Design Document
Visual Cue System

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I. Customer

The customer for this project is a group of hearing-impaired individuals residing in university or college dormitories where accessibility is limited. This group faces challenges due to inadequate infrastructure and lack of assistive technologies that could provide equitable living conditions. According to the **World Health Organization (WHO)**, hearing impairments affect approximately 5% of the global population, and many students in higher education experience difficulties when accessibility is lacking. In the U.S., around **1.4% of college students** are deaf or hard of hearing. Specifically this visual cue system will be initially targeting the students of the University of Waterloo.[1][2]

Geographic Attributes:
The University of Waterloo is located in Waterloo, Ontario with the campus housing spanning all throughout the 1000-acre main campus with 100+ buildings and six faculties [3]

Demographic Attributes:
The population of our client is about 42000 full and part-time students. of which about 1000 students reported they have a disability classified under ‘ongoing medical condition’ which would also include hard of hearing and deaf individuals [4].

Economic Attributes:
Of the students from Ontario ⅔ of students rely entirely on the Ontario Student Assistance Program which is a government student loan. The rest are often relying entirely on their guardian(s) funding their education with a small population earning a low income working part time while studying. In all the overall income of students is low and thus do not have the luxury of premium accessible goods[5].

II. Client Challenge

Hearing-impaired students often struggle in dormitory environments due to the lack of visual alert systems, captioned communication tools, and other assistive devices necessary for daily living. These challenges include being unable to hear fire alarms, announcements, or door knocks, which poses both safety risks and social isolation. Limited access to technology such as **visual alert systems** for fire alarms and doorbells compounds the problem, making dormitories less inclusive. Many universities do not provide sufficient accommodations to address these issues, with only a small percentage offering fully accessible housing.[6][7] A simple, yet reliable wireless notification system would significantly improve the safety and accessibility of their homes, ensuring they are always aware when someone is at the door. By solving this problem, the quality of life and safety of hearing-impaired students can be significantly improved.

III. Competitive Landscape

Social System: ***Accessibility Policies in Canadian Higher Education***

Description: Canadian universities follow accessibility standards set by policies such as the Accessibility for Ontarians with Disabilities Act (AODA) and the Canadian Human Rights Act (CHRA). These policies require that institutions provide reasonable accommodations for students with disabilities, including hearing impairments, to promote equitable access to campus resources and facilities. For dormitories, this can involve providing visual alert systems, accessible emergency alarms, and other assistive devices. The

AODA, in particular, mandates accessibility in residential facilities for educational institutions in Ontario, aiming to create fully accessible environments by 2025 [8] [9] .

Relevance to Defined Challenges: These policies establish a framework for accessible campus housing and promote inclusivity for hearing-impaired students. By mandating visual alarms and accessible dorm rooms, they aim to address safety and communication challenges that hearing-impaired students face in dormitory settings, such as fire alarm alerts and door knock notifications.

Shortcomings: Despite these policies, accessibility in dormitories varies significantly across Canadian universities, particularly in older buildings where implementing upgrades is costly. Many institutions face budgetary constraints or lack clear guidelines for retrofitting dormitories to meet accessibility standards, leaving some hearing-impaired students without essential visual alert systems. Consequently, the effectiveness of these policies is limited by inconsistent enforcement and funding gaps, impacting the accessibility of dormitory living spaces for hearing-impaired students

Technological System #2: Smart Doorbells with Visual Alerts

Description: Smart doorbells, like the Ring Doorbell, integrate visual alerts and are increasingly used to enhance accessibility in private residences. These doorbells provide visual notifications via smartphone apps or flashing lights when someone is at the door, offering flexibility and accessibility for individuals with hearing impairments. [10]

Relevance to Defined Challenges: Smart doorbells offer an accessible solution for dormitory environments by providing hearing-impaired students with a visual notification system for visitors. The smartphone notification feature enables students to receive alerts wherever they are, enhancing the convenience and inclusivity of dormitory living.

Shortcomings: These systems often depend on reliable Wi-Fi, which can be inconsistent in dorm settings. Additionally, privacy concerns arise as shared living arrangements may not accommodate camera-based systems comfortably. Furthermore, they do not integrate with broader dormitory emergency systems, which limits their ability to comprehensively meet the safety needs of hearing-impaired students

Technological System #3: Standalone Visual Alert Systems

Description: Devices like the Sonic Alert HomeAware function as standalone visual alert systems, flashing lights or emitting vibrations to alert users to specific events. These devices can connect with alarm clocks, doorbells, and phones, making them versatile and practical for various dormitory scenarios. [11]

Relevance to Defined Challenges: Standalone systems are beneficial in dormitories, as they provide visual alerts without requiring structural changes. Hearing-impaired students can receive alerts for various events, enhancing accessibility and safety in shared living spaces.

Shortcomings: These systems are often costly, and comprehensive coverage typically requires multiple devices, increasing expenses. Additionally, they may lack integration with existing dormitory emergency alarms, limiting their effectiveness in critical situations

IV. Functional Requirements

A. Motion Detection:

Function: The system detects movement within the dorm room vicinity (outside the door), which triggers the visual alert system. The system will use a detection algorithm that processes incoming signals from the motion sensor at a frequency of **10 Hz** to detect movements, ensuring real-time responsiveness and preventing false positives

Quantified Values: The system must detect movement between **1 to 3 meters** with a detection angle of **90 degrees** using a passive infrared (PIR) sensor. This is based on the specifications of common infrared and passive infrared (PIR) sensors used in similar indoor security systems [12]

Feasibility: This range and angle are standard in commercially available motion detectors, and can be achieved using off-the-shelf PIR sensors compatible with STM32 NUCLEO boards

Measurability: The movement detection range can be measured using simple distance tests, verifying the detection at different points from the door. Tools like a ruler or laser measure can verify accuracy within ±10 cm

Appropriateness: This functionality ensures that there is a way to alert the user of a presence outside their door, the range allows only individuals standing directly outside the door to trigger the alert, preventing unnecessary alerts from distant passersby, making it well-suited for dormitory settings

B. Visual Alert System Response

Function: The system triggers a flashing LED to alert the hearing-impaired user of movement outside their door.

*Quantified Values: The visual alert should have a brightness between **100 and 150 lumens** and should respond within **500 milliseconds** of detecting motion. [13]*

Feasibility: LEDs that meet these brightness requirements are commonly available and can be easily driven by the STM32 NUCLEO board at low power

Measurement: The brightness can be measured using a lux meter or photometer. The response time can be measured using a timer in the firmware, which logs the delay between motion detection and LED activation

Appropriateness: This ensures that the light is sufficiently bright to be noticeable in a typical dorm room environment, while maintaining a response time that aligns with real-time user expectations

C. Data Communication Between STM32 Boards Using Bluetooth

Function: The system transmits motion detection data wirelessly between two STM32 boards via Bluetooth. The Bluetooth modules enable wireless communication, allowing motion detected by the sensor to be transmitted reliably to the secondary board, which then triggers the LED visual alert. This wireless setup provides flexibility and reduces the need for physical wiring, making it ideal for dormitory environments.

Quantified Values: **Transmission Range:** Reliable data transmission up to 10 meters indoors, accommodating typical dormitory layouts. **Transmission Delay:** Data transmission should incur minimal delay, with a maximum latency of 100 ms to ensure the visual alert responds in real time. **Error Rate:** The system should maintain a data error rate below 5% to ensure accurate data transfer and minimize false alerts.
[14]

Feasibility: Bluetooth communication modules, such as the HC-05 or HC-06, are compatible with STM32 microcontrollers via UART. These modules provide a simple and cost-effective solution for short-range wireless communication, with sufficient range and data integrity for dormitory settings. Additionally, Bluetooth's frequency-hopping feature helps mitigate interference, enhancing reliability in shared living spaces where multiple wireless devices are in use.[14]

Measurability: transmission range and latency can be tested by measuring the maximum distance over which the Bluetooth modules maintain reliable communication, using a signal testing tool or a smartphone app to verify connectivity strength. Latency can be assessed by measuring the time taken from motion detection to LED activation using a timer. Error rate and packet integrity can be verified by running repeated data transmission tests and observing any anomalies or dropped signals, with error-checking mechanisms embedded in the firmware.

Appropriateness: Bluetooth provides a robust, wireless communication solution for a dormitory-based accessibility device, minimizing setup complexity and physical wiring. Its flexibility, paired with efficient data handling, ensures that hearing-impaired students receive timely visual alerts without interruption. Bluetooth's short-range nature and ability to handle interference make it well-suited for this type of application, addressing the accessibility challenges without requiring significant infrastructural changes.

D. Power Consumption

Function: The system must operate efficiently to ensure long-term use without excessive energy drain.

Quantified Values: The entire system (sensor, LED, microcontroller) must consume no more than **100 mW** of power during operation [15]

Feasibility: STM32 NUCLEO boards and associated PIR sensors typically consume less than 100 mW, making this target realistic for an embedded system design

Measurability: Power consumption can be measured using a power meter or an oscilloscope to monitor current draw during various operation modes

Appropriateness: Low power consumption is in best favour for this device to decrease chance of failure. This requirement ensures the system can run for extended periods without battery drain or risk of failure during use.

V. Technical Requirements

A. Bluetooth Communication Stability

The system must establish a stable wireless communication link between the STM32 boards using Bluetooth modules, ensuring reliable data transfer for real-time activation of the LED alert. The Bluetooth communication link should be robust enough to handle typical dormitory interference and provide a seamless connection for immediate response to motion detection events. **Bluetooth Module Selection and Configuration:** The Bluetooth modules will interface with the STM32 boards via UART at a baud rate aligned with the Bluetooth module's capabilities (typically 9600 bps or 115200 bps). This setup supports a stable UART interface while managing wireless transmission. The modules should be configured in *master-slave mode* to ensure one-way data flow without conflicting signals, enhancing connection stability. **Frequency Hopping to Mitigate Interference:** Bluetooth uses adaptive frequency-hopping spread spectrum (AFH), shifting between channels within the 2.4 GHz band to avoid interference. By configuring the Bluetooth modules to enable AFH, the system automatically reduces potential interference from other devices (e.g., Wi-Fi networks or other Bluetooth connections) within the dormitory.[14]

B. Flashing Light Control

The LED brightness should be set to **100 to 150 lumens**, with a flashing frequency of **2 Hz** for clear visibility. This frequency ensures that the light is noticeable without being overly distracting. The STM32 board will use a timer-based interrupt to control the flashing frequency of the LED, ensuring precise timing of **2 Hz** per flash [16][17]

C. Motion Sensor Polling Rate

The motion sensor must be polled frequently enough to detect movement in real-time and avoid false positives or delays in triggering the visual alert. The polling rate of the motion sensor should be set at **10 Hz** (10 times per second) to ensure real-time responsiveness and accurate motion detection. The STM32 NUCLEO board will continuously check the sensor state in a loop that runs every **100 milliseconds** (10 times per second). The sensor output will be debounced using a simple software filter to prevent false triggering from noise. The STM32 NUCLEO board supports high-speed GPIO inputs, making it feasible to implement a 10 Hz polling rate without significant performance overhead. The polling rate can be measured by timing the interval between successive sensor checks, using logging functions in the firmware. The accuracy of the real-time response can be tested by measuring the delay between actual movement and the visual alert trigger. A polling rate of 10 Hz ensures that fast movements (such as someone walking by) are detected promptly, without missing events. [18]

VI. Safety Requirements

A. Fire Safety and Electrical Compliance:

The system must comply with **UL 94V-0** standards, which ensure that all materials used are flame-resistant and safe for residential installation, as well as operating at low voltages (3.3 - 5.0 Volts) so as to ensure the microcontroller does not heat up, a possible cause of a fire. [19]

B. Signal Integrity

The bluetooth communication link must include error-checking mechanisms to maintain a signal-to-noise ratio of at least **60 dB**, ensuring that the system is not susceptible to interference from nearby electronic devices [13] [14]

VII. Design

This project implements a visual cue notification system tailored for deaf individuals, using two STM32 Nucleo boards connected wirelessly through Bluetooth. The system is designed to alert the user in real-time if motion is detected near their door, using a PIR motion sensor to detect movement and an LED light as a visual cue. The system is divided into two distinct parts: the sensor unit and the alert unit, which work collaboratively to provide immediate, reliable notifications. Packaged in a plastic casing for protection, the user is responsible for mounting the sensor in their dorm or home.

Key Components

- **2 STM32 Nucleo Boards:** Used to operate the specific sensor and alert units using code to translate data from the motion sensor into light on the bredboard
- **PIR Motion Sensor**: A passive infrared sensor that detects infrared radiation emitted by moving objects, providing a digital output signal to indicate detected motion.
- **HC-05 Bluetooth Module**: A wireless communication module that allows the STM32 boards to transmit and receive data over short distances, enabling seamless communication between the sensor and alert units.
- **65 Ω Resistor:** Fundamental component of our system to control the electron flow and increase the safety and functionality of our systems.
- **Breadboard:** Allows for a significantly greater ease of wiring, considering that we will be utilizing a resistor.
- Minor Components include LEDs and jumper wires.

SEE DIAGRAM FOR MOTION SENSOR BLUETOOTH MODULE IN NEXT PAGE

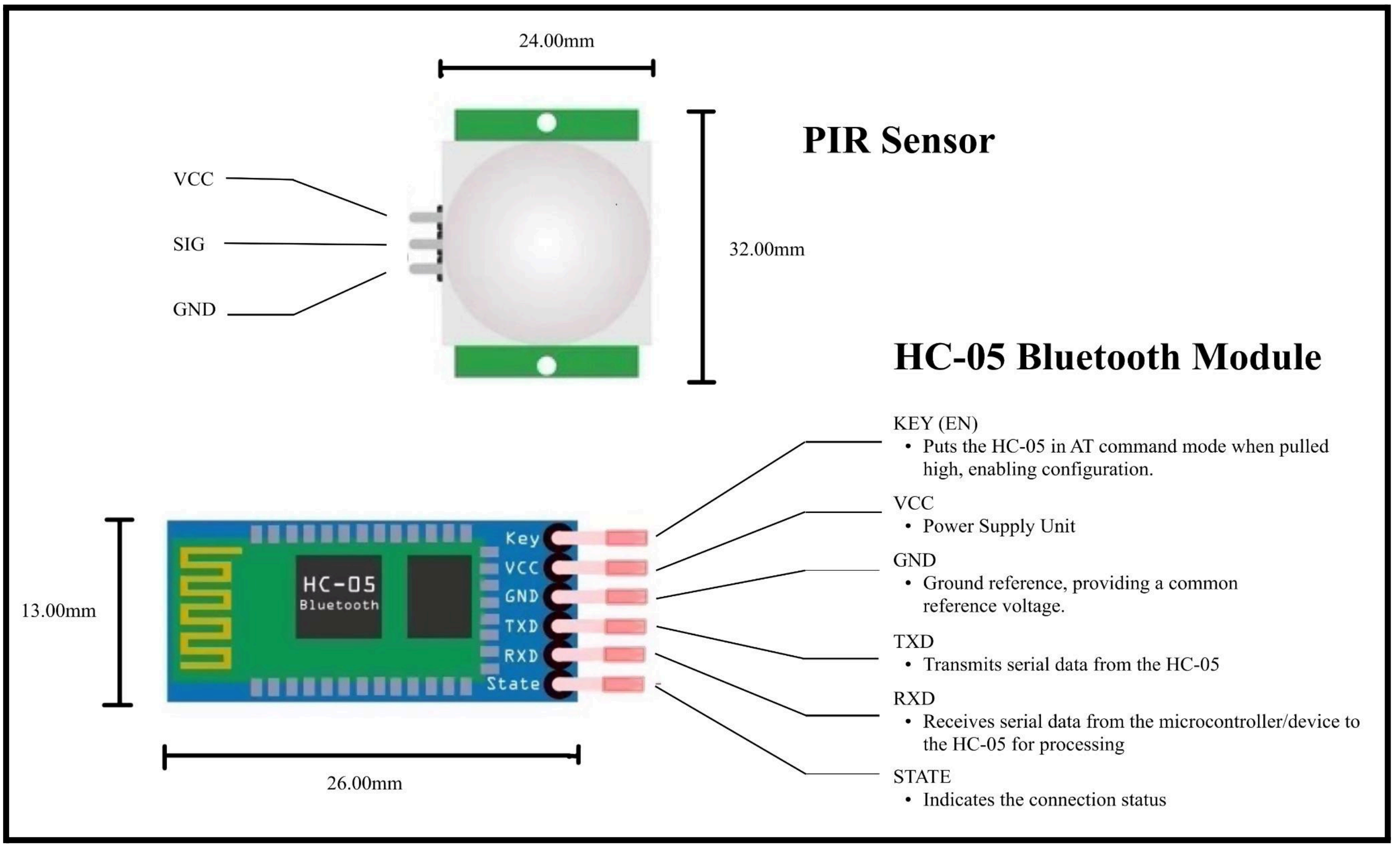

Figure 1: PIR Sensor & Bluetooth Module

Sensor Unit:

Board 1 (Sensor and Transmitter): The first STM32 Nucleo board functions as the sensor and transmitter unit. Connected to a PIR motion sensor, this board is responsible for detecting any motion in its vicinity. When the PIR sensor senses movement, it generates a digital output signal, which the board processes as a trigger to activate the HC-05 Bluetooth module. This module then wirelessly sends a notification signal to the second STM32 board, indicating detected motion.

Alert Unit:

Board 2 (Receiver and Visual Cue): The second STM32 Nucleo board serves as the receiver and visual alert unit. Equipped with its own HC-05 bluetooth module, this board receives the signal transmitted by the first board. Upon receiving this signal, it activates an LED light, providing a quick, visual response to the detected activity. The LED is driven by a digital output pin, ensuring a reliable visual cue that alerts the user to the presence of motion near their door.

Power Supply:

To ensure our system is user friendly, portable, and features excellent functionality, we will utilize batteries as our main power supply. The STM32 typically requires between 5V or 3V to operate. Thus, we will power our system with multiple AA batteries.

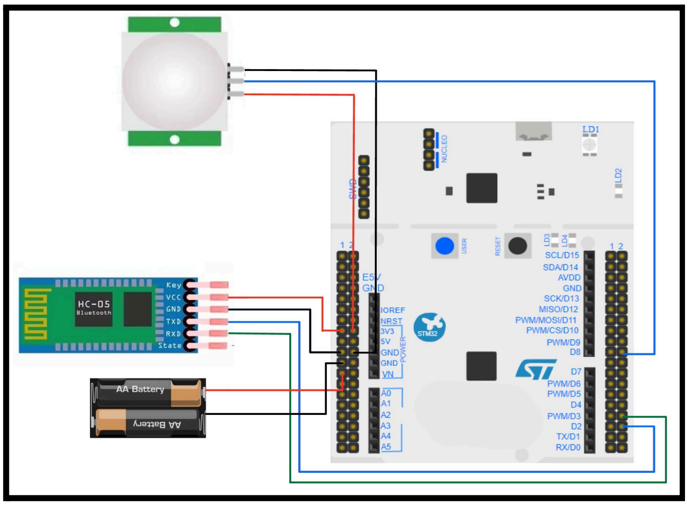

Figure 2: Circuit Diagram for Sensor Unit

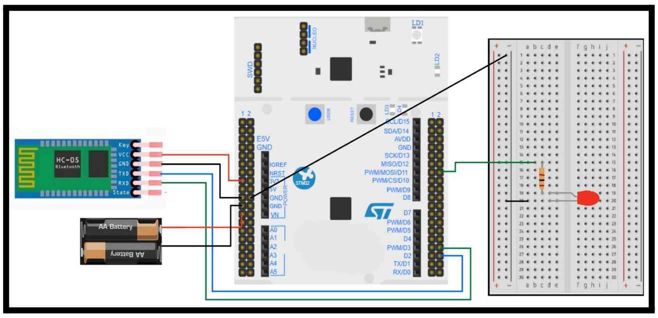

Figure 3: Circuit Diagram for Alert Unit

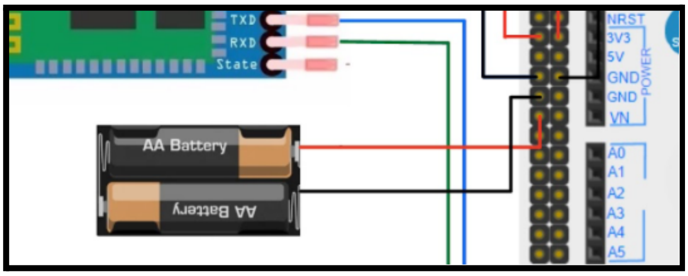

Figure 4: Close-up of power configuration

Wiring Implementation:

Microcontroller #1:

As seen in the figures above, the HC-05 Bluetooth module possess the following wiring connections (from HC-05 to STM32)

1. VCC → 3V3
2. GND → GND
3. TXD → D2
4. RXD → PWM/D3

After the first HC-05 module has been connected to microcontroller #1, we implement the PIR sensor through the following steps:

a. GND → GND
b. SIG (Signal) → D8
c. VCC → 3V3

Microcontroller #2:

Similar to step #1 in first microcontroller, we connect the HC-05 bluetooth module to the STM32

1. VCC → 3V3
2. GND → GND
3. TXD → D2
4. RXD → PWM/D3

In microcontroller #2, we utilize a 400pc breadboard for ease and convenience of wiring. Using the resources:

a. LED
b. 65 Ω resistor
c. 400pc breadboard

We conduct the following wiring applications:

- Identify the longer leg (anode, positive) and the shorter leg (cathode, negative) of the LED.
- Connect the other end of the resistor to the ground (GND) pin on the STM32.
- Connect the anode to a digital I/O pin on the STM32.
- Connect the cathode to one end of the resistor.

CAD components:

To provide the user with the best possible experience, we designed two custom 3D-printed cases with lids to encase each circuit. Using precise measurements from the key components, we tailored each case to securely fit and protect the circuits. The cases are designed not only to shield the hardware from external factors but also to make the system more user-friendly and portable.

The figure in the following page is the design of the first microcontroller — the sensor. The design features a snug and secure compartment for the STM32 boards, while allowing enough space for the flow of wires. The HC-05 bluetooth module also has its own compartment, and there is enough space for the battery to rest. The PIR sensor will be nested on four square corners, accounting for the wires that will have to be plugged into the bottom of the device.

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The second figure is the design for the Alert unit Similar to the first microcontroller, the STM32 and HC-05 bluetooth module will have their own spaces to rest in. However, this case features a new compartment for the breadboard, which will utilize an LED and a resistor. Again, enough space is provided for the battery.

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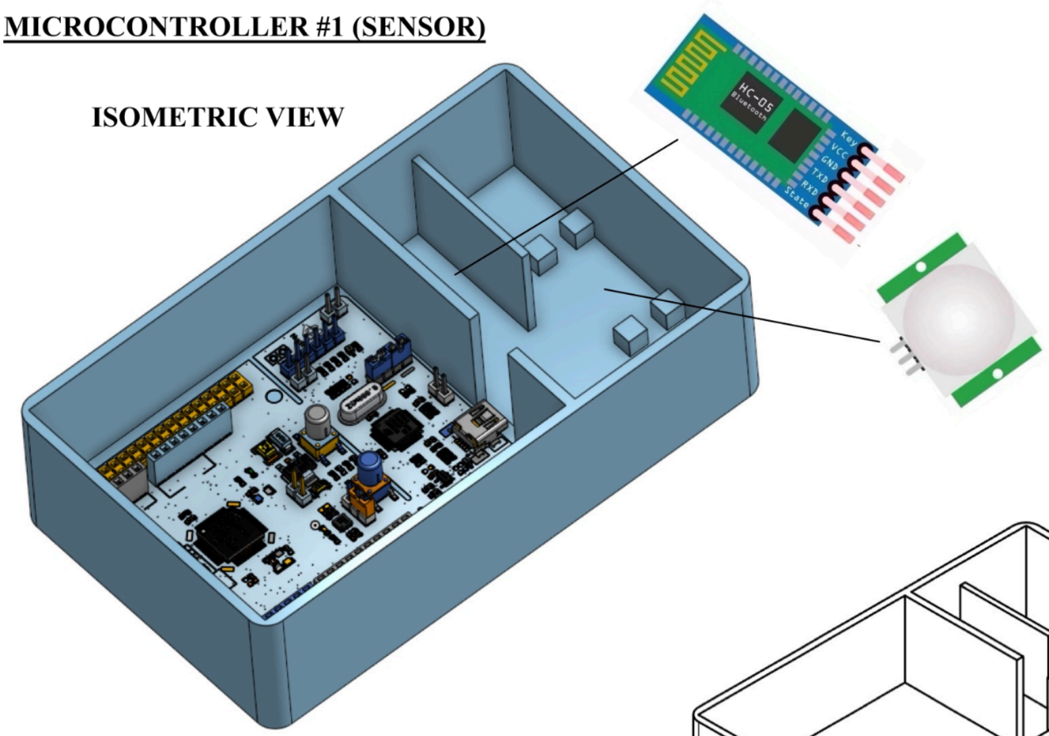
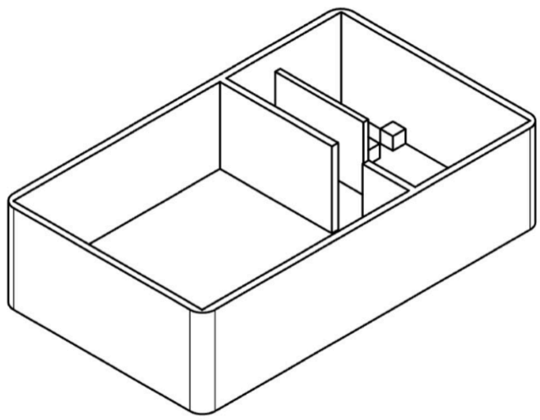
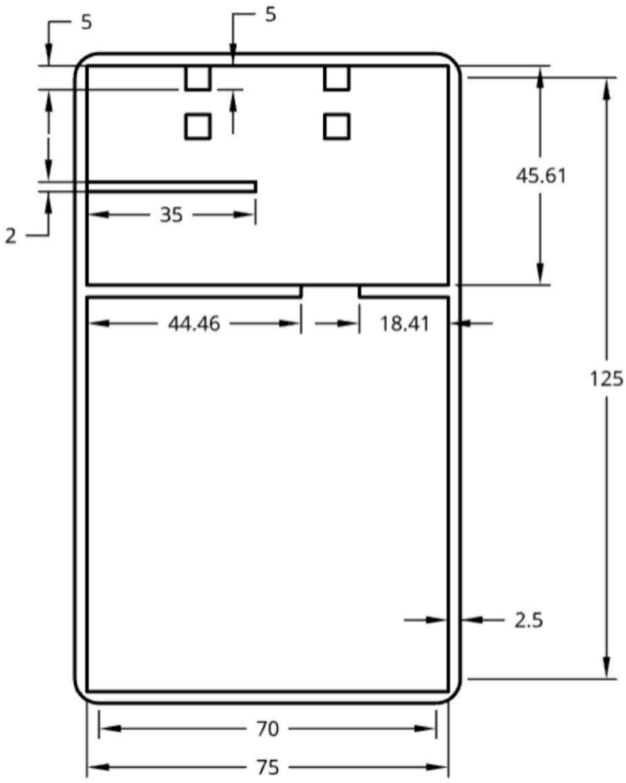
MICROCONTROLLER #1 (SENSOR)

ISOMETRIC VIEW

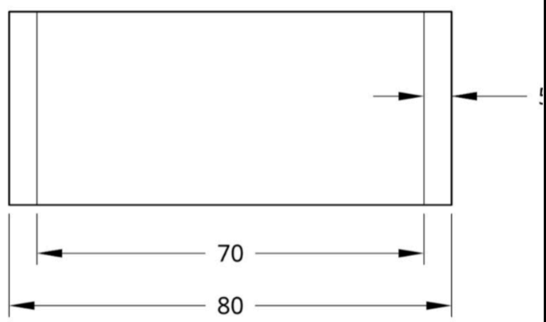




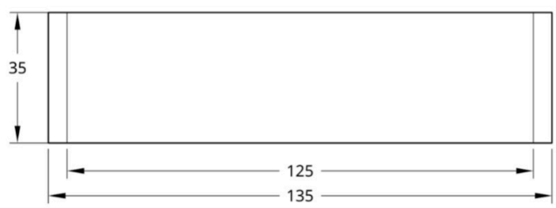
TOP VIEW



FRONT VIEW

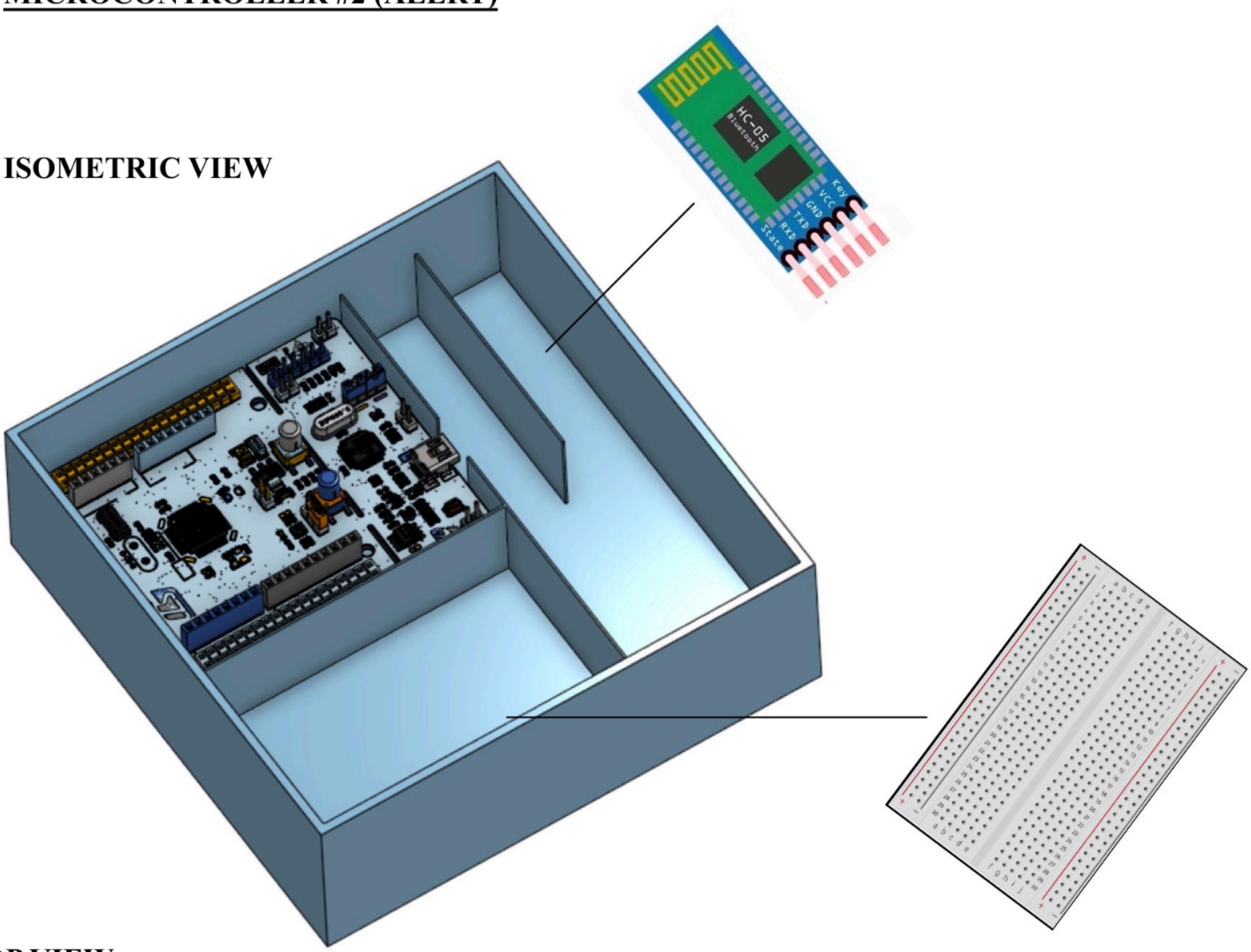


RIGHT VIEW

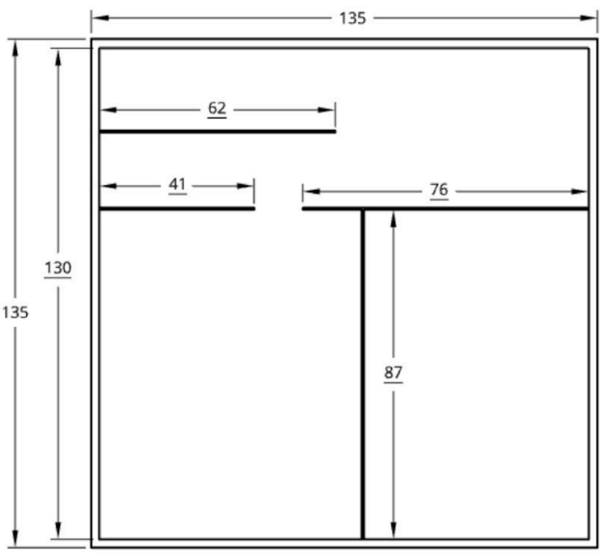


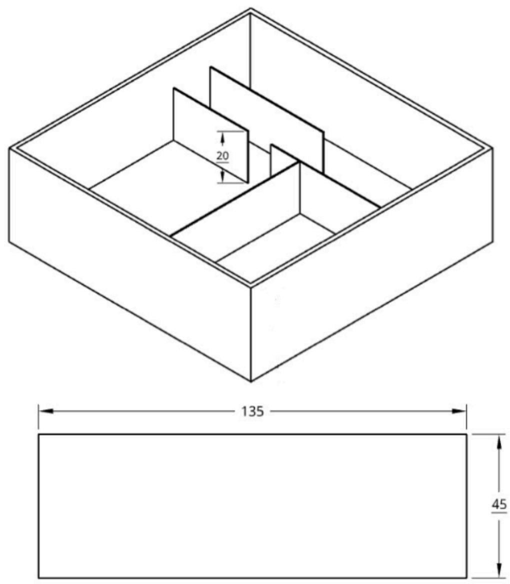
MICROCONTROLLER #2 (ALERT)

ISOMETRIC VIEW



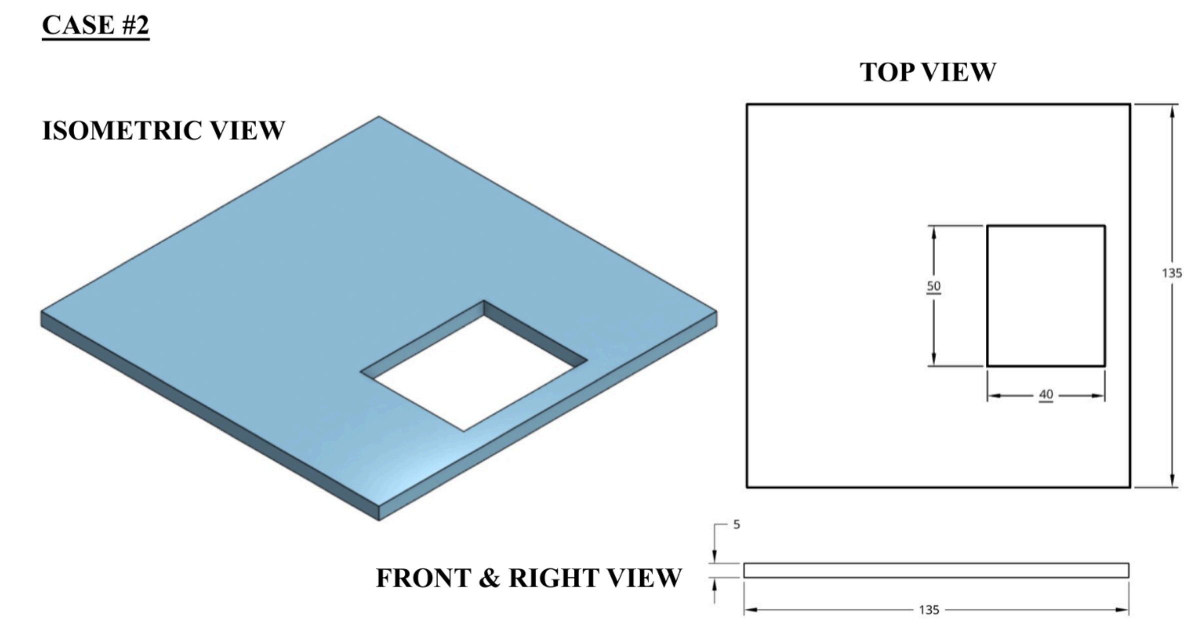
TOP VIEW

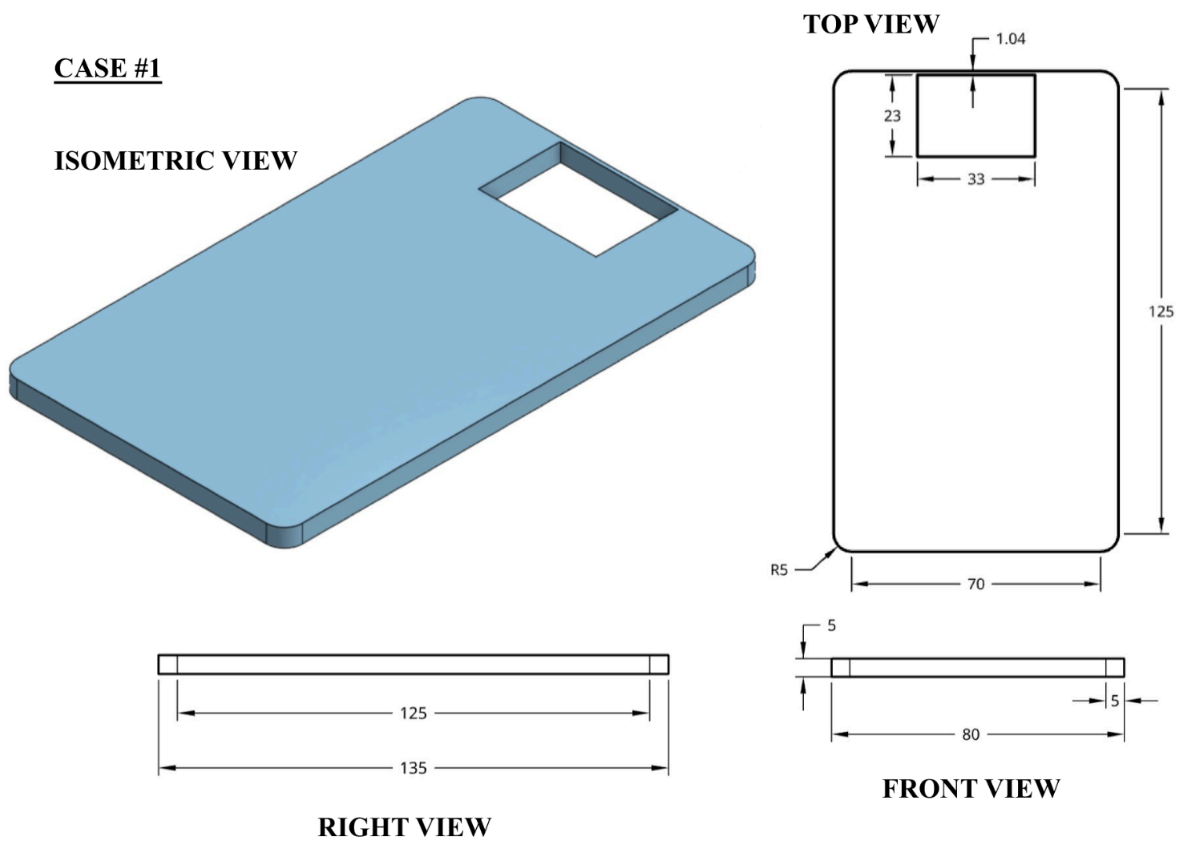




FRONT & RIGHT VIEW

The figure below features the lids for their respective cases, along with their measurements. These lids are meant to prevent all components from falling out, as well as preventing tampering with the technology, while enhancing the design of the systems. Notice that there are openings in the lids — these will prevent the casing from blocking the light and/or sensor.





Alternative Solutions:

Ultrasonic sensor: an electronic device that utilizes sound waves to measure distance or detect objects. Ideally, a PIR sensor is more suitable, but an ultrasonic sensor can serve as a feasible alternative. It emits high-frequency sound waves (typically about 20kHz) and measures the time it takes for the waves to bounce back after hitting an object. [20]

Wired communication: If the HC-05 bluetooth modules spark a rise in issues and problems, an alternative would be to utilize UART communication through a long wire that connects the two microcontrollers. Although it may hinder the design and portability of the system, it serves as an alternate method that technically would work. Technically speaking it would only be advantageous in reducing latency which is already low through the bluetooth modules. Often, as will be seen below, bluetooth, and wired connections often operate at the same baud rate.

VIII. Technical Analysis

A. Ohm's Law and Circuit Analysis

Description: Ohm's Law states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points, expressed as $V = IR$, where V is the voltage, I is the current, and R is the resistance. This principle is fundamental in determining the power consumption and current requirements for components such as the LEDs and sensors in the system.

Equation: $V = IR$, Using this equation, we will calculate the required current and voltage values to power the LED visual alert and ensure safe operation within the microcontroller's power output range. [22]

Standard/Section: The relevant electrical standards here align with **IEC 61000-4-5**, which covers electrical safety and protection from surges in electronic systems. Adhering to these standards ensures that the circuit remains within safe operating parameters [23]

Contribution to Solving the Problem: By applying Ohm's Law, we will ensure that the power supplied to the motion sensor and the LED is appropriate for their safe and efficient operation. This ensures reliability and longevity, especially in a dorm environment where safety is paramount

During the design of the LED circuit, Ohm's Law is applied to calculate the necessary resistor values to achieve the desired LED brightness (100–150 lumens). By calculating the current required for the chosen brightness, we select a resistor value that ensures the LED operates safely within the STM32 board's voltage output.

To control the LED brightness, we need a resistor that limits current appropriately, ensuring that the LED operates safely within its power specifications.

Sample Calculations:

LED Specifications:

- Desired LED current (I) = 20 mA (0.02 A)
- Forward voltage LED (V_{LED}) = 2.0 V
- Power Supply Voltage from STM32 Board: $V_{Supply} = 3.30\ V$

Using Ohm's Law:

$$V_{Supply} = V_{LED} + I \times R$$

$$R = \frac{V_{Supply} - V_{LED}}{I} = \frac{3.3V - 2.0V}{0.02} = 65\Omega$$

Therefore, a resistor of approximately 65 Ω is required to limit the current and safely power the LED at the desired brightness.

B. Pulse Width Modulation (PWM) Control

Description: Pulse Width Modulation (PWM) is a technique used to control the brightness of LEDs by switching them on and off at a high frequency. The duty cycle, or the fraction of time the signal is high, determines the brightness. This principle is applied to control the flashing frequency and brightness of the visual alert.

Equation: $D = \frac{T_{ON}}{T_{TOTAL}}$, where D is the duty cycle, T_{ON} is the time the signal is high, and T_{TOTAL} is the period of the signal. The duty cycle can be adjusted to change the perceived brightness of the LED [24]

Standard/Section: The principle applies to the **ISO 26262-10** standard for the functional safety of electronic systems, which ensures that PWM control in embedded systems is handled in a safe and reliable manner. The relevant section provides guidance on the implementation of reliable control mechanisms in safety-critical systems [25]

Contribution to Solving the Problem: PWM is crucial for controlling the LED alert, ensuring the right balance between power consumption and visual effectiveness. By adjusting the duty cycle, the system can save energy while maintaining a clear visual signal for hearing-impaired individuals

To achieve the desired brightness (100–150 lumens) and flashing frequency (2 Hz) for the LED, we can calculate the duty cycle for the PWM signal.

Assumptions:

- Maximum LED brightness is reached at a 100% duty cycle.
- Desired brightness corresponds to a 50% duty cycle (for simplicity in this example).

$$D = \frac{T_{ON}}{T_{TOTAL}} = 50\%$$

This means the PWM signal should be “high” for 50% of each cycle to achieve the target brightness. With a 2 Hz flashing frequency, the STM32 board’s PWM output can be configured to alternate the LED on and off every 0.5 seconds (500 ms), providing the required visibility.

C. UART Communication Protocol

Description: The **Universal Asynchronous Receiver-Transmitter (UART)** is a hardware communication protocol that allows the STM32 microcontrollers to communicate serially over a specified baud rate. UART is asynchronous, meaning data is transmitted without a clock signal, using start and stop bits to manage data flow.

Equation: $BaudRate = \frac{1}{Time\ per\ bit}$. For a communication rate of **115200 bps**, the time per bit is approximately **8.68 microseconds**. This formula helps to calculate the timing for data transmission across the UART link [26]

Standard/Section: This project adheres to **RS-232** standards, which define the electrical characteristics for serial communication. RS-232 specifies voltage levels, timing, and data format, ensuring that the UART communication is robust and reliable [27]

Contribution to Solving the Problem: By implementing UART, the system ensures that movement data is quickly and reliably transmitted between the two STM32 boards. This communication allows for real-time feedback between the motion sensor and the visual alert system, addressing the core functionality of alerting hearing-impaired users of nearby movement

The UART communication is set to a baud rate of 115200 bps, meaning that each bit is transmitted in a fixed time period.

Baud Rate (B) = 115200 bps

The time per T_{Bit} is:

$$T_{Bit} = \frac{1}{B} = \frac{1}{115200\ bps} \approx 8.68\mu s$$

This means each bit takes approximately 8.68 microseconds to transmit. For an 8-bit data frame with a start and stop bit (10 bits total), the time per frame T_{Frame} is:

$$T_{Frame} = T_{Bit} \times 10 = 8.68\mu s \times 10 = 86.8\mu$$

Thus, each frame takes approximately 86.8 microseconds to transmit, allowing for fast data exchange between the two STM32 boards and enabling a quick response from the LED to motion detection.

IX. Costs

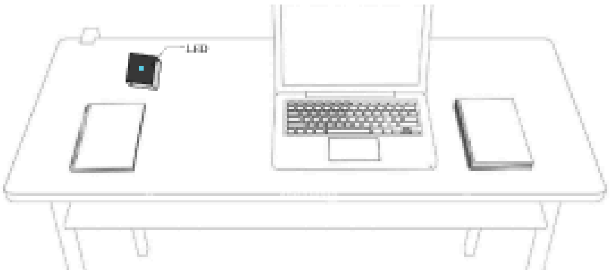
Bill of Materials:

Bill of Materials (BOM)					
Component	**Manufacturer**	**M. Location**	**Vendor**	**V. Location**	**Cost (CAD)**
STM32 Nucleo Board (x2)	STMicroelectronics	Mississauga, Ontario.	University of Waterloo	W-Store	\$80.00
Bluetooth Modules - HC-05 (x2)	Funsto	Shanghai, China	Amazon Canada	Toronto, Ontario	\$15.59
PIR Motion Sensor	SparkFun	Boulder, CO	SparkFun	Boulder, CO	\$10.95
Jumper Wires	ELEGOO	Shenzhen, China	Amazon Canada	Toronto, Ontario	\$12.99
Breadboard (small solderless, 400pc)	SparkFun	Boulder, CO	SparkFun	Boulder, CO	\$5.50
Coloured LEDs (assorted)	Novelty Place	California, US	Amazon	Toronto, Ontario	\$8.95
Resistors	SparkFun	Boulder, CO	SparkFun	Boulder, CO	\$3.95
3D Printer Filament (100g, PLA)	3D Printing Canada	Hamilton, ON	University of Waterloo	E7 Floor 2	\$6.00 (\$0.06 per gram)
Super Glue	Gorilla	Sharonville, Ohio	Walmart	Waterloo, Ontario	\$6.47
AA Batteries (x4, 1.5V each)	Amazon Basics	Vietnam	Amazon	Seattle, USA	\$9.10
Total:					**\$159.50**

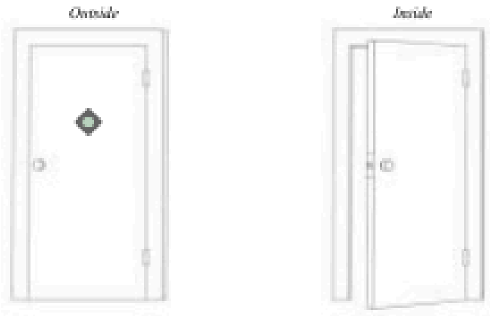
SEE NEXT PAGE FOR USER MANUAL ***SEE NEXT PAGE FOR USER MANUAL***

INSTALLATION MANUAL & USER GUIDE

Thank you for choosing the Visual Cue Notification System by Lumosense. This manual will guide you through the setup and installation process to ensure you can quickly begin using your device for effective and accessible notifications. Upon receiving your product, please inspect it for any potential damage from shipping, especially on the main unit casing and sensor attachments. If you notice any issues such as cracked components or loose connections, reach out to our Customer Support team at 1-800-482-4545 or email us at support@lumosense.com. Include images of any visible damage if possible. Thank you for choosing Lumosense, and we're excited to support your seamless notification experience.



Place Visual Alarm component on desk, counter, or any preferred location of use. Ensure the LED light is facing upwards.

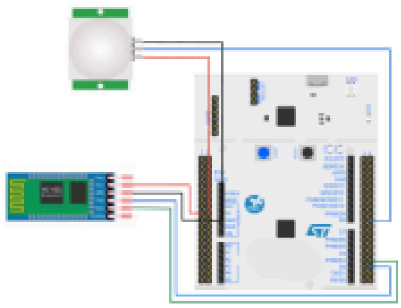


Ensuring the PIR sensor is facing towards yourself, screw the sensor component into place, at your preferred location. These locations include doors or walls.

Insert batteries into device to connect to power supply.

If you encounter any malfunctions with your Visual Cue Notification System, please follow these troubleshooting steps to identify and resolve the issue BEFORE reaching out:

- Inspect the Device: Begin by examining the device for any visible physical damage or loose components, such as wires or sensors. Ensure that all connections are secure.
- Reset the Device: If everything appears intact, reset the connection from the power supply to the device.
- Replace the Battery: If the device is still not functioning properly, check the battery and replace it with a new one to ensure a reliable power source.



Set-up must be completed by an adult. Keep device wiring away from children ages 8 and under.

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X. Energy Analysis

The energy analysis of the Visual Cue System focuses on ensuring that the device operates within safe power limits, consumes minimal energy, and adheres to safety standards relevant for dormitory use.

1. Reference Power Standard

- **Standard:** The system is designed to operate at low voltages (3.3–5.0 V) and limited power consumption. It follows the IEC 62368-1 standard for low-power electronic devices, which specifies safe operating limits for consumer electronics and provides guidance on protecting against electrical hazards.
- **Baseline Power Level:** To ensure user safety and reliable operation, the entire system (sensor, LED, microcontroller) is designed not to exceed 100 mW of power consumption under standard operating conditions.

2. Power Consumption Analysis

- **Analysis Process:**
    - Each component's power draw was assessed individually, including the PIR motion sensor, LED visual alert, and STM32 microcontroller.
    - By monitoring current and voltage for each component, the total energy consumption was calculated, confirming that the system remains within the 100 mW power cap.
- **Measurement Requirements:** Power measurements should be taken using a digital multimeter or oscilloscope to confirm the current draw and overall power consumption of the system, with readings compared against the calculated values in a spreadsheet for accuracy.

3. Energy Storage and Heat Dissipation Analysis

- **Energy Storage Assessment:** The system's low-power design minimizes energy storage, reducing risks associated with overheating or excessive energy buildup. Since the STM32 microcontroller and other components are designed for efficient operation, no significant energy storage occurs in any part of the circuit.
- **Heat Dissipation Requirements:** A heat dissipation test is recommended to ensure that any generated heat remains within safe limits. Components should remain cool to the touch after extended operation. This test can be done by measuring surface temperature after continuous use with a non-contact thermometer or thermal camera.

4. Conformance to Safety Standards

Testing for Compliance:
The system should be tested under typical dormitory environmental conditions to confirm compliance with IEC 62368-1 power limits. This involves verifying that the system remains stable and does not exceed power limits, even under extended usage scenarios.

Pass Criteria:
The system passes energy compliance if its total power consumption stays within 100 mW and it maintains a safe temperature during prolonged operation.

XI. Risk Analysis

This section identifies and analyzes potential risks associated with the Visual Cue System, evaluating possible consequences on safety and functionality in both intended and unintended usage scenarios.

1. Potential Negative Consequences from Intended Use

- ❖ **Risk:** *Power Failure or Battery Depletion*
    - ➢ **Description:** Power failure may cause the system to cease

functioning, resulting in the user not being alerted to important events.
  - **Consequences:** The dormitory environment becomes less safe, particularly during emergencies, as the user might not receive critical visual alerts.
  - **Mitigation:** Ensure low power consumption by keeping system operation under 100 mW and implementing a battery backup feature or low-battery indicator.
- **Risk:** *Visual Alert Overload*
  - **Description:** Frequent or prolonged activation of the LED could be distracting or uncomfortable for the user.
  - **Consequences:** User experience could be negatively impacted, reducing the effectiveness of the system.
  - **Mitigation:** Configure the motion sensor to minimize false positives and set a time interval between alert activations to prevent excessive flashing.

2. Potential Negative Consequences from Incorrect Use

- **Risk:** *Sensor Obstruction or Misalignment*
  - **Description:** If the motion sensor is blocked or misaligned, it may fail to detect movement accurately.
  - **Consequences:** The system might not activate when someone is at the door, potentially leading to missed notifications and a compromised user experience.
  - **Mitigation:** Include setup instructions emphasizing proper placement and alignment of the motion sensor and conduct routine checks to ensure it remains unobstructed.
- **Risk:** *Overheating from Prolonged* Operation
  - **Description:** Continuous activation of the system could result in overheating, especially if the components are not rated for extended use.
  - **Consequences:** Overheating could damage system components, pose a fire hazard, and increase maintenance needs.
  - **Mitigation:** Use components with a low thermal footprint and implement an auto-shutoff or standby mode to reduce continuous operation.

3. Potential Negative Consequences from Misuse

- **Risk:** *Tampering with System Components*
  - **Description:** Unauthorized attempts to modify or repair the system might compromise its functionality or safety.
  - **Consequences:** Tampering could lead to malfunction or render the system non-functional, reducing its reliability for the hearing-impaired user.
  - **Mitigation:** Add tamper-resistant enclosures for critical components and include a clear disclaimer advising against unauthorized repairs.
- **Risk:** *Excessive Power Source Variability*
  - **Description:** If the system is connected to a non-standard power source, voltage fluctuations could damage the circuitry.
  - **Consequences:** Circuitry damage may cause total system failure or unreliable operation, leading to inconsistent alert functionality.
  - **Mitigation:** Integrate voltage regulators and include warnings in the installation manual specifying appropriate power sources.

4. Possible Failure Mechanisms and Their Consequences

- **Failure Mechanism:** *Bluetooth Communication Failure*
  - **Description:** If bluetooth communication between the STM32 boards fails, the LED alert may not activate.
  - **Consequences:** Motion detection data may not be transmitted, compromising the system's core alert functionality.
  - **Mitigation:** Implement error-checking and retransmission protocols to ensure data integrity. If communication fails, design the system to display a status indicator warning the user.
- **Failure Mechanism:** *LED Burnout or Dim Lighting*
  - **Description:** Over time, the LED might degrade or burn out, reducing its effectiveness as a visual alert.
  - **Consequences:** The user may not notice alerts, compromising safety and accessibility.
  - **Mitigation:** Use LEDs rated for long life spans, conduct periodic brightness tests, and offer guidance on LED replacement when needed.

XII. Test Plan

The following tests evaluate the functionality and performance of the Visual Cue System, designed to alert hearing-impaired students in dormitory settings. Each test includes a setup description, environmental conditions, inputs, measurement standards, and pass/fail criteria.

1. Motion Detection Range and Accuracy Test

- **Test Setup:** Place the Visual Cue System's motion sensor at a standard dorm room entrance.
- **Environmental Parameters:** Indoor setting, with ambient lighting and typical room temperature.
- **Test Inputs:** A person will walk towards the sensor from a distance of 5 meters.
- **Measurement Standard:** The sensor must detect movement accurately between 1 to 3 meters, within a detection angle of 90 degrees.
- **Pass/Fail Criteria:** The test passes if the sensor consistently detects movement within the specified range and angle without triggering false positives.

2. Visual Alert Brightness and Response Time Test

- **Test Setup:** Trigger the motion sensor to activate the visual alert (LED).
- **Environmental Parameters:** A moderately lit dormitory room to simulate typical conditions.
- **Test Inputs:** A person walking in the sensor's detection range to activate the LED alert.
- **Measurement Standard:** LED brightness must reach 100–150 lumens and activate within 500 milliseconds after motion detection.
- **Pass/Fail Criteria:** The test passes if the LED brightness meets the specified range and activates within 500 milliseconds of detection.

3. Bluetooth Communication Stability Test

- **Test Setup:** Set up the motion sensor and LED systems on two STM32 boards and connect them via UART communication.
- **Environmental Parameters:** Controlled lab setting with minimal electronic interference.
- **Test Inputs:** Send a series of test signals to simulate motion detection data transfer.
- **Measurement Standard:** Communication should maintain a baud rate of 115200 bps with an error rate below 5% over a 5-meter connection.
- **Pass/Fail Criteria:** The test passes if data is transferred with an error rate below 5%, and the LED responds to sensor signals without delay.

4. Power Consumption Test

- **Test Setup:** Connect the Visual Cue System to a power source with a meter for monitoring power draw.
- **Environmental Parameters:** Standard dormitory room environment.
- **Test Inputs:** Activate the motion sensor and visual alert continuously for a specified period.
- **Measurement Standard:** The system's power draw must not exceed 100 mW during operation.
- **Pass/Fail Criteria:** The test passes if the total power consumption remains under 100 mW during regular operation.

5. Safety Compliance Test (UL 94V-0 Standard)

- **Test Setup:** Test the materials used in the Visual Cue System against flame resistance standards.
- **Environmental Parameters:** Controlled testing environment in accordance with UL 94V-0 protocols.
- **Test Inputs:** Subject system components to flame exposure as specified in UL 94V-0 testing.
- **Measurement Standard:** Materials must be rated as flame-resistant and capable of withstanding temperatures specified in UL 94V-0.
- **Pass/Fail Criteria:** The test passes if all materials meet the UL 94V-0 standard for flame resistance.

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