Design Document

Asmi Nagra | Se Yeon Bark
Group 2

Mission

★ Our mission is to innovate and create a wearable assistive technology piece that empowers individuals facing visual impairment, more specifically, legal blindness, as a way to enhance their independence and quality of life.

Client/Customer Definition

~ Background & Associated Issues ~

A study by Roberto Manduchi and Sri Kurniawan, from the Department of Computer Engineering, University of California, Santa Cruz presents the findings of a survey conducted with over 280 legally blind or blind individuals, between the ages of 18 to 75, focusing on the frequency, nature, and causes of head-level and fall accidents in the context of independent mobility [22, p. 1]. Within this article, many viable issues are presented, such as:

- Head-Level Accidents: Legally blind respondents experienced head-level accidents more frequently than blind respondents. These accidents predominantly occurred outdoors and were caused by objects like tree branches, poles, and signs. Some accidents resulted in medical consequences, changes in walking habits, and reduced confidence in independent travel [22, p. 8].
- Trip/Fall Accidents: Legally blind respondents also experienced trip and fall accidents more frequently than blind respondents. The causes included lack of attention, unexpected obstacles, and misjudgment of distances. These accidents often led to similar consequences that were mentioned in the previous point [22, p. 10].

These examples illustrate that legally blind individuals, who make up about 41.7 percent of the 300 individuals surveyed, who still possess some degree of vision, albeit not very clear, tend to be more impacted by obstacles obstructing their path compared to completely blind individuals [22, p. 3]. The study cited above suggests that this discrepancy arises from the fact that legally blind individuals often possess residual vision, such as light perception or a limited visual field [22, p. 3]. This residual vision can inadvertently lead them to place more reliance on their remaining sight, leading them to have fewer visual cues to alert themselves, thus increasing the likelihood of encountering obstacles that they can partially perceive but struggle to fully identify or navigate around [27]. **Hence, our clients for this project are the 41.7 percent of the 300 (or 125) legally blind individuals who were studied in this research.**

~ Customer Attributes ~

- Demographic
  - Visual Impairment Status: The most prominent demographic attribute mentioned above is the distinction between legally blind individuals and completely blind individuals. This attribute categorizes the target audience based on their level of

visual impairment, hence focusing on their role as the primary customer base for this project [22, p. 2].
    - Age: Additionally, the study specifies that the surveyed individuals fall within the age range of 18 to 75, thus showing that this is another important demographic attribute that segments the target audience by age group [22, p. 2].
    - Walking Aids: Within the scope of this study, two categories of participants were identified: those who exclusively relied on a long cane for mobility, and those who used a dog guide, sometimes alongside a long cane. Legally blind individuals, in this case, constituted 45 percent of the long cane users and 35 percent of the dog guide users [22, p. 4].
- Geographic
    - For this study, there were a total of 289 respondents based in the United States, with representation from 32 different states. Additionally, some respondents were located in various other countries, including 10 in Canada, 2 in New Zealand, 2 in Bulgaria, 1 in Mexico, 1 in Indonesia, 1 in the United Kingdom, and 1 in Germany [22, p. 2].
- Economic
    - The individuals in this study were said to utilize various wayfinding and mobility aids. For instance, 9% stated that they use GPS. Another 9% stated that they also use aids such as monoculars, telescopes, TalkingSigns, tactile maps, or sighted companions [22 p. 3-4]. However, the main focus for this project is the amount of individuals utilizing solely mobility aids, such as long canes and guide dogs — legally blind respondents accounted for 45% of long cane users and for 35% of guide dog users [22 p. 3-4]. Also, it is notable to understand that 17% of respondents were retired, either due to age or disabilities, and 5% were unemployed, while the remaining population were either employed or students [22 p. 3]. Therefore, considering these points, we can conclude that individuals who use mobility aids have some financial implications to care for as a result of their lack of sight, especially in high-income areas. [1]
        - Guide Dogs: In today's day and age, it costs around $150 to $500 per month for the care of a guide dog, which may be a lot or a little depending on the individual and their income status, whether it comes from a working job, government benefits, or any other means. [2]
        - Long Canes: Additionally, long canes, despite being potentially cheaper than a guide dog, come at varied costs. For example, smart canes can run anywhere from $100 to upwards of $1,000, while a standard white cane typically costs $20 to $60, which again can be a little or a lot depending on the economic standing of the individual [3].

Competitive Landscape

1. OrCam MyEye: The OrCam MyEye is a wearable assistive technology device designed to assist individuals with visual impairments, including those who are legally blind. It has a tiny camera and microphone that attaches to a pair of glasses and is linked to a processing base unit that is small enough to fit in a reasonably sized pocket or clipped to a belt. As the OrCam MyEye device uses artificial intelligence (AI) and computer vision, the user can trigger the text-recognition technology and voice reads out what's in front

of the camera by pointing a finger at a text. This device can also detect faces, money and other objects. It costs about 3,120 pounds sterling, which is approximately 5,195 Canadian dollars [32].

   a. Shortcomings:
      i. Cost: The OrCam MyEye glasses are relatively expensive, which makes it hard for individuals with lower incomes to access the device.
      ii. Limited Range: It may not be effective for tasks that require long-range vision, such as navigation in unfamiliar outdoor environments. This can be a flaw of the device in the social system.
      iii. Learning Curve: Some users may find it challenging to learn and fully utilize all of its features.

2. Be My Eyes: Be My Eyes is a mobile app that connects blind and visually impaired individuals with sighted volunteers through live video calls. Users can request assistance with various tasks, such as reading labels, identifying objects, or even getting guidance in unfamiliar places. This crowdsourced approach leverages the power of human assistance to enhance the independence and quality of life for those with visual impairments. Number of volunteers signed up, which means it would be quicker for the user to get a volunteer [33].
   a. Shortcomings:
      i. Dependence on volunteers: The availability of volunteers may vary, leading to potential delays in assistance. If there are too many volunteers signed up, it would be hard to get a call to help someone in visual need [33].
      ii. Privacy Concerns: Users need to share their live video feed with volunteers, raising privacy considerations.
      iii. Limited to Tasks: Be My Eyes is primarily focused on tasks requiring visual assistance and does not address all the challenges faced by visually impaired individuals.
3. Microsoft Seeing AI: Microsoft Seeing AI is a free mobile app that leverages AI and machine learning to assist individuals with visual impairments. The app provides a range of features, including reading text, identifying objects and people, describing scenes, and recognizing currency denominations. It works in real-time and can be used for various daily tasks, thus promoting independence and enhancing the quality of life for its users [34].
   a. Shortcomings:
      i. Smartphone dependency: Users need a compatible smartphone to use the app, which may exclude individuals who don't own or are not comfortable with smartphones.
      ii. Technical Limitations: while powerful, the app may not always provide 100% accurate descriptions or identifications.
      iii. Limited hardware integration: it relies on the smartphone's camera and may not be as hands-free as some wearable solutions.

Requirement Specification

1. The system shall detect obstacles in the user's path and provide real-time alerts. These real-time alerts, or the vibrations in this case, will allow the user's brain to register the

vibration in about 0.15 seconds, therefore giving more than enough time for the user to avoid obstacles [21].

2. The system designed should be configured with a sensor, more specifically with the Passive Infrared PIR Motion Sensor. This sensor is able to have detection distances ranging from 25 centimetres to 20 meters [11] which is in accordance with the distance that a regular blind cane, which typically has a range of 1.2 meters, can reach [17]. By using this sensor, a visually impaired individual is able to be notified of an obstacle in advance, and is able to move accordingly.
3. In addition, the system designed should also output a vibration as a warning to the individual of an oncoming obstacle, specifically with the PWM Vibration Motor. To elaborate, it is proven by research that blind individuals perceive touch faster than those with sight [16]. Knowing this, and the fact that humans are able to respond to vibration levels that are typically from about 6 Hz to 200 Hz, we can program the MCU to sense objects within the individual's path and output a vibration with a sensible level as a response [15].
4. The use of a power bank is necessary for the use of this system. To explain, if an individual is going to wear the system on their person, then they must have a power supply source connected to supply power to the system. The power bank typically needs to be charged every 50 hours, as the power bank for this project has a battery capacity of 5000mAh, or 5000 milliamp-hours [19], a unit of electric charge used to describe the battery capacity [20]. This will allow the individual not to have to charge the device often, hence increasing its efficiency.
5. We will create and outwardly protect the device in such a way that it can adapt to changing temperature conditions, such as weather. This characteristic of withstanding temperature changes will be implemented when we create the wearable aspect of the project by using materials, such as nylon, which can withstand temperatures up to -30°C to 95°C [30]. This indicates that a visually impaired individual is able to go out in extreme weather without having to worry about the hardware becoming damaged due to the heat/cold, which will be enclosed in a nylon bag.

Design

~ General Focus ~

- The design encompasses an assistive, wearable device to enhance independent travel for legally impaired individuals.
- The device's primary function is to detect obstacles in the user's path and communicate their presence through vibration alerts.
- This design aims to empower visually impaired individuals by providing a compact, simple, and effective means of detecting and navigating obstacles during independent travel.
- This design is packed into a crossbody nylon bag, which houses the essential components for object detection and vibration feedback.

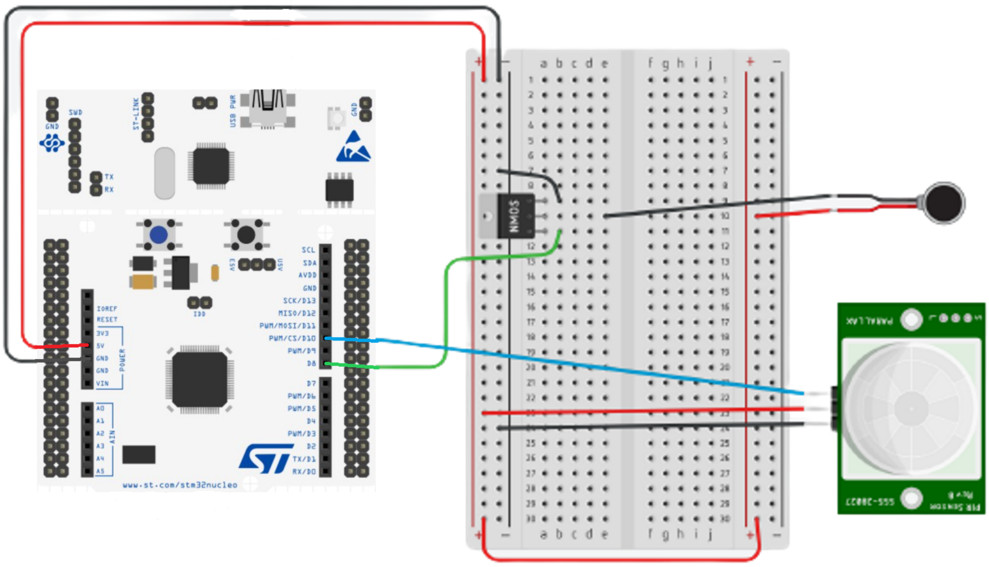
~ Key Components ~

1. Obstacle Detection Sensor
    a. The system incorporates a sensor, positioned to face the environment, that uses infrared sensing technology to detect obstacles in the user's path.

2. Vibration Motor
    a. Vibration alerts are generated by a motor connected to the microcontroller. These vibrations are generated as a result of the sensor detecting an obstacle.
3. Power Supply
    a. A portable battery provides the necessary power for device operation, ensuring mobility and convenience.

~ Wiring Diagram & Instructions ~

This diagram details the relative positions of the components that make up the project, and how they are connected.



1. Checking the Wires:
    a. Connect the black wire (the one coming out of the STM32) to the "negative" side of the board for grounding.
    b. Connect the red wire (the one coming out of the STM32) to the "positive" side of the board for power (5 volts).

    * Make sure the connections are secure and the wires are well-covered *

2. Transistor Position:
    a. Place the transistor on the board as shown in the picture, the label should be facing away from the STM32.
    b. Connect a black wire to the "Source" pin and a green wire to the "Gate" pin. The green wire should go to a specific point on your board marked as "pin 8."

3. Checking Sensor:
    a. Connect the blue wire to a spot on the board labeled "PWM/CS/D10."
    b. Connect the red wire to the same point you connected your "positive" wire.
    c. Connect the black wire to the same point you connected your "negative" wire.

4. Examining Vibration Motor:

a. Since the motor's wires are very thin, twist them around the solid wires and secure them with electrical tape.
b. Connect the black wire near the "Source" on your board for grounding, and the red wire to the nearest point labeled "positive" for power.

* Make sure the connections are secure and insulated. *

If all these components and wires are correctly set up, the product is ready to use. Simply connect the STM32 to a portable power source and place the system in the provided bag.

~ Housing Structure ~

This three-dimensional diagram is of the bag that is going to house all of the components shown above.

This bag is expected to have a capacity of 1 litre [31], therefore, it should hold all of the components without any problem.

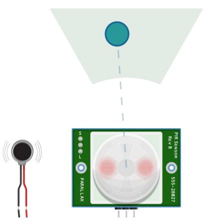
The bag will be made out of nylon.

~ Pseudocode ~

```
while (true) {
  if (motion_detected()) {
    turn_on_led();
    turn_on_motor();
    delay(1000);  // Wait for 1 second
    turn_off_motor();
    delay(2000);  // Wait for an additional 2 seconds
  } else {
    turn_off_led();
    turn_off_motor();
  }
}
```

~ Operation ~

- When activated (power source turned on), the device continuously scans the environment for obstacles.
- Upon obstacle detection, the sensor triggers the vibration motor to provide tactile feedback to the user.



In this diagram, when the sensor, on the right, detects an obstacle of some sort, represented by the blue dot, it informs the vibration motor, on the left, to turn on.

~ Safety and Environmental Considerations ~

- The device's correct usage is key for user safety and environmental awareness. In the event of a threat to safety when using this device, ensure you are aware of your surroundings, and always have a backup plan, such as a cane or guide dog.

Scientific & Mathematical Principles

~ Scientific Principle: Electronics and Circuitry ~

Description: Electronics and circuitry refer to the field of electrical engineering and technology that deals with the practical applications of electricity, such as the design, development, and application of electronic devices and circuits [26].

<u>Key Points:</u>

- Circuitry is a principle in creating the electronic components of the device. It involves determining how various electronic components, such as sensors, microcontrollers, power sources, and output mechanisms, are interconnected to perform specific functions. These principles help ensure that the device operates reliably and efficiently [7]. Complying with the guidelines of circuitry will allow all of the components, such as the sensors and vibration motor to function together without any errors, thus increasing the viability and value of the device.
- Three fundamental electrical parameters play a crucial role in electronics:
  - Voltage (V): represents the electric potential difference between two points in a circuit, and determines the force that drives current through components [6].
  - Current (I): is the flow of electric charge, typically measured in amperes (A), and describes the rate of electron movement through a conductor [6].
  - Resistance (R): is a property of materials that opposes the flow of current, measured in ohms (Ω), and determines how much current flows through a component for a given voltage [6].

  By knowing what these parameters of electronics do we are able to utilize them to regulate the electricity that flows through the system as a way to maintain safety when working with electrical equipment.
- Power dissipation, measured in watts (W), is the rate at which electrical energy is converted into heat within electronic components. Understanding power dissipation is crucial for selecting the right components and ensuring they operate within safe temperature limits [5]. This aspect may be crucial as we do not want our device to face the problem of overheating, thus keeping an eye on the power dissipation will be highly important.
- Ohm's Law is a fundamental principle in electronics that relates voltage, current, and resistance, expressed as $V = I * R$, where V is voltage, I is current, and R is resistance [4]. Ohm's Law will help design the project to achieve the specific

voltage and current levels required and help us to not go over the designated energy levels.

Electronics and Circuitry Contribution & Implementation:

The above scientific principle, and its additional points, showcase the importance of how to use electrical circuits safely to both us, the manufacturers, and the user. Knowing more about the parameters that make circuitry functional will prove to be an important part of keeping in the guidelines of not "expending more than 30W of power at any given point in time." The inclusion of maths principles and power dissipation will most likely play a crucial role in making sure that the final product upholds safety hazards.

For the implementation aspect, as the design gets further into its production, a continuous set of calculations will be done as a way to ensure that our design upholds the viable constraints placed on it. However, the initial power dissipation calculations will be detailed below for the PIR sensor and the vibration motor:

Power Dissipation
Formula: Power (P) [W] = Voltage (V) [V] × Current (I) [Amps]

P is the power dissipation (in watts).
V is the voltage (in volts)
I is the current (in amps)

PIR Sensor	Vibration Motor
Power (P) = Voltage (V) × Current (I) = 3.3 V × 100 uA = 3.3 V × 100 uA / 1000000 = 3.3 V × 0.0001 A = 0.00033 W	Power (P) = Voltage (V) × Current (I) = 3.3 V × 0.07 A = 0.231 W

* ALL KNOWN VALUES CAN BE FOUND IN “ENERGY ANALYSIS” SECTION *

~ Scientific Principle: Sensor Technology ~

Description: Sensor technology is a field focused on creating and using sensors to detect and measure different properties in the environment, converting them into a readable signal [24]. Typically, it has broad applications across healthcare, automotive, and environmental monitoring industries, facilitating data collection and control systems [25].

Key Points:

- Principles of sensor operation, such as passive infrared (PIR) sensors for motion detection, are crucial for accurate obstacle detection, as they have a significantly large range of detection of up to 20 metres [11]. This trait is highly useful for this project as the sensor used should be able to sense objects from a significant distance.

- PIR sensors work based on the principle of detecting changes in heat radiation. They consist of two pyroelectric sensors that generate electrical signals when exposed to heat [10]. When an object within the sensor's field of view moves, it causes a change in the heat pattern, leading to a voltage change in the sensors [23]. The sensor's ability to do this will allow it to identify objects in front of it, thus allowing for the electrical signal to be sent to the vibration motor, which will further inform the user.
- To optimize the device's battery life, principles of energy-efficient sensors are considered. PIR sensors are designed to consume minimal power when in standby mode and activate when motion is detected [9]. This will allow the device to function for significant amounts of time without the need for a recharge, hence increasing its user-friendliness.
- PIR sensors have a specific field of view, typically represented as an angle, such as 180 or 360 degrees detection area [8]. The principles of sensor placement and field of view optimize the efficiency of the device to detect obstacles in the user's path.

<u>Sensor Technology Contribution & Implementation</u>

The above scientific principle, and its supplementary points, are critical to the functioning of our project, as they discuss the full scope of the sensor. This technology is essential as it forms the foundation for our project. It enables the sensor to detect obstacles in the path of visually impaired individuals and relay this information via an electrical signal to a vibrator, assisting users in obstacle avoidance.

The essence of this implementation is to confirm the true range of the PIR sensor, which is known to be a key component in this project. Understanding this range is critical because, without this knowledge, the design may lead to inaccurate object detection, potentially compromising user safety. Therefore, the below implementation steps will be taken into consideration:

Implementation Steps
First, we will place an object (acting as an obstacle) at the maximum specified range of the sensor, which is said to be 25 cm to 20 m. Then, upon activating and connecting the sensor, an accurate indication of the sensor's range can be determined, so that measurements are accurate and repeatable, especially at various distances within the sensor's range. Afterwards, a comparison of the sensor's range measurements to the actual distance of the object from the sensor will be taken into account, which will be used to calculate the difference, thus giving us an accurate depiction of the range.

~ Mathematical Principle: Vibration Frequency ~

Description: In a mathematical principle context, vibration frequency refers to the number of oscillations of a vibrating or oscillating object per unit of time [12]. The study of vibration in physical systems is an important part of almost all fields in physics and engineering, playing a crucial role in electrical, mechanical and acoustic systems [13].

Key Points:

- The key frequency ranges associated with human body vibration sensitivity typically span from approximately 3 Hz to 17 Hz. However, as per the International Standard ISO 2631, concerning vertical vibrations affecting the human body, the region of heightened sensitivity is particularly centred around 6 Hz to 8 Hz [14]. This informs us of the maximum vibration that we cannot exceed, as a way to ensure the safety of the users.
- In assessing the overall vibration of any vibration system, typically the evaluation involves measuring vibrations in millimetres per second (mm/s) within a frequency bandwidth spanning from 10 Hz to 1000 Hz. ISO 10816-1 provides guidelines for setting vibration severity limits, which vary based on the motor classes in use [18]. For our use, however, the vibration motor to be used has a vibrational frequency of 233 Hz, thus showing that it is within the range indicated above [28].
- In terms of human perception, the threshold value for Peak Particle Velocity (PPV) is typically 0.018 mm/s. When PPV reaches 0.56 mm/s, individuals can unmistakably perceive vibrations, and only when PPV exceeds 1.8 mm/s is vibratory tolerance considered acceptable if experienced infrequently or for short durations [29]. In our case, we will program the vibration motor (which has a normalized amplitude of 1.1 mm/s) only to vibrate for short and infrequent exposure as a way to indicate an obstacle [35].

Vibration Frequency Contribution & Implementation

The above mathematical principle, and its supplementary points, are crucial to the safety of the user in terms of the vibration motor. Therefore, we will be defining and calculating the various vibration parameters, including frequency and amplitude. Additionally, we will alter the duration of the vibration and the silent (pause) time in between consecutive vibrations in a pattern during the programming and testing phase.

Also, an important method to understand how much vibration an individual is feeling comes down to how intense the vibration is, which can alter the duration of the vibration and the silent (pause) time, as mentioned above. Therefore, to calculate the minimum velocity of intensity, the following procedure is required:

Velocity of Intensity

Since the rated vibration speed in rpm and the radius is known, it can be converted into m/s using this formula:

$V = (2\pi * r) / 60) * N$

Where:

v is the velocity of the vibrating particles or medium (in meters per second, m/s).
N is the speed in rpm
r (m) is the radius of the motor

* ALL KNOWN SPECIFICATIONS CAN BE FOUND IN "ENERGY ANALYSIS SECTION *

Expected Intensity:

$V = ((2\pi * r) / 60) * N$
$= ((2\pi * 0.005) / 60) * 14{,}000$
$= 7.33$ m/s

A daily exposure limit value of 9.51 m/s is required, therefore indicating that our design should be safe for the users in terms of the vibrational aspect [36].

Manufacturing Costs

~ Materials ~

- Nucleo STM32 F402RE (Cost: $34.99 + $1.75(GST) + $2.80(H13-ON) + $4.55(Tax) = **$39.54 (Total)**; bought from W Store) [55]
    - Manufacturer: STMicroelectronics
        - Geographical Location: Geneva, Switzerland
    - Vendors/Distributors: Digi-Key
        - Geographical Location: Thief River Falls, Minnesota, USA
    - Another vendors/distributors: W Store
        - Geographical Location: University of Waterloo, Waterloo, Ontario, Canada
- Passive Infrared PIR Motion Sensor (Cost: $9.85) [51]
    - Manufacturer: Adafruit Industries LLC
        - Geographical Location: New York, New York, United States
    - Vendors/Distributors: Digi-Key
        - Geographical Location: Thief River Falls, Minnesota, USA
- 10mm Vibration Motor (Cost: $1.83(Vibration motor itself) + $8(Shipping from USA) + $1.28(HST) = **$11.11 (total)**) [56]
    - Manufacturer: JIE YI ELECTRONICS LIMITED
        - Geographical Location: Shanghai, China
    - Vendors/Distributors: Digi-Key
        - Geographical Location: Thief River Falls, Minnesota, USA.
- Breadboard (Cost: $4.75) [49]
    - Manufacturer: DFRobot
        - Geographical Location: Shanghai, China
    - Vendors/Distributors: Digi-Key
        - Geographical Location: Thief River Falls, Minnesota, USA.
- N-Channel Mosfet Transistor (Cost: $1.99) [46]

        - Manufacturer: Infineon Technologies
            - Geographical Location: Neubiberg, Germany
        - Vendors/Distributors: Digi-Key
            - Geographical Location: Thief River Falls, Minnesota, USA.
- Jumper Wires + Electrical Tape (Cost:$ 4.75) [47]
            - Manufacturer: Adafruit Industries LLC
                - Geographical Location: New York, New York, United States
            - Vendors/Distributors: Digi-Key
                - Geographical Location: Thief River Falls, Minnesota, USA
- Cross-Body Bag (Cost: $16.99) [31]
    - Manufacturer: Lole
        - Geographical Location: Montreal, Canada
    - Vendors/Distributors: Lole
        - Geographical Location: Montreal, Canada

~ Technology ~

- STM32CubeIDE 1.13.1 (Cost: Free)
    - Manufacturer: STMicroelectronics
        - Geographical Location: Geneva, Switzerland
    - Vendors/Distributors: STMicroelectronics
        - Geographical Location: N/A - Downloaded through STMicroelectronics

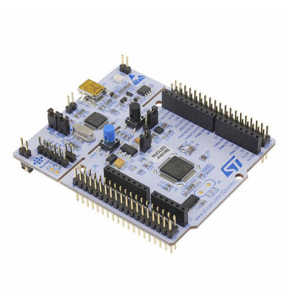
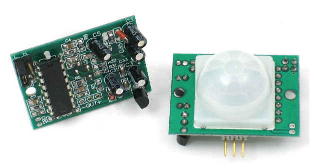
Total: $88.98

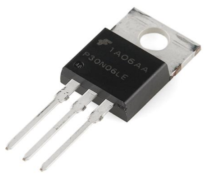
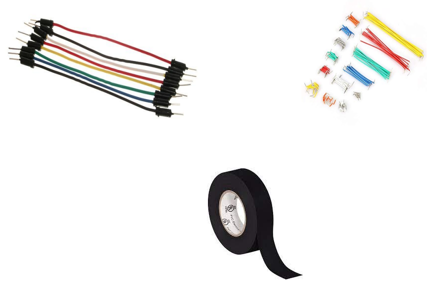
Implementation Cost

~ Installation Manual ~

The following procedures and figures provide a comprehensive guide for the installation of the design, for the possibility of an unexpected occurrence.

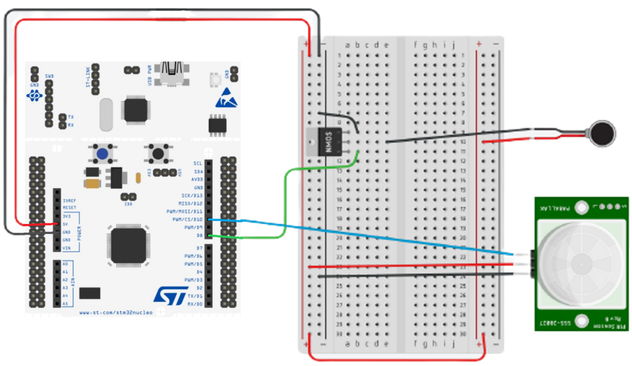
- ★ **Step 1:**
    - Ensure all of the components are there, which consist of:

STM32 F401RE	Passive Infrared PIR Motion Sensor
	
Source: Adapted from [42]	Source: Adapted from [43]
Vibration Motor (10mm)	Bread Board

Source: Adapted from [44]	Source: Adapted from [45]
N-Channel Mosfet Transistor	Jumper Wires + Electrical Tape
 Source: Adapted from [46]	 Source: Adapted from [47 ,48]

- ★ **Step 2:**
  - ○ Check that the wire connections match the ones in the following diagram

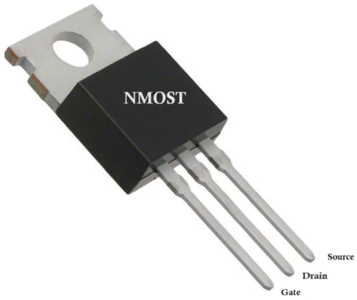
---



1. Check Jumper Wires for Ground & Power from STM32
   a. The black wire should be connected to the negative terminal on the breadboard to supply GND from the STM32 to the rest of the breadboard.
   b. The red wire connects to the positive terminal on the breadboard, providing 5 volts of power.
   c. Ensure the wires are securely connected and

well-insulated.

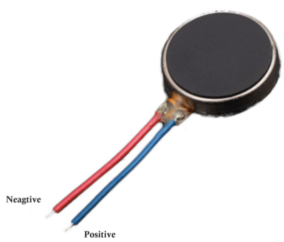
Note: The solid red jumper wire at the bottom of the breadboard extends the reach of power.



2. Inspect N-Channel Mosfet Transistor
    a. The transistor should be installed as shown in the diagram, with the pins in a vertical orientation, so that no short circuits occur. The pins should be inserted in the following order (from top to bottom, look at the diagram on the left)
        i. Source
        ii. Drain
        iii. Gate
    b. A black ground wire is attached in front of the **Source** pin, connected to the negative ground terminal.
    c. A green wire is attached in front of the **Gate** pin, connected to pin 8 (D8) of the STM32. Source: Adapted from [46]

3. Check Sensor
    a. Three flexible wires are required to connect the PIR sensor to the STM32 via the breadboard
    b. The connections are as follows (as seen on the diagram):
        i. Signal (Blue Wire): Connect to the PWM/CS/D10 on STM32
        ii. Power (Red Wire): Connect to the breadboard where the power supply is coming from (the positive terminal)
        iii. Ground (Black Wire): Connect to the breadboard where the connection from the ground is coming from (the negative terminal)
        Source: Adapted from [43]

4. Examine Vibration Motor
    a. Two solid jumper wires are required to connect the Vibration Motor to the STM32 via the breadboard. Note: *Due to the motor's slender wires, it's impossible and dangerous to connect them directly to the breadboard. As a result, they must be fastened by twisting the motor wires around the metal portion of the solid jumper wires and secured with electrical tape.* ***Make sure that the wires are fully connected, and that no loose wiring can be seen or touched.***
    b. The black wire near the **Source** pin of the transistor should be connected via the



breadboard, so that the negative wire of the motor can receive ground power from the STM32
   c. The red wire should be attached to the nearest positive terminal, so that the motor may be supplied with power from the STM32. Source: Adapted from [44]

If all of these components and wires are in place, then the product is ready to be used. Just simply connect the STM32 directly to a portable power source (with at least 5000mAh, or 5000 milliamp-hours), and place the whole system in the provided bag

~ User Guide ~

1. Introduction
   a. Here is a brief outlook on the intended usage of the device
2. Safety Precautions
   a. Maintain awareness at all times. Do not solely rely on the device for navigation. Continue using other mobility aids, such as canes or guide dogs, in complex or unfamiliar environments.
   b. Regularly check the device's battery status and charge it as needed. Low battery levels can lead to a loss of functionality at critical moments.
   c. In emergencies, prioritize your safety above all else. The device is meant to *assist* but should not replace common-sense safety precautions.
   d. Be aware of the impact of weather conditions on the device's functionality. Extreme weather, such as rain, snow, or very high or low temperatures, may affect performance.
   e. Inform those around you, such as friends, family, or caregivers, about the device and how it works, so they can assist or understand the device's alerts when necessary.
3. Using the Device
   a. Activating the Device
      i. To activate the device, ensure that the power supply (portable battery) is turned on and has sufficient power for proper operation.
   b. Sensor Position
      i. Position the sensor in a way that it faces away from you, towards the environment, to maximize obstacle detection.
   c. Interpreting Vibration Alerts
      i. When the sensor detects an obstacle, understand that the vibration alerts indicate the presence of an obstacle in your path. Adjust your movement accordingly.
   d. Deactivating the Device
      i. To deactivate the device, simply turn off the power supply.

Energy Analysis

~ Reference Standard ~

- The design must not consume, transfer, discharge, or otherwise expend more than **30W** of power at any point in time and within any component of the design during its operation, including all forms of energy: electric energy, electric potential energy, mechanical kinetic energy, or mechanical potential energy.
- The design must not store or otherwise contain more than **500mJ** of energy at any point in time, including all forms of energy: electric energy, electric potential energy, mechanical kinetic energy, or mechanical potential energy.

~ Appropriate Reference Standard ~

The CSA C22 standard, officially known as the "Canadian Electrical Code," is a set of standards and regulations developed by the Canadian Standards Association (CSA). It predominantly addresses the safe installation and use of electrical equipment and systems in Canada. Therefore, when comparing the components of the project to the regulations, we see that,

- The CSA-C22 standard sets safety requirements and guidelines for the installation and use of electrical equipment in Canada. By referencing this standard, a demonstration of compliance with Canadian safety regulations is upheld. For example,
    - According to the CSA, battery chargers for use on minor system voltages should not exceed 600 V, which is per the input voltage range of the sensor, is 3.0-5.5V, thus it is within the safe operating limits of the CSA-C22 standard.
    - The rated operating voltage of 3 V for the vibration motor also complies with CSA-C22 [37].

~ Component Analysis ~

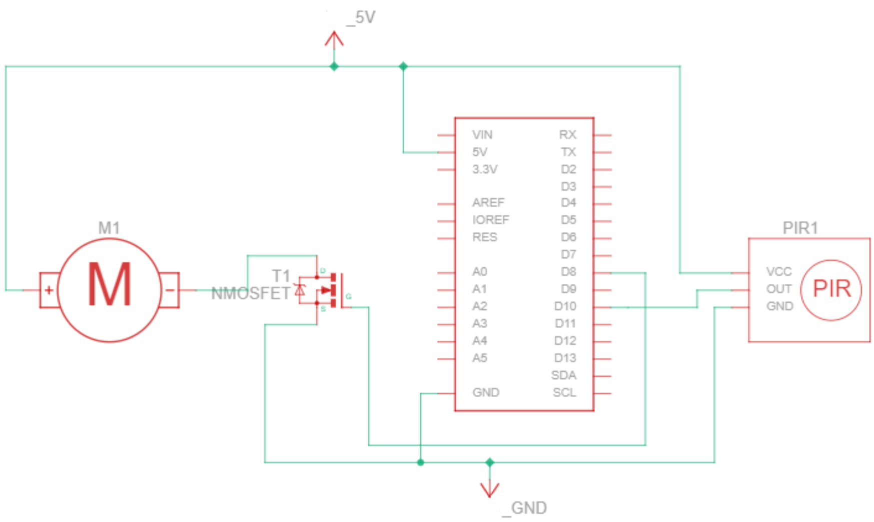
When analyzing the two main components by specification, we see that:

Passive Infrared PIR Motion Sensor	10mm Vibration Motor
• Specifications ○ Input Voltage: DC3.0-5.5V ○ Current: 100uA(max) ○ Output signal: 0, VCC (Output high when motion detected) ○ Sentry Angle: 120° ○ Connector: 3 Pin 254mm pitch ○ Expected Voltage: 3.3V [38] From these values and knowing that PIR sensors dramatically reduce lighting usage and energy	• Key Features ○ Body Diameter: 10 mm [+/- 0.1] ○ Body Length: 2.1 mm [+/- 0.1] ○ Unit Weight: 0.8 g • Operational Specification: ○ Rated Operating Voltage: 3 V ○ Rated Vibration Speed: 14,000 rpm [+/- 3,500] ○ Max. Rated Operating Current: 90 mA ○ Max. Start Voltage 2.3 V ○ Rated Inertial Test Load Mass: 100 g ○ Max. Operating Voltage 3.3 V

consumption, one can conclude that these sensors are energy efficient. This gives rise to the fact that they are widely used in smart lighting systems and save money [39]. This can be further proven as the power used by these sensors is only 0.00033 W (as calculated in the “Requirement Specifications”).	○ Min. Vibration Amplitude: 0.8 G ○ Max. Start Current: 120 mA ○ Min. Insulation Resistance: 10 MOhm [40] Also, when looking at the vibration motor, its power consumption and storage are set to be around 0.231 W (as calculated in the “Requirement Specifications”), which indicates that not much power nor energy goes into making this component function properly.

~ Schematic Diagram ~

This diagram details the relative positions of the components that make up the project, and describes the electron source, electron path, and components of the circuit



~ Quantifying Maximum Stored Energy ~

Estimating Energy Storage: Sensor
Formula: $E = ½ * C * V^2$

E is the electrical energy stored in joules (J).
C is the capacitance of the component in farads (F).
V is the voltage across the component in volts (V).

* Since the capacitance (C) is not known for the PIR sensor, we will assume a typical or average capacitance value for similar components [41]*

PIR Sensor

$$
\begin{aligned}
E &= ½ * C * V^2 \\
&= ½ * (15\ nF) * (3.3\ V)^2 \\
&= ½ * (15\ nF / 1{,}000{,}000{,}000) * (3.3\ V)^2 \\
&= ½ * (1.5E\text{-}8\ F) * (3.3\ V)^2 \\
&= ½ * (1.5E\text{-}8\ F) * (3.3\ V)^2 \\
&= 8.1675\ E\text{-}8
\end{aligned}
$$

Estimating Energy Storage: 10 mm Vibration Motor
Formula: $E\_mech = 0.5 * I * \omega^2$

E_mech is the mechanical energy (J)
I is the moment of inertia (kg/m^2)
ω is the angular velocity (rad/s)

First, find the moment of inertia using the following equation; $I = ½ * m * R^2$

I (moment of inertia) is measured in kilogram square meters (kg·m^2).
m (mass) is measured in kilograms (kg).
R (radius) is measured in meters (m).

$$
\begin{aligned}
I &= ½ * m * R^2 \\
&= ½ * (0.8\ g) * (5\ mm)^2 \\
&= ½ * (0.8\ g / 1000) * (5\ mm / 1000)^2 \\
&= ½ * (0.0008\ kg) * (0.005\ m)^2 \\
&= 1.0\ E\text{-}8\ kg/m^2
\end{aligned}
$$

Next, find the angular velocity using the following equation; $\omega = (2\pi * rpm) / 60$

$$
\begin{aligned}
\omega &= (2\pi * rpm) / 60 \\
&= (2\pi * 14{,}000) / 60 \\
&= (2\pi * 14{,}000) / 60 \\
&= 1466.076\ rad/s
\end{aligned}
$$

Now, find the mechanical energy storage for the motor using the above equation;

$$
\begin{aligned}
E\_mech &= 0.5 * I * \omega^2 \\
&= 0.5 * (\ 1.0\ E\text{-}8\ kg/m^2) * (1466.076\ rad/s)^2
\end{aligned}
$$

= 0.0107 J

Therefore, after computing the above calculations, it is evident that the power and energy limits will not exceed the project requirements.

Risk Analysis

1. What are possible negative consequences on safety or the environment might there be from using the design as intended?
    a. Sensory Overload: The continuous use of a vibrating device could lead to sensory overload for some users. To show, if the device constantly provides feedback even for minor obstructions, it might lead to confusion or reduced attention to more critical warnings, potentially affecting safety.
    b. Over/Under Tolerance: Individuals exhibit varying degrees of sensitivity to tactile sensations. Therefore, if an individual cannot perceive the motor's vibrations or has limited sensory perception, this design may not be suitable for their needs. Conversely, for those with heightened sensitivity, particularly in crowded environments with numerous obstacles, the continuous vibrations may lead to discomfort.
    c. Distraction: Vibrations may distract the user from their immediate environment, especially in situations where it's not necessary. This distraction could lead to accidents or reduced safety, as the user may not hear or notice other important cues.
    d. False Positives: The device may not always accurately detect objects in the user's path, leading to false positives. If the device frequently warns of non-existent obstacles, users may begin to ignore the warnings, which can compromise their safety.
    e. Dependency on Technology: Overreliance on technology can lead to issues if the device malfunctions, runs out of power, or becomes damaged. Users may become overly dependent on the device, which could compromise their safety when it's not functioning correctly.
2. What are possible negative consequences on safety or the environment might there be from using the design incorrectly?
    a. ncorrect usage of the device may result in various safety concerns, for instance
    b. Orientation: If the sensor is oriented the incorrect way, such as facing the person, and not the environment, then the sensor will be unable to detect obstacles, thus defeating the purpose of the device.
    c. Misinterpretation: Users who do not properly understand the device's feedback might misinterpret warnings, leading to misguided actions and potentially unsafe situations.
    d. Unintended Wearability: If one wears the device the unintended way, such as off the shoulder, then this would result in the inability to perceive vibrations, thereby undermining the device's intended functionality. Similarly, wearing it in reverse would cause the sensor to detect objects behind the individual rather than in front, which compromises the device's intended purpose.

3. What are possible negative consequences on safety or the environment might there be from misusing the design or using it in a manner that was not intended?
    a. Accident Risk: Misuse of the device, such as not knowing how the vibrational aspect functions, might lead to misinterpretation of warnings or false alarms, potentially causing accidents or injuries.
    b. Reduced Awareness: Using the device in a way it was not intended can lead to reduced situational awareness, as the user may become distracted by the vibrations, thus losing attention to other important cues in their environment.
4. What are possible ways that the design could malfunction?
    a. Sensor Failure: The external sensor that detects obstacles may malfunction, leading to inaccurate or no object detection, resulting from damage to the sensor or electronic failures.
    b. Vibration Mechanism Issues: The vibration motor may malfunction, causing it to vibrate constantly, not vibrate at all, or vibrate at the wrong times. This could be due to detection issues, electrical/circuit problems, or battery failures.
    c. Power Source Problems: Issues with the power source, such as battery draining, can cause the device to turn off unexpectedly, leaving the user without assistance.
    d. Wear and Tear: Over time, the device's components may degrade due to everyday wear and tear, potentially leading to malfunctions. This includes issues like fraying wires, loose connections, or sensor deterioration.
    e. Environmental Factors: The device may malfunction in various diverse environmental conditions, such as extreme temperatures, humidity, or exposure to water, which can damage its components.
    f. User Misuse: Incorrect use of the device, as discussed earlier, can lead to malfunctions, such as wearing the device in unintended ways, which may cause the sensor harm if not properly worn.
    g. Component Damage: Physical damage to the device, such as dropping it or subjecting it to impact, can lead to malfunctions in various components.
5. What are the consequences on safety or the environment for each of the failure mechanisms specified?
    a. Sensor Failure: Inaccurate object detection or sensor failure can lead to the user not receiving warnings about obstacles in their path, thus potentially resulting in accidents or collisions.
    b. Vibration Mechanism Issues: If the vibration motor malfunctions, it can lead to incorrect or lack of feedback to the user, potentially jeopardizing their safety as they may not receive timely warnings.
    c. Power Source Problems: Power source problems, such as battery drainage can cause the device to unexpectedly turn off, leaving the user without assistance, which can be unsafe, especially in critical situations, such as areas with lots of people.
    d. Wear and Tear: Wear and tear can lead to unexpected failures, such as fraying wires or loose connections, which may result in a loss of functionality and potentially compromise safety as the device will be unable to function properly.
    e. Environmental Factors: Environmental factors can affect the device's operation, leading to safety risks if it malfunctions due to exposure to extreme conditions. This can result in the individual being subjected to external collisions.

f. User Misuse: Incorrect use or frequent setting adjustments can result in confusion, distraction, or reduced situational awareness, thus affecting the user's safety.
g. Component Damage: Physical damage to the device can lead to sudden malfunctions, compromising safety and potentially causing accidents.

Test Plan

1. The system shall detect obstacles in the user's path and provide real-time alerts. These real-time alerts, or the vibrations in this case, will allow the user's brain to register the vibration in about 0.15 seconds, therefore giving more than enough time for the user to avoid obstacles [21].
   a. Test Setup
      i. This test will be done starting from when the sensor detects an object to the point in time when the vibration motor starts to vibrate.
   b. Environmental Parameters
      i. Indoor environments and outdoor parameters should be similar, as in they should be moderate (ie. permissible lighting conditions), as this test is based on the amount of time needed for the vibration motor to be signalled to turn on.
   c. Test Inputs
      i. To fully realize the time that it takes for the vibration motor to turn on, a varied number of complex situations can be tested to see the response time for the motor, namely:
         - The motion of the object; moving
         - Distance of the object (ie 25 cm to 5 m)
         - Different obstacle configurations; single obstacles, multiple obstacles, or obstacles positioned at angles to the sensor
   d. Quantifiable Measurement Standard
      i. The minimum time for the vibration motor to activate is 0.15 seconds, thus allowing, as stated above, the human brain to take an additional 0.15 seconds to process the tactile information. Therefore, the vibration motor should be turned on for 1 second, stop and then turn on for 2 seconds, in a cycle until the motion stops. This will allow the individual to fully be aware of the vibration.
   e. Pass Criteria
      i. This test is considered a pass when the time for the vibration motor can be felt by the individual.

2. The system designed should be configured with a sensor, more specifically with the Passive Infrared PIR Motion Sensor. This sensor is able to have detection distances ranging from 25 centimeters to 20 meters [11] which is in accordance with the distance that a regular blind cane, which typically has a range of 1.2 meters, can reach [17]. By using this sensor, a visually impaired individual is able to be notified of an obstacle in advance, and is able to move accordingly.
   a. Test Setup

        i. Put different sizes and types of obstacles in front of the sensor to see if the product detects their motion while moving.
    b. Environmental Parameters
        i. Indoor environment: well-lit room with controlled lighting conditions for the sensor to be able to properly detect objects
        ii. Outdoor environment: an open space with natural lighting. In terms of weather, it should be moderate for testing purposes, so a full idea of the sensor can be obtained.
    c. Test Inputs
        i. A variety of objects to simulate real-world conditions, including moving objects
        ii. Test scenarios will vary in complexity as objects of different distances and sizes can be different. The angle of approach to the obstacle can be another factor that makes up various scenarios.
    d. Quantifiable Measurement Standard
        i. To ensure precise and consistent measurements within the sensor's range of 25 cm to 20 m, it is recommended to place an obstacle at the maximum distance and activate the sensor. By doing so, an accurate indication of the sensor's range can be determined, making it easier to obtain reliable measurements at various distances within the range.
    e. Pass Criteria
        i. If the range of the sensor is consistent after various trials, with a low percent error, then it is considered a pass. However, if there are inconsistencies with the ranges that the sensor detects, then the device does not pass the test.

3. The system should also output a vibration as a warning to the individual of an oncoming obstacle, specifically with the PWM Vibration Motor. To elaborate, it is proven by research that blind individuals perceive touch faster than those with sight [16]. Knowing this, and the fact that humans are able to respond to vibration levels that are typically from about 6 Hz to 200 Hz, we can program the MCU to sense objects within the individual's path and output a vibration with a sensible level as a response [15].
    a. Test Setup
        i. Make sure that the user is wearing the product properly so that they can feel the vibration well enough.
    b. Environmental Parameters
        i. Try to use the product in moderate weather conditions to ensure that the system can operate in the sense that the individual can feel the vibrations.
    c. Test Input
        i. The user can try to approach an obstacle in a different angle to ensure that the vibration motor works in any angle of detection of an object.
    d. Quantifiable Measurement Standard
        i. Considering that 6Hz to 200 Hz is the level of vibration that humans are able to respond to, try different levels of vibrations when obstacles are detected. This will give an idea of what level of vibration is most

comfortable and not too aggressive for users to feel, especially when individuals with impaired vision are sensitive to touch.

e. Pass Criteria
    i. If the comfortable range of Hz of vibration is figured out and it is vibrating enough for users to feel the vibration, then it is considered pass.
    ii. If the vibration motor fails to vibrate when an obstacle is detected, or it vibrates too small that the user can't feel it or too much that the user feels uncomfortable, the test fails to pass.

4. The use of a power bank is necessary for the use of this system. To explain, if an individual is going to wear the system on their person, then they must have a power supply source connected to supply power to the system. The power bank typically needs to be charged every 50 hours, as the power bank for this project has a battery capacity of 5000mAh, or 5000 milliamp-hours [19], a unit of electric charge used to describe the battery capacity [20]. This will allow the individual not to have to charge the device often, hence increasing its efficiency.
    a. Test Setup
        i. Initially, the power supply will be charged to full so that its duration can be accurately measured. Also, thus will inform us of how much power the device needs for a certain period.
    b. Environmental Parameters
        i. During testing, extreme caution will be taken to avoid exposing the power supply to rain. Testing will occur in various weather conditions, including sunny, snowy, and windy.
    c. Test Input
        i. As a power bank is necessary for the user to utilize the product, the product will be observed if it can last 50 hours when its power bank is fully charged for 50 hours.
    d. Quantifiable Measurement Standard
        i. The power supply having a minimum battery capacity of 5000mAh, will lead up to 50 hours of usage, thereby limiting the amount of charging the individual will have to do.
    e. Pass Criteria
        i. If the power supply can last up to 50 hours of use, or in other words, if the device can function for up to a total of 50 hours, then the test will be a success.

5. We will create and outwardly protect the device in such a way that it can adapt to changing temperature conditions, such as weather. This characteristic of withstanding temperature changes will be implemented when we create the wearable aspect of the project by using materials, such as nylon, which can withstand temperatures up to -30°C to 95°C [30]. This indicates that a visually impaired individual is able to go out in extreme weather without having to worry about the hardware becoming damaged due to the heat/cold, which will be enclosed in a nylon bag.
    a. Test Setup
        i. This test will be done in both indoor and outdoor environments. For the indoors, a moderate and comfortable temperature will be upheld,

whereas the outdoors will have significantly different temperatures, typically colder.

b. Environmental Parameters
    i. The temperatures have to vary for this test to be viable. Since simulating extreme weather conditions in a controlled environment is difficult, we will instead test the device indoors, where it is warmer, and outdoors, where it will be colder, due to the changing seasons.
c. Test Input
    i. When the nylon material is subjected to various temperature levels, it should protect the components inside of it, especially the power source and the STM32 chip.
d. Quantifiable Measurement Standard
    i. The device should be able to at least withstand temperatures between -30°C to 95°C in the nylon material continuously.
e. Pass Criteria
    i. If the device can function properly in both of these environments, then it is considered a pass. If not, then further investigation into the material will be done.

References

[1] J. Köberlein, C. Schaffert, R. Finger, and K. Beifus, "The economic burden of visual impairment and blindness: a systematic review," National Library of Medicine, [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3822298/

[2] K. Hitchcock, "How Much is a Guide [2] Dog in 2023? Cost Breakdown & FAQs," Hepper, May 30, 2023. https://www.hepper.com/how-much-is-a-guide-dog/

[3] S. Yin, "Why is creating electronic canes for the blind so hard?," WHYY, Jun. 14, 2019. [Online]. Available: https://whyy.org/segments/why-is-creating-electronic-canes-for-the-blind-so-hard/

[4] I. Poole. "What is Ohms Law - key details formula equation calculator." Electronics Notes. https://www.electronics-notes.com/articles/basic_concepts/resistance/what-is-ohms-law-formula-equation.php (accessed Sep. 18, 2023).

[5] P. B. Admin. "What is Power Dissipation? and How to Calculate?." MADPCB. https://madpcb.com/glossary/power-dissipation/ (accessed Sep. 18, 2023).

[6] "Voltage, Current, Resistance, and Ohm's Law." Voltage, Current, Resistance, and Ohm's Law - SparkFun Learn. https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law/all (accessed Sep. 18, 2023).

[7] Home Economics: Foods and Nutrition 8 to 12 IRP (2007) - Gov. https://www2.gov.bc.ca/assets/gov/education/kindergarten-to-grade-12/teach/pdfs/curriculum/appliedskills/2007he_foodnutri812.pdf (accessed Sep. 19, 2023).

[8] Rayzeek. "What is a PIR Motion Sensor and How Does it Work?." Rayzeek. https://www.rayzeek.com/blog/pir-motion-sensor (accessed Sep. 18, 2023).

[9] Circuit of a ultra-low standby power PIR-sensor-based lighting device ..., https://www.researchgate.net/figure/Circuit-of-a-ultra-low-standby-power-PIR-sensor-based-lighting-device_fig1_241185162 (accessed Sep. 18, 2023).

[10] - Robocraze. “PIR Sensor Working Principle.” Robocraze. https://robocraze.com/blogs/post/pir-sensor-working-principle (accessed Sep. 19, 2023).
[11] Macfos. “PIR Sensor Working Principle: How PIR Sensor Works.” Robu.in | Indian Online Store | RC Hobby | Robotics. https://robu.in/pir-sensor-working-principle/ (accessed Sep. 19, 2023).
[12] Lumen Learning, “Period and frequency in oscillations | Physics.” https://courses.lumenlearning.com/suny-physics/chapter/16-2-period-and-frequency-in-oscillations/
[13] “project mechanical vibrations: Topics by Science.gov.” https://www.science.gov/topicpages/p/project+mechanical+vibrations.html
[14] W. Ren, B. Peng, J. Shen, Y. Li, and Y. Yu, “Study on vibration characteristics and human riding comfort of a special equipment cab,” Journal of Sensors, vol. 2018, pp. 1–8, Jan. 2018, doi: 10.1155/2018/7140610.
[15] “Vibration Fact Sheet - metrocouncil.org,” metrocouncil.org, https://metrocouncil.org/getattachment/458e5e99-f1fb-4ab1-8fd7-d2261cbd637a/Southwest-LRT-Vibration-Fact-Sheet.aspx (accessed Sep. 20, 2023).
[16] D. Goldreich. “Blind people perceive touch faster than those with sight.” ScienceDaily. https://www.sciencedaily.com/releases/2010/10/101026172021.htm (accessed Sep. 19, 2023).
[17] I. Khan, S. Khusro, and I. Ullah. “Technology-assisted white cane: evaluation and future directions.” PeerJ. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6292384/ (accessed Sep. 19, 2023).
[18] “VIBRATION - ELECTRIC MOTORS,” https://www.welkon.net/. https://www.welkon.net/downloads/vibration.pdf
[19] Utmel, “Battery life calculator: Tools,” Utmel, https://www.utmel.com/tools/battery-life-calculator?id=1 (accessed Sep. 29, 2023).
[20] “The ultimate guide to what is mah (milliamp hour),” Jackery, https://www.jackery.com/blogs/knowledge/what-is-mah (accessed Sep. 29, 2023).
[21] “How Fast Your Brain Reacts To Stimuli.” Experiment: How Fast Your Brain Reacts To Stimuli. https://backyardbrains.com/experiments/reactiontime (accessed Sep. 19, 2023).
[22] R. Manduchi and S. Kurniawan, University of Santa Cruz, Santa Cruz, CA, rep., 2011, https://users.soe.ucsc.edu/~manduchi/papers/MobilityAccidents.pdf
[23] “What Are PIR Sensors and Why Do I Need Them?.” Electrical Industry Newsweek. https://electricalindustry.ca/latest-articles/4272-what-are-pir-sensors-and-why-do-i-need-them/ (accessed Sep. 19, 2023).
[24] “Definition of sensor and sensing technology,” Definition of Sensor and Sensing Technology | Yokogawa Electric Corporation, https://www.yokogawa.com/special/sensing-technology/definition/ (accessed Sep. 20, 2023).
[25] M. Javaid, A. Haleem , S. Rab , R. P. Singh , and R. Suman, “Sensors for daily life: A Review,” Sensors International, https://www.sciencedirect.com/science/article/pii/S2666351121000425 (accessed Sep. 20, 2023).
[26] “Electrical and electronics engineering,” Encyclopædia Britannica, https://www.britannica.com/technology/electrical-and-electronics-engineering (accessed Sep. 20, 2023).
[27] R. Legood, P. Scuffham, and C. Cryer, “Are we blind to injuries in the visually impaired? A review of the literature,” Injury Prevention, https://injuryprevention.bmj.com/content/8/2/155 (accessed Sep. 28, 2023).
[28] “L2: Vibromotors,” Physical Computing. https://makeabilitylab.github.io/physcomp/advancedio/vibromotor.html “Vibration Technical

[29] Data Report," https://www.broadwaysubway.ca.
https://www.broadwaysubway.ca/app/uploads/sites/626/2020/08/Vibration-Assessment-Technical-Data-Report-October-2019.pdf
[30] "Thermal resistance," Minimum and Maximum Operating Temperatures,
http://www.stug.com.au/materials/engineering-plastics-properties/min-max-operating-temperatures.php
[31] "Jamie Belt Bag: Bags: Lolë," Jamie Belt Bag | Bags | Lolë,
https://www.lolelife.com/en-ca/product/jamie-bag-ssl0111-N415?gad=1&gclid=EAIaIQobChMIzbe8j7nNgQMVj5fCCB0hawRCEAsYAyABEgJxQvD_BwE (accessed Sep. 28, 2023).
[32] A. Anthony. "Orcam's Myeye for the Visually Impaired: 'it's opened up a whole New World,.'" The Guardian.
https://www.theguardian.com/society/2017/dec/03/orcam-myeye-technology-aid-visually-impaired-dyslexia (accessed Oct. 21, 2023).
[33] E. Salam. "I tried be my eyes, the popular app that pairs blind people with helpers." The Guardian.
https://www.theguardian.com/lifeandstyle/2019/jul/12/be-my-eyes-app-blind-people-helpers (accessed Oct. 22, 2023).
[34] J. Novet. "Microsoft has a new app that tells the visually impaired what's in front of them." CNBC. https://www.cnbc.com/2017/07/12/microsoft-launches-seeing-ai-app-for-ios.html (accessed Oct. 22, 2023).
[35] "L2: Vibromotors," Physical Computing.
https://makeabilitylab.github.io/physcomp/advancedio/vibromotor.html
[36] Dewes. DOO, "Human body and Whole-body Vibration, Hand-arm vibration | Dewesoft."
https://training.dewesoft.com/online/course/human-vibration
[37] CSA Group, "Product - CSA Group," CSA Group, Sep. 17, 2022.
https://www.csagroup.org/store/product/2701469/ Electrical Industry Newsweek,
[38] "What are PIR sensors and why do I need them? - Electrical Industry News Week," Electrical Industry Newsweek, May 07, 2018.
https://electricalindustry.ca/latest-articles/4272-what-are-pir-sensors-and-why-do-i-need-them/
[39]"PIR Motion Sensor - Large Lens version," Seeed.
https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/1062/101020060_Web.pdf
[40] "Product Data Sheet," Precision Microdrivers.
https://catalogue.precisionmicrodrives.com/product/datasheet/310-118-001-10mm-vibration-motor-2mm-type-datasheet.pdf
[41] "Low-Cost Passive IR Sensing with RS08KA."
https://www.nxp.com/docs/en/application-note/AN4305.pdf
[42] "NUCLEO-F401RE," Digikey.
https://www.digikey.in/en/products/detail/stmicroelectronics/NUCLEO-F401RE/4695525
[43] "PIR Motion Sensor," Adafruit Learning System, Jan. 28, 2014.
https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/overview
[44] "10mm diameter 1034 Flat button type Cell phone Vibration motor," Techtonics.
https://www.techtonics.in/10mm-diameter-1034-flat-button-type-cellphone-vibration-motor-2-pcs RobotShop Canada,

[45] “White Solderless Prototype PCB Board Breadboard 400 tie-points 83x55mm,” RobotShop Canada.https://ca.robotshop.com/products/white-solderless-prototype-pcb-board-breadboard-400-tie-points-83x55mm
[46] “N-Channel MOSFET 60V 30A,” COM-10213 - SparkFun Electronics.
https://www.sparkfun.com/products/retired/10213 Wikipedia contributors,
[47] “Jump wire,” Wikipedia, May 30, 2023. https://en.wikipedia.org/wiki/Jump_wire
[48] “Amazon.com: Right-Angled Breadboard jumper Wires, jumper wire, wide application for prototyping use. convenient for store and fetch : Electronics.”
[49]https://www.amazon.com/Right-Angled-Breadboard-Application-Prototyping-Convenient/dp/B08G1ST2PM
[50] “Gikfun RFP30N06LE 30A 60V N-Channel MosFet TO-220 ESD Rated for Arduino (Pack of 5pcs) EK1658 : Amazon.ca: Electronics.”
[51]https://www.amazon.ca/dp/B01GNORMWA?psc=1&ref=ppx_pop_dt_b_product_details
“MERQC Pyroelectric Infrared Sensor IR PIR Motion Sensor Detector Module HC-SR501, Motion Detectors - Amazon Canada.”
[52]https://www.amazon.ca/dp/B0CHZDLSK5?psc=1&ref=ppx_pop_dt_b_product_details
“140Pcs Breadboard Jumper Wire, Acogedor Solderless Breadboard Jumper Cable Wire Kit with Case, for DIY Shield, Electrical Wire - Amazon Canada.”
[53]https://www.amazon.ca/dp/B07GFDX6ZH?psc=1&ref=ppx_pop_dt_b_product_details
“1Pcs 830 tie points + 1 pcs 400 tie points solderless breadboard + 1 mini breadboard 170 points + 65 pcs flexible breadboard Jumper wires for Arduino and Proto Shield electrical connections Block : Amazon.ca: Tools & home improvement.”
[54]https://www.amazon.ca/dp/B0BNPMYLRG?psc=1&ref=ppx_pop_dt_b_product_details
[55] “ECE 198/MTE 241 Kit.” https://wstore.uwaterloo.ca/ece-198-kit.html “316040001,”
[56]316040001 Seeed Technology Co., Ltd - DigiKey Canada,
https://www.digikey.ca/en/products/detail/seeed-technology-co-ltd/316040001/5487672.