possible Negative Consequences on Safety or Environment from using the Design Incorrectly

1. **Misuse of Emergency Alerts**: One significant risk associated with the RescueTouch Emergency System is the potential for misuse by individuals. If someone frequently activates the emergency alerts without a genuine need, it can lead to "boy who cried wolf" scenarios. Emergency responders may become desensitized to alerts from the system, which could delay response times for legitimate emergencies. This not only jeopardizes the safety of the person overreacting but also puts others at risk who may require immediate assistance.
2. **Increased Workload for Emergency Services**: The unique nature of the system, which relies on a different communication method compared to traditional 911 calls, may result in longer response times. If multiple false alarms occur, it could overwhelm emergency services, diverting resources away from genuine emergencies. This strain on emergency personnel could lead to delays in responses to other urgent situations, potentially resulting in adverse outcomes for individuals who truly need help.
3. **Social Implications**: Overusing the emergency system can have social repercussions as well. If a user consistently activates the device unnecessarily, it could lead to stigmatization within their community. Friends, family, or even emergency responders may begin to view the individual as a nuisance rather than someone in genuine need of support. This could discourage the user from seeking help when they actually require it, ultimately compromising their safety.
4. **Technical Failures**: Incorrect usage may also result in technical failures. For example, if users mishandle the device—such as by applying excessive force on buttons or exposing it to harsh conditions—the components may become damaged. This could lead to system malfunctions during emergencies when the device is genuinely needed, further endangering the user.
5. **Environmental Concerns from Discarded Devices**: If users become frustrated with the system due to misuse or technical issues, they may be inclined to dispose of the device improperly. This can contribute to electronic waste, which poses environmental hazards. Components of the device, such as batteries and plastics, may release toxic substances into the environment if not disposed of correctly, leading to soil and water contamination.
6. **User Dependency**: Over-reliance on the system could lead individuals to neglect other means of emergency communication. If users assume that the RescueTouch device will always work without fail, they may disregard traditional communication methods, such as cell phones. In emergencies, this dependency could lead to dangerous situations if the device fails or is inaccessible, leaving users without any means to call for help.
7. **Potential for Panic Situations**: In emergencies, the activation of the device might lead to panic, especially if multiple users are alerted simultaneously. This panic could create chaotic situations, making it difficult for both users and responders to coordinate effectively, potentially hindering the assistance needed.

Incorrect usage of the RescueTouch Emergency System can pose significant safety risks not only to the users themselves but also to emergency services and the broader community. Education and guidelines on the appropriate use of the device are crucial to mitigating these risks and ensuring that the system functions as intended, providing a reliable safety net for Deaf-Blind individuals in genuine need of assistance.

5.2.3 Possible Negative Consequences on Safety or Environment from Misusing/Using the Design in and Unintended Way

1. **Physical Injury from Misuse:** While the RescueTouch Emergency System is designed to be safe and user-friendly, misuse can lead to physical injuries. If an individual removes the device from its casing or uses it as a projectile, the exposed STM32 pins could pose a sharp hazard. Contact with these pins may result in cuts or puncture wounds, leading to infections or other medical issues.
2. **Unintended Harm to Others:** Using the device inappropriately, such as striking someone with it or throwing it, could cause significant injury. The compact and hard nature of the device makes it a potential blunt object that, when used aggressively, could lead to bruises, fractures, or concussions. This misuse not only endangers the person being hit but can also put the user at risk of legal consequences for assault.
3. **Environmental Damage from Improper Handling:** If the device is mishandled and damaged, its components may become exposed to the environment. For example, batteries or electronic parts could leak hazardous materials, contaminating soil and water sources. Discarding the device carelessly in the environment could contribute to electronic waste pollution, which is harmful to ecosystems and wildlife.
4. **Impact on Device Integrity:** Physical misuse can compromise the integrity of the device, leading to malfunctions during critical situations. If the device is damaged, it may fail to transmit emergency alerts when genuinely needed, leaving users vulnerable in emergencies and unable to seek help.
5. **Encouraging Recklessness:** If individuals misuse the device, it may promote a culture of recklessness, where users feel empowered to treat the device as a toy or object for physical activities. This behavior can normalize dangerous practices and lead to more severe incidents in the future.

Misusing the RescueTouch Emergency System can have serious safety implications for both the user and those around them. It is essential to educate users on the intended use of the device and the potential dangers of misuse to ensure that it remains a safe and effective tool for emergency communication.

5.2.4 Possible Ways that the Design could Malfunction

1. **Data Loss During Wireless Transmission**: One significant risk in the operation of the RescueTouch Emergency System is the potential for data loss during wireless communication. Factors such as signal interference from other electronic devices, obstacles between the transmitter and receiver, or weak signal strength could lead to incomplete or corrupted data being sent to emergency services. This malfunction could delay response times or result in inaccurate information being conveyed, putting users at risk during emergencies.
2. **Hardware Failures**: The device's components, such as the STM32 microcontroller, sensors, and actuators, may experience hardware failures due to manufacturing defects, wear and tear, or environmental conditions. A malfunctioning component could result in

the system not activating correctly or failing to send alerts when needed. For example, if the button interface becomes unresponsive, users may be unable to trigger the emergency notification system.

3. **Overheating**: Excessive current flow through components can lead to overheating, which may cause damage to the device. Components such as resistors, servos, or the microcontroller could exceed their temperature limits, leading to physical deformation, melting, or even fire hazards. Proper thermal management is crucial to prevent overheating and ensure the device operates safely.
4. **Battery Failures**: The power source is critical for the functionality of the device. If the battery is not adequately maintained or is defective, it may fail to provide sufficient power. A depleted or faulty battery could result in the device shutting down unexpectedly, leaving users unable to access emergency communication.
5. **Software Bugs**: The programming of the device is essential for its proper functioning. Software bugs or glitches in the firmware could lead to unintended behavior, such as the device not responding to button presses or not sending notifications correctly. Regular updates and thorough testing are necessary to minimize the risk of software-related malfunctions.
6. **Environmental Factors**: Exposure to extreme temperatures, moisture, or physical shock can adversely affect the device's functionality. For instance, using the device in wet conditions could lead to short circuits or corrosion of electronic components. Additionally, if the device is dropped or subjected to excessive force, it could result in physical damage to sensitive parts.
7. **Connection Issues**: The reliability of the wireless communication between the two STM32 boards is crucial. If there are issues with the connection, such as loss of pairing or interference from nearby devices, the system may not function as intended. This could prevent messages from being sent or received, hindering the user's ability to communicate in an emergency.
8. **Component Compatibility**: Using incompatible components or sensors may lead to malfunctioning or suboptimal performance. For example, if the selected push buttons do not meet the electrical specifications required for the microcontroller, this could result in erratic behavior or failure to detect button presses.

The potential for malfunction in the RescueTouch Emergency System underscores the importance of thorough design, testing, and quality assurance processes. By identifying and addressing these potential failure points, we can enhance the reliability and effectiveness of the device, ultimately ensuring that it serves its purpose of providing critical emergency communication for users.

5.2.5 Consequences for Malfunctions

1. **Data Loss During Transmission to Emergency Services**:
   - **Scenario 1: Data Lost While Sending to 911**:
     - **Safety Consequences**: If data is lost during transmission, critical information about the emergency situation may not reach 911. This can lead to delayed or inadequate responses, putting the user at greater risk. Users may assume that their message has not been sent and delay seeking

        alternative help, which could result in serious injuries or worsening conditions.
        - **Environmental Consequences**: Although the immediate environmental impact may be minimal, repeated instances of users needing to signal for help multiple times due to data loss can lead to increased strain on emergency services. This may indirectly affect environmental resources by diverting emergency resources from other areas.
    - **Scenario 2: Lack of Acknowledgment from 911**:
        - **Safety Consequences**: If the user does not receive confirmation from 911, they may mistakenly believe that their call for help has gone unanswered. This could lead to unnecessary anxiety and potentially dangerous situations if they wait too long for a response, assuming help is delayed. The user may take additional risks in seeking help elsewhere, increasing the likelihood of injury.
        - **Environmental Consequences**: Similar to the first scenario, the environmental impact here is indirect. Miscommunication could lead to over-reliance on emergency services, straining their resources and potentially leading to inefficiencies that could impact community safety and environmental health.
2. **Overheating of Components**:
    - **Safety Consequences**: Overheating can present significant safety hazards to users. If the device becomes excessively hot, users may sustain burns when holding or using it. In extreme cases, overheating could result in fire hazards, posing risks to the user and nearby individuals or property. Furthermore, if the device fails catastrophically, it may cause injury to the user or others in proximity.
    - **Environmental Consequences**: Overheating may cause components to melt, releasing potentially harmful chemicals and materials into the environment. If molten plastic or electronic components leak onto the ground, it can negatively affect soil quality and harm local vegetation and wildlife. Proper disposal of damaged devices is essential to minimize environmental contamination.
3. **Physical Damage Due to Misuse**:
    - **Safety Consequences**: If the device is misused—such as being thrown or used as a weapon—there is a risk of physical injury to the user or others. Sharp edges from damaged components could cause cuts or punctures, while the device's weight and construction may lead to blunt force injuries.
    - **Environmental Consequences**: Physical damage to the device could lead to its components breaking apart and contributing to electronic waste. If not disposed of properly, these materials may contaminate soil and water systems, posing long-term environmental hazards. Additionally, discarded devices may litter public spaces, affecting local ecosystems.

By understanding these potential failure mechanisms and their consequences, the design and implementation of the emergency call system can prioritize user safety and environmental sustainability. Proper precautions, such as ensuring robust data transmission protocols and thermal management, are essential to mitigate these risks.

6. Testing and Validation Plan

6.1.1 Test 1: Communication Test

Test setup: The purpose of this test is to verify wireless transmission between STM32 boards in real time. The test is to be conducted between 2 STM32 boards. They are to be placed 10 meters away from each other. One STM 32 board will send information to the other STM 32 board once the specified button is pressed (enter send state once button is pressed). The other STM 32 board will be configured to start a timer when a button is pressed (waiting state) and end the timer once the relevant information is received (received state). Once the second STM 32 board enters received state, it will display the time it took between its button press and receiving information, as well as the information it received. Two people will be in charge of button pressing (physically pressing the buttons on the STM 32 boards), and another person will coordinate the exact timing of the press (3 2 1 Go, etc.). The information to send will be preconfigured, since this will be how the real product works.

Environmental parameters: The test will be done in E7, as the temperature control should mimic normal indoor conditions, where most accidents will occur without access to pedestrians. The important environmental parameters in this situation are temperature and signal interference. Temperature is maintained at around 22 degrees celsius and there should be little signal interference in an empty room where the STM32 boards are 10 meters apart.

Test inputs: The only inputs in the device in this test case are the inputs to the STM32 boards from a button and the signals from one STM32 board to the other one. In terms of the test, the input that is tested is the communication between boards.

Quantifiable measurement standard: A timer in milliseconds will be used to verify results.

Pass criteria: To pass this test, the time displayed for receiving the information on the second STM 32 board must be equal to or under 5000 milliseconds. Additionally, the information received must contain the following: name, address, healthcare information.

6.1.2 Test 2: Battery Life Test

Test setup: The purpose of this test is to make sure that the battery life of the device can last up to 24 hours. This test is to be conducted between 2 STM32 boards. They are to be placed 10 meters away from each other. One STM32 board will be configured to send a signal to the other one every 30 seconds (instead of button press). The other STM32 board will have a counter to count how many times it has received a signal. This program will be left running on a battery(what battery are we using) for 24 hours. Once the elapsed time has passed, the second device will display how many times it has received a signal from the other one. A timer will also be running since the start of the test. Once 24 hours have elapsed, the program will stop.

Environmental parameters: The test will be done in a bedroom, as the temperature control should mimic normal indoor conditions, where most accidents will occur without access to pedestrians as well as a 911 contact center. The important environmental parameters in this situation are temperature and signal interference. Temperature is maintained at around 22 degrees celsius and there should be little signal interference in an empty room where the STM32 boards are 10 meters apart.

Test inputs: The only inputs in this situation are the signals from one STM32 board to the other one.

Quantifiable measurement standard: The measurement standard for this case is number of signals and the elapsed time counter on the STM32.

Pass criteria: If the device has received 2880 signals at the end of the 24 hour period then the device has passed the test. It can operate in reasonable conditions for 24 hours. The device's 24 hour clock must be accurate to 24 hours for this test case to pass as well since this confirms the device's usage for 24 hours.

6.1.3 Test 3: User Input Test

Test setup: The purpose of this test is to validate both the user input into one STM32 and to validate feedback from the other STM32 when it confirms a signal. This test will be conducted between 2 STM32 boards 10 meters away from each other. One of them will have a servo motor connected. A button on the first STM32 board will be pressed to initiate a signal to the other one and a timer will be started on the STM32. Once the other STM32 board receives the signal, a button will be pressed to send a feedback signal back to confirm that it received the signal. Once the signal is received, the motor on the first STM32 will move for one second to indicate a signal and the timer will be stopped. This shows the user (person asking for help) that they will be getting help.

Environmental parameters: The test will be done in E7, as the temperature control should mimic normal indoor conditions, where most accidents will occur without access to pedestrians. The important environmental parameters in this situation are temperature and signal interference. Temperature is maintained at around 22 degrees celsius and there should be little signal interference in an empty room where the STM32 boards are 10 meters apart.

Test inputs: The device inputs in this case are the signals to and from each STM32 board as well as the buttons that are being pressed. In terms of test, the user feedback is being tested for this test case.

Quantifiable measurement standard: The measurement standard in this case is the time it takes for feedback to occur.

Pass criteria: The test will be passed when the servo motor moves to indicate a return signal within 1 second of the first STM32 button press.

6.1.4 Test 4: Durability Test

Test setup: The purpose of this test is to make sure that there is no failure in the hardware after 100 uses of the device. This test will be conducted between 2 STM32 boards as specified in the design. They will be placed 10 meters apart. A button on the first STM32 board will be pressed to send a signal to the second one. After the second STM32 receives the signal, it will send a signal back to initiate the feedback. This will be the servo motor moving on the first STM32 board. This process will be repeated 100 times.

Environmental parameters: The test will be done in E7, as the temperature control should mimic normal indoor conditions, where most accidents will occur without access to pedestrians. The important environmental parameters in this situation are temperature and signal interference. Temperature is maintained at around 22 degrees celsius and there should be little signal interference in an empty room where the STM32 boards are 10 meters apart.

Test inputs: The device inputs in this case are the signals between the STM32 boards and the buttons. In terms of test, the durability of the hardware is what is being tested for in this case.

Quantifiable measurement standard: The measurement standard in this case is one full cycle. Each cycle being: button press -> signal to board 2 -> signal back to board 1 -> servo movement for 1 second.

Pass criteria: To pass this test, the device must go through the 100 cycles without any hardware breaking. For example, the buttons must not break, the servo must keep moving, and the boards must keep being able to send signals.

6.1.5 Test 5: Environmental Test

Test setup: The purpose of this test is to make sure that the device can operate under a wide variety of temperature conditions. A thermometer will be used in this test. The test will be conducted between 2 STM32 boards. They will be placed 30 centimeters away from each other (due to space constraints). In the first test case, the STM32 boards will be placed in a freezer. This will mimic below freezing temperatures. One full cycle will be conducted (button press -> signal to board 2 -> signal back to board 1 -> servo movement for 1 second). In the second case, a bucket will be filled with water. It will be filled with 40 degree celsius water. The STM32 boards will be placed inside another smaller bucket that will be placed in the large bucket. The lid on the small bucket will be closed for 10 minutes while the 40 degree celsius temperature in the large bucket is maintained. After 10 minutes, one cycle will be conducted with the devices.

Environmental parameters: The environmental parameters in this situation are the temperature and the humidity. In the freezer, the temperature will be around -18 degrees celsius and not too humid. In the bucket, the temperature will be around 40 degrees celsius and also not too humid.

Test inputs: The device inputs in this case are the buttons, the signals between the boards, as well as the temperature. In terms of testing, the device's ability to function in a wide variety of temperatures is being tested.

Quantifiable measurement standard: The temperature will be measured in degrees celsius using a thermometer.

Pass criteria: This test will be passed when the boards go through both test cases without failing.

7. References

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