GNG 1103

Design Project User and Product Manual

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1. List of Acronyms and Glossary:

Table: Acronyms and Glossary

Acronym	Definition
BBT	Bat Box and Tracking (A specially designed box that provides a safe habitat for bats while tracking their movements via sensors).
IR	Infrared (A sensor that uses infrared light to detect objects or movement by measuring changes in light levels).
UNO	Universal Notation Output (Microcontroller: A small computing device used in electronic projects to control sensors, input, and output devices).
SD	Secured Digital (A small storage device used to store data, such as bat movement data, in the Bat Box and Tracking System).
MACS	This is the name of the group that designed and created this specific Bat Box and Tracking system. It stands for the names of the group members.
TIREE	Company that employed our work
Roosting Chamber	A small space inside the bat box designed to mimic the natural habitat of bats, such as tree bark.
USB	Universal Serial Bus (The system for connecting electronic equipment to devices such as computers, smartphones, etc.).

2. Introduction

This User and Product Manual provides the information necessary for clients, maintenance personnel, and engineering teams to effectively use the Bat Box and Tracking System (BBT) and serves as comprehensive documentation for the prototype. The BBT is an outdoor monitoring system designed to track bat activity using infrared (IR) sensors to detect entries and exits while logging data to an SD (secure digital) Card through a low-energy, battery-powered setup. The manual assumes users have basic knowledge of electronics and data logging and is intended to ensure the BBT system can be easily set up, maintained, and replicated for ecological research or other applications.

The document is structured to guide users through all aspects of the BBT system. The first section provides an overview of the system, describing its components and their functions. Following this, setup instructions are provided, detailing the steps necessary to assemble and configure the system. The operation guide explains how to monitor bat activity and manage logged data, while the maintenance and troubleshooting section offers solutions for common issues and care routines. Additionally, a Bill of Materials (BOM) is included to assist with replication and modifications, and the manual concludes with safety and privacy guidelines.

The purpose of this document is to enable users to set up, operate, and maintain the BBT system effectively while providing a blueprint for its replication or customization. The scope of activities covered includes initial setup, daily operation, routine maintenance, and troubleshooting. The intended audience includes clients conducting ecological research, maintenance personnel responsible for the system's upkeep, and engineering teams involved in its enhancement or replication.

Regarding security, privacy, and safety considerations, the BBT system is designed to protect user data and prevent hazards. While the system does not collect personally identifiable information, securing data logs is recommended to avoid unauthorized access. Safety measures during installation and maintenance, such as careful handling of electronic components and adherence to the provided guidelines, are essential to minimize risks. By addressing these considerations, the manual ensures that the BBT system can be used safely and effectively for its intended purposes.

3. Overview

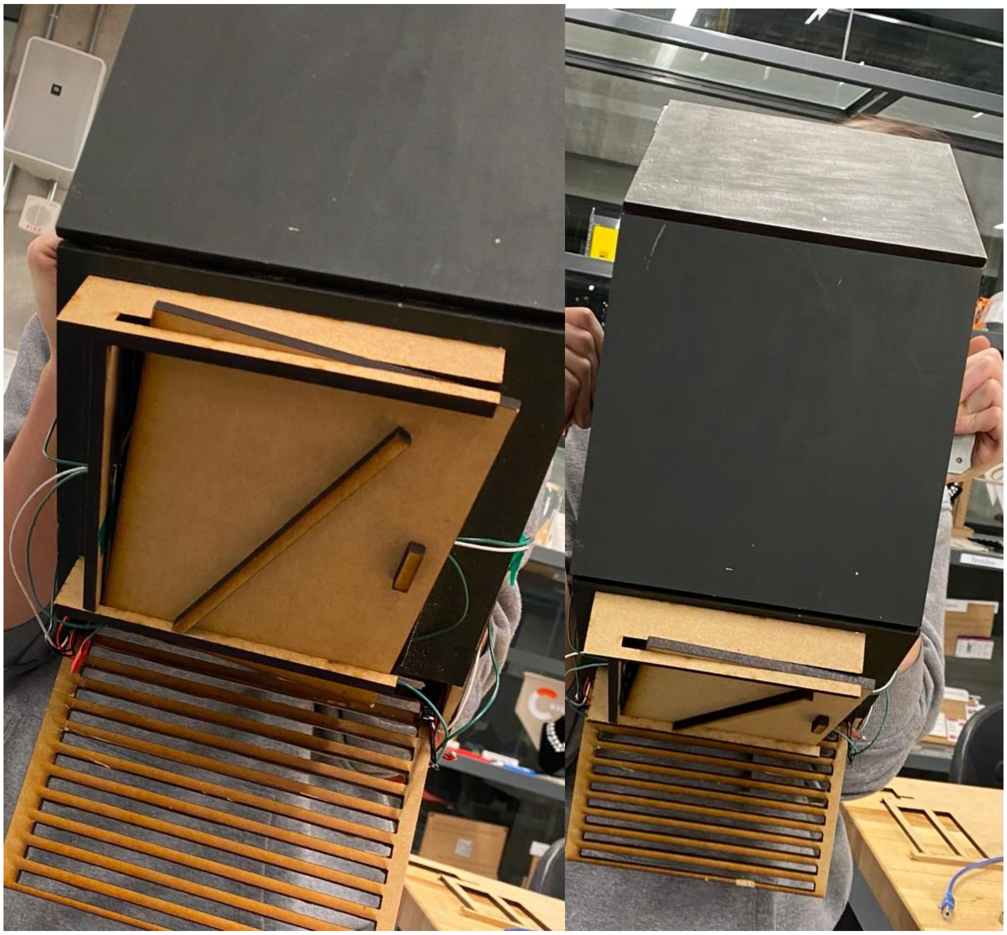
Within the Ottawa region and beyond, bats have been faced with the loss of their natural habitat due to urbanization and climate change. This has led them susceptible to the harsh climate, more predators, and no place to escape any other circumstance that can affect their overall survival. In many places where this is occurring, individuals have implemented a bat box system, a box that is mounted above the ground with roosting chambers so that the bats can comfortably stay to escape from any conditions they need.

To increase the research on the bats in Ottawa, namely the small and large brown bats, TIREE has instructed us to create a bat box that has a sensor component to it, so that all movement into the box can be tracked. All this data must be stored for the duration between April and October of any given year and is able to withstand the elements, without interfering with the wellbeing of the bats.

To complete this, MACS has implemented an IR break beam system, that is triggered when a bat enters or exists in the bat box, allowing for differentiation of the exits and entrances.

The design of the bat box incorporates a landing pad for the bats to easily climb up and down with, as well as three roosting chambers on the interior so simulate bark that the bats typically roost in in the wild. There are also two 45° slants, the top preventing any accumulation of twigs or dirt as well as preventing birds from nesting on top, and the bottom preventing guano build up from the bats in the box to allow for minimal cleaning maintenance.

The sensor utilizes an Arduino UNO microcontroller which encodes the needed data into the two sets of IR break beams which lie parallel across the entrance which tracks when there is an interference. When an entrance or exist is triggered, the data is sent to an SD card which stores the data until a user access this by uploading the micro-SD card onto a computer. All this is powered by a 9V battery and is stored within a casing found on the underside of the bat box, which has a sliding door so that all electronics can be easily accessible.



3.1. Conventions

This document follows consistent stylistic and command syntax conventions to enhance clarity and usability. Actions required by the reader begin with 'Action' followed by a colon (e.g., Action: Insert the SD card into the slot). Critical safety information is highlighted with 'Warning', while additional tips use 'Note'. Instructions are presented in numbered or bulleted lists for easy navigation, and technical terms or acronyms (e.g., IR for Infrared) are defined upon first use. These conventions ensure the document is intuitive and user-friendly.

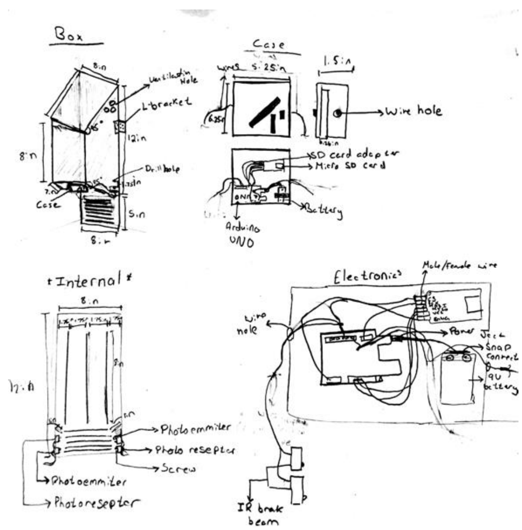
3.2. Cautions & Warnings

Before using the prototype, users should be aware that the power of the system is limited and may only last at most a week with the current 9V under continuous use. This can be fixed by adding a higher watt battery so that the sensor can run longer without maintenance, however a resistor should be put in place to prevent over heating of the battery.

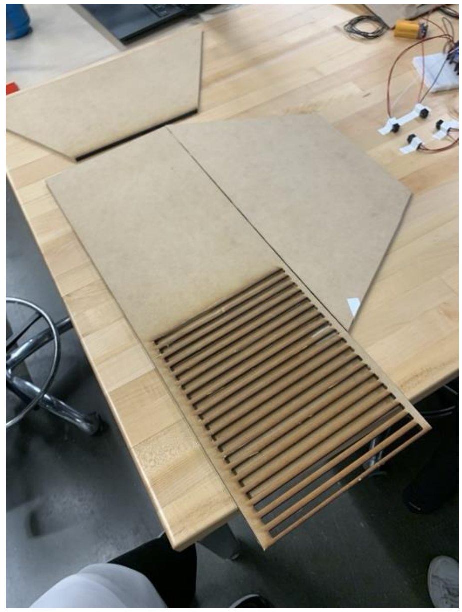
4. Getting Started

Bat box:

1. Cut out all pieces of wood using a laser cutter in the given dimensions



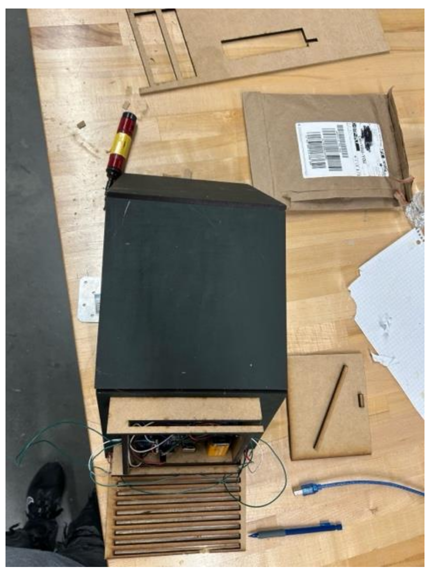
2. Set the back piece on a flat surface



3. Apply wood glue to the sides of the back piece and attach both side pieces, adding pressure when drying
4. Apply wood glue to the roosting chambers and attach them vertically, ensuring they are evenly spaced from each other on the back panel.

5. Apply wood glue to the top of the side pieces and attach the front piece, adding pressure when drying
6. Apply wood glue to the diagonal sides of the side pieces and attach the respective roof and bottom piece, adding pressure again

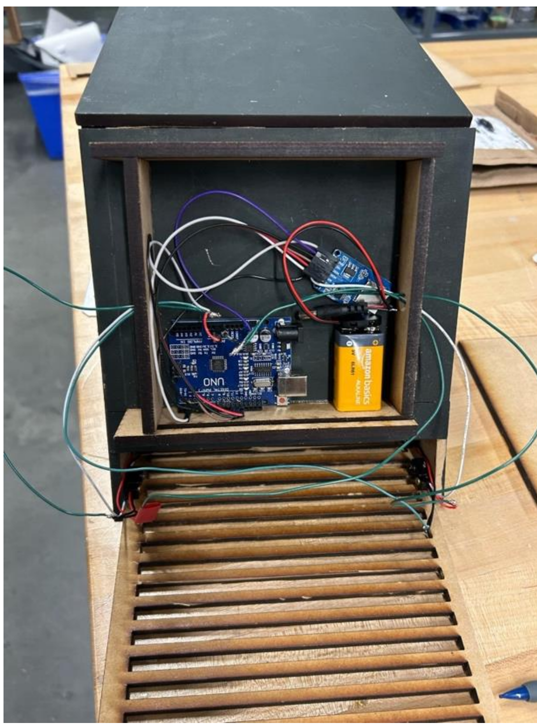
7. Drill holes on the side of the box at given locations and screw in the mounting brackets
8. Build the case and sliding door and attach it to the bottom of the bat box

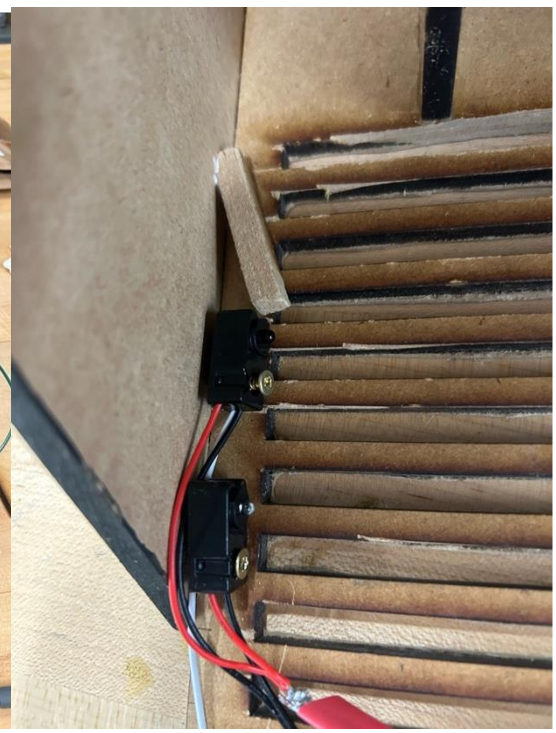


Tracker:

1. Attach the positive set of wires to the 5V port on the Arduino microcontroller
2. Attach the negative set of wires to the GND port on the Arduino
3. Attach the white wire in IR set 1 to pin 4 on the Arduino

4. Attach the white wire in IR set 2 to pin 5 port on the Arduino
5. Connect CS from SD card adapter to pin 2
6. Connect SCK from SD card adapter to pin 13
7. Connect MOSI from SD card adapter to pin 11
8. Connect MISO from SD card adapter to pin 12
9. Upload the pre-configured code onto the Arduino microcontroller through a USB type b to type a cord.
10. Place directly in the protective case at the bottom of the bat box
11. Plug in the battery to the power jack and the system is ready for use.
12. The sensors will now be active, and the system will begin tracking bat movements.





4.1. Configuration Considerations

The Bat Box and Tracking System (BBT) is designed to provide a safe habitat for bats while monitoring their activity using infrared sensors. Below is a description and graphical representation of the system configuration, designed for non-technical users.

Physical Prototype Configuration

The BBT consists of the following main components:

1. **Bat Box**: A wooden enclosure with three interior roosting chambers, a slanted roof, and a base to simulate natural bark-like textures and prevent guano buildup.
2. **IR Sensors**: Two infrared break beam sensors installed parallel to each other at the entrance to detect bat movements.
3. **Electronics Casing**: A weatherproof box underneath the bat box that houses the Arduino UNO microcontroller, SD card module, and 9V battery.
4. **Mounting Brackets**: Used to securely attach the bat box to a pole, wall, or tree.

Tools Required:

- Screwdriver (Phillips head)
- Drill (for wall or pole mounting)
- Ladder (for elevated installation)

Connections:

- **IR Sensors to Arduino**: Wired connections transmit detection signals.
- **Arduino to SD Card Module**: For data storage.
- **Power Supply**: A 9V battery powers the system.

Software Prototype Configuration

The BBT system processes and logs data using an Arduino UNO microcontroller programmed to record bat movements.

1. **Input Devices**:
   - IR break beam sensors detect entries and exits.
2. **Processing**:
   - Arduino UNO processes the signals.

   Output Devices:
   - SD card module logs the data for later retrieval.

Graphical Depiction:

- A simple block diagram showing connections:
  - **Sensors → Arduino → SD Card → Power Supply**.

4.2. User Access Considerations

<u>Researchers:</u> Researchers in the Ottawa region and beyond will be able to use the device to track bats in their local areas. For this kind of professional use, it is advised to implement a higher quality battery system so that the bat box can be left undisturbed for longer periods of time.

<u>Individuals:</u> The average individual will be able to implement the bat box, as long as they are able to install it at a high enough elevation, and so that it doesn't interfere with any other systems in the area.

4.3. Accessing/Setting up the System

To set up the system, users must start by ensuring all hardware components are correctly assembled (including the bat box, IR sensors, Arduino microcontroller, SD card, and battery). Once the physical assembly is complete, upload the pre-configured code onto the Arduino microcontroller using any software, preferably Arduino IDE which can easily be downloaded for free. Once uploaded the proper code, plug in the battery and the system is ready for use. After the code is uploaded, connect the 9V battery to the system to power it on. The sensors will now be active, and the system will begin tracking bat movements.

Note: If needed, users can adjust the sensitivity of the IR sensors by modifying the code to fit specific research needs.

Once the physical system is set up and powered on, the software will automatically start logging data to the SD card. No user logins are required for basic use. If further configuration is needed, such as updating the system or changing parameters in the software, users can open the Arduino IDE, modify the code, and upload it again to the Arduino microcontroller. The system does not require user IDs or passwords, but access to data (from the SD card) is possible through manual retrieval and uploading to a computer for analysis.

4.4. System Organization & Navigation

For Physical Prototypes:

The Bat Box and Tracking System (BBT) is organized into several key components that work together to track and log bat movements. These components are connected to ensure seamless data collection, power management, and ease of maintenance. Below is an overview of the system organization and its key features.

1. Bat Box

- **Description**: The primary housing unit for the system, the bat box, is made from durable wood, providing roosting chambers for bats. The box is mounted at a height, with the entrance designed for easy bat access.
- **Function**: It houses all the other components, including the sensors, microcontroller, and data storage. It also provides a safe and suitable environment for bats to roost.

2. IR Sensors

- **Description**: Two infrared break beam sensors are positioned at the entrance of the bat box.
- **Connection**: The sensors are wired to the Arduino UNO microcontroller. When a bat enters or exits the box, the IR beam is interrupted, triggering the sensor and logging the data.
- **Function**: These sensors are responsible for detecting bat movement and sending the signal to the microcontroller.

3. Arduino Microcontroller

- **Description**: The heart of the system, the Arduino UNO microcontroller, is responsible for processing signals from the IR sensors, logging the data, and managing system operations.

- **Connection**: The Arduino is connected to the IR sensors and the SD card module. It receives sensor input, processes it, and stores the results in the SD card.
- **Function**: It executes the pre-uploaded code, processes the sensor data, and logs the activity of the bats.

4. SD Card Module

- **Description**: A micro-SD card module is connected to the Arduino to store the logged data.
- **Connection**: It is connected directly to the Arduino, allowing data to be written in real-time as the sensors are triggered.
- **Function**: Stores the bat movement data (entries and exits), which can later be accessed by removing the SD card and uploading it to a computer.

5. Power Supply

- **Description**: The system is powered by a 9V battery, housed in a casing underneath the bat box.
- **Connection**: The battery is connected to the Arduino and other components via wired connections.
- **Function**: Provides power to all components, ensuring the system runs continuously for tracking bat activity.

For Software Prototypes:

The software system of the Bat Box and Tracking System (BBT) manages the communication between the Arduino microcontroller, sensors, and data logging functions. The system is organized in a way that makes it easy for users to monitor and modify operations.

1. Main Menu / Home Page

- **Description**: The main interface users interact with is the Arduino IDE, where the code is uploaded, and the system settings are adjusted.

- **Navigation Path**: From the main menu of the IDE, users can access the file system, open a new project, and manage code.

2. Code Upload Function

- **Description**: Once the system is physically set up, the code needs to be uploaded to Arduino to start operation.
- **Navigation Path**: In the Arduino IDE, the user opens the sketch (the pre-configured code), selects the correct board (Arduino UNO), and uploads it. The code then runs on the microcontroller.
- **Function**: This step activates the system, enabling it to collect and log data from the sensors.

3. Sensor Data Processing

- **Description**: The system reads the data from the sensors, processes it, and logs it onto the SD card.
- **Navigation Path**: While the system runs, the user does not interact with the data processing directly. Data is automatically processed and stored.
- **Function**: The microcontroller handles the communication between the sensors and the SD card.

4. Data Retrieval

- **Description**: The data is stored on the micro-SD card, which can be removed and uploaded to a computer.
- **Navigation Path**: To retrieve the data, the user removes the SD card from the module, inserts it into a computer, and views the logged data.
- **Function**: Users can then analyze the data to study bat activity patterns based on the recorded entries and exits.

4.5. Exiting the System

For **physical prototypes**, properly shutting down and storing the Bat Box and Tracking System (BBT) involves a few key steps to ensure that the system is safely powered down and ready for future use. First, remove the SD card from the system to retrieve the logged data, ensuring that the data is safely transferred to a computer or storage device. Next, disconnect the 9V battery to turn off the system, preventing any unnecessary power drainage. Afterward, securely store the battery in a cool, dry place to maintain its longevity. Finally, if the bat box is being stored for an extended period, consider cleaning the components and ensuring that the box is in a safe, dry location to protect it from the elements.

For **software prototypes**, turning off the system involves closing the Arduino IDE or any other software used to interact with the system. Ensure that any data processing or configuration changes have been saved before exiting the program. Once the code has been uploaded to the microcontroller, no further interaction with the software is required unless the system is being modified or updated. Simply exit the IDE or software, ensuring that all settings are intact for the next time the system is used.

5. Using the System

This section provides a detailed walkthrough of how to use the Bat Box and Tracking System (BBT), outlining the key functions and features of the system. Each function is described in step-by-step instructions, with clear guidance on user inputs, system outputs, and expected behaviors. This section is designed to help users navigate the system easily, whether it's setting up the system, tracking bat movements, retrieving data, or properly powering off the system. The instructions are tailored to ensure that anyone, regardless of technical expertise, can operate the system effectively and efficiently.

5.1. (IR Break Beam)

Two IR Break Beams are placed across the entrance of the bat box. This system controls the tracking of both the entrances and the exits of the bat box by using two sets that allow for differentiation.

5.1.1. (Entrances)

When break beam 1 (closer to the outside of the box) is broken first, followed by break beam 2 (further in the box), this will be triggered as an entrance into the box

5.1.2. (Exits)

When break beam 2 is broken first, followed by break beam 1, it'll be triggered as an exit.

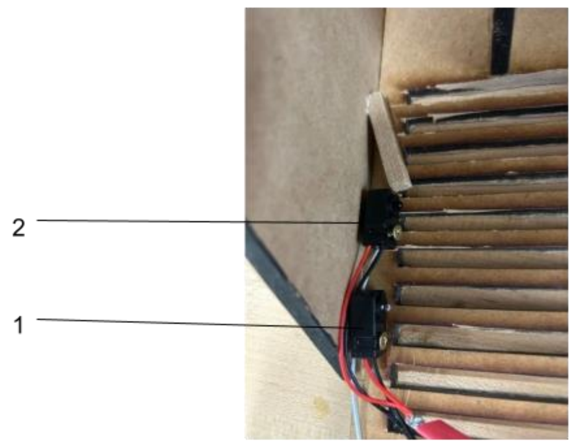


Figure 5.1: One side of the IR Break Beam entrance system, each set of beams labeled.

5.2 (Power)

With the help of a snap connector, a 9V battery is connected to the Arduino through the microcontroller's power jack port. To replace a batter, simply disconnect the snap connector and reattach a new battery

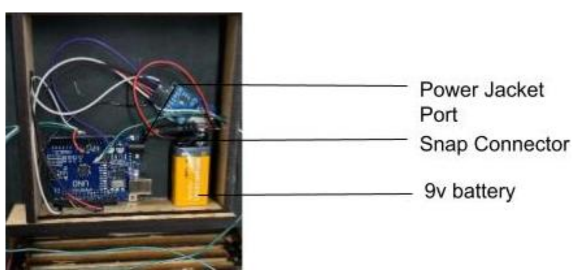


Figure 5.2: Labeled diagram of the interior of the electronics case

5.3 (Data Collection)

Once either an exit or entrance has been triggered, the Arduino UNO sends this data into a micro-SD card that stores this data onto it until collected by user. To collect, simply remove the SD card from the adapter, and insert the micro-SD card into one's computer or cellular device. At this point, the user can decide if they want to clear all data on the card or insert it right back into the system as is.

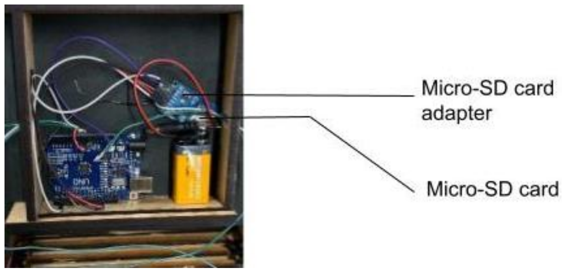


Figure 5.3: Data collection system located within electronics case

5.4 (Electronics Casing)

To ensure protection of all electrical components, they are located with a case on the underside of the bat box within an MDF made compartment. To access the inside, the user must slide out the door out and perform any needed task. They should remember to replace the door once they are finished.

Figure 5.4: Electronics compartment with the sliding door in place

6. Troubleshooting & Support

6.1. Error Messages or Behaviors

1. Power Issues: The system fails to power on or shuts down unexpectedly.

Possible Causes:

- Low or faulty battery.
- Loose or improper battery connections.
- Insufficient power supply to the Arduino microcontroller.

Corrective Actions:

1. Check the battery level and ensure it's properly inserted. If the battery is low, replace it with a fresh one.
2. Inspect the battery connections for any loose wires. Reconnect as necessary.
3. Test the system with a new battery if power issues persist.

2. Sensor Malfunction: The sensors fail to detect bat movements or produce inaccurate data.

Possible Causes:

- Misalignment of the IR sensors.
- Obstructions in the sensor's line of sight.
- Damaged or disconnected sensor wiring.

Corrective Actions:

1. Ensure the IR sensors are aligned directly across from each other, with no obstructions in their path.
2. Clear any debris or objects that may block the sensor's beams.
3. Check the sensor wiring and reconnect any loose or damaged wires.

3. Data Logging Issues: The system fails to log data or logs incomplete data.

Possible Causes:

- Full or corrupted micro-SD card.
- Incorrectly inserted SD card.
- Arduino code is not written on the SD card.

Corrective Actions:

1. Verify that the SD card is properly inserted and has sufficient storage space.
2. Format the SD card if necessary and ensure its properly set up to store data.
3. Reload the Arduino code if data is not being logged to the SD card.

4. Communication Errors: The system fails to communicate with the computer or upload data.

Possible Causes:

- Improper SD card connection.
- Faulty or incompatible SD card reader.
- Arduino is not properly connected to the computer.

Corrective Actions:

1. Ensure the SD card reader is properly connected to the computer and the SD card is securely inserted.
2. Test with a different SD card reader or USB port.
3. Confirm the Arduino is correctly connected to the computer and that the proper port is selected in the Arduino IDE.

6.2. Special Considerations

Environmental Factors

When setting up the bat box, consider environmental factors that could interfere with sensor functionality, such as high winds, rain, or temperature fluctuations. Ensure the bat box is installed in a location that minimizes exposure to these conditions.

Battery Life

The system is powered by a 9V battery, which may last for a limited period (approximately one week). For longer operation, consider using a higher-capacity battery. Ensure a resistor is used to prevent overheating.

Sensor Sensitivity

If the sensors trigger false readings or fail to detect bats, adjust the sensitivity settings in the Arduino code. The sensors should be calibrated according to the conditions in which they are placed (e.g., height, proximity to bat activity).

6.3. Maintenance

Regular Maintenance

1. **Battery Check**: Regularly check the battery charge, especially if the system is left in operation for extended periods. Replace the battery when necessary.
2. **Sensor Cleaning**: Clean the IR sensors periodically to ensure no dust, guano or debris interferes with sensor performance.
3. **Data Backup**: Regularly back up the data from the SD card to prevent data loss and ensure that the system is functioning correctly.
4. **Visual Inspection**: Inspect the system for any signs of wear or damage, particularly the wiring and connectors. Ensure the components are securely fastened and that there is no corrosion.

6.4. Support

For any issues with the Bat Box and Tracking System (BBT), users can reach out to the following points of contact for support:

Technical Support

- **Name**: MACS
- **Email**: MACS@gmail.com
- **Phone**: 613 - 555 - 6789

For emergency assistance, users should contact support immediately. For general inquiries or to report a non-urgent issue, email support with a description of the problem.

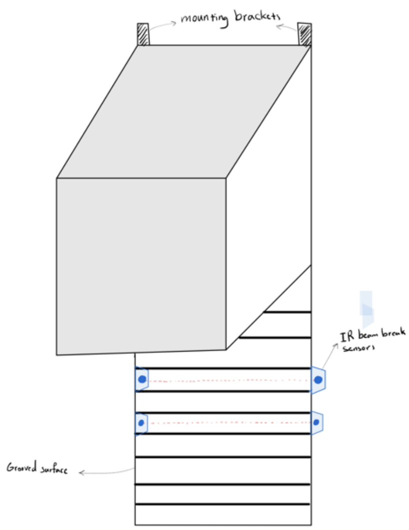
Incident Handling

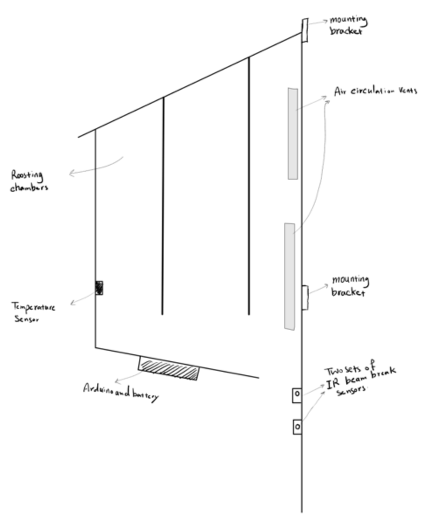
If a security incident or system malfunction is detected, users should immediately contact the support team. Provide a detailed description of the issue, including any error messages or behaviors observed.

7. Product Documentation

Mechanical Design

The mechanical design of the Bat Box and Tracking System (BBT) prototype focuses on creating a durable and functional structure for housing the sensors, microcontroller, and other components. The primary goals were to ensure that the system could withstand outdoor weather conditions, provide proper access for the bats, and securely house the electronics.





Material Selection

Initially, we considered several materials for the bat box structure, including wood. After conducting a cost-benefit analysis, wood (specifically MDF) was chosen for its combination of durability, ease of handling, and low cost. MDF is relatively inexpensive, can be cut precisely using a laser cutter, and has a good resistance to outdoor conditions when properly sealed. It also provides a natural aesthetic that is in line with the environmental goals of the design.

Design Features

The bat box was designed to include:

- **Roosting Chambers**: The interior of the box has three chambers designed to simulate tree bark, providing a comfortable space for the bats. The chambers were sized based on common bat roosting patterns and were spaced to ensure proper airflow and temperature regulation.
- **Landing Pad**: A small, angled landing pad was included at the entrance to help the bats easily land and enter the box. This feature was designed based on observations of bat behavior in natural roosts.
- **Weatherproofing**: The box includes slanted walls at both the top and bottom to prevent water accumulation and guano buildup. The top slant also discourages birds from nesting on the box.

Manufacturing Process

The box was laser cut from MDF panels, with precise measurements to ensure the parts fit together securely without the need for additional fasteners. The panels were then assembled using strong wood glue to create a sturdy frame. The surface of the box can be sealed with an exterior wood finish to protect it from moisture and UV rays.

6.2 Electrical Design

The electrical design is crucial for tracking bat movements accurately and logging data for research purposes. This involved selecting the right components, wiring, and ensuring the system could operate efficiently in outdoor conditions.

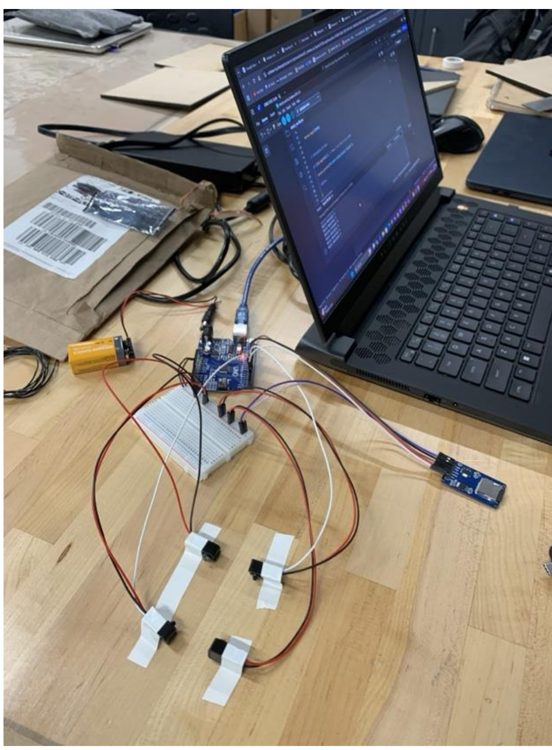
Component Selection

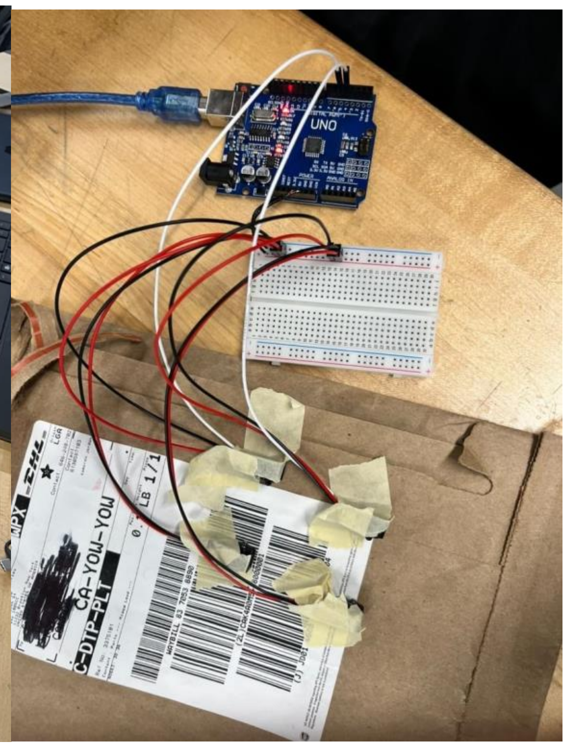
- **Microcontroller**: The Arduino UNO was chosen as the microcontroller due to its ease of use, reliability, and compatibility with the other components (IR sensors, SD card, etc.). The Arduino also offers ample I/O ports for expansion, if needed in the future.
- **IR Break Beam Sensors**: Two IR break beam sensors were used to detect when bats enter or exit the bat box. These sensors were placed at the entrance to detect movement by measuring interruptions in the IR beam. The sensors were selected for their reliability, low cost, and low power consumption, crucial for extended use with limited battery power.
- **Power Supply**: A 9V battery was initially chosen to power the system. However, testing showed that it would only last about a week. To address this, a higher-capacity battery, such as a 12V rechargeable battery, would be a better option for longer operation. A resistor is also recommended to prevent overheating.

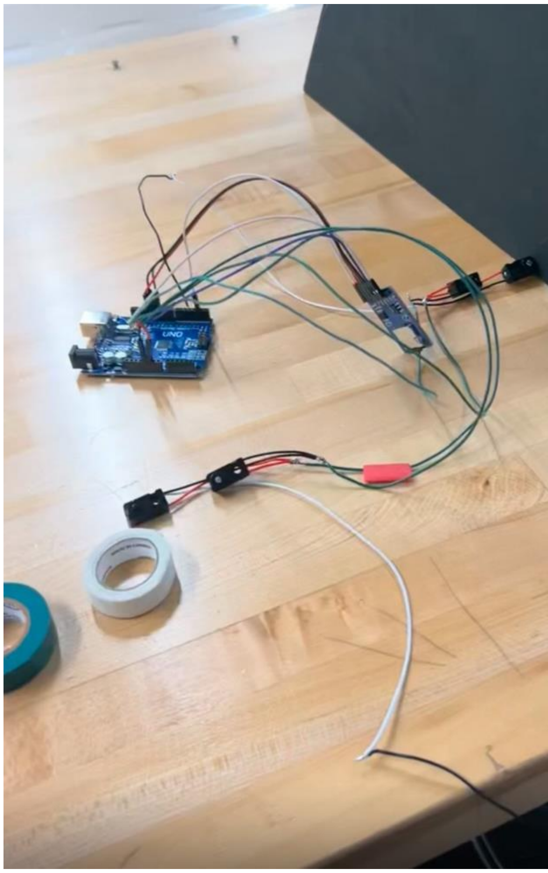
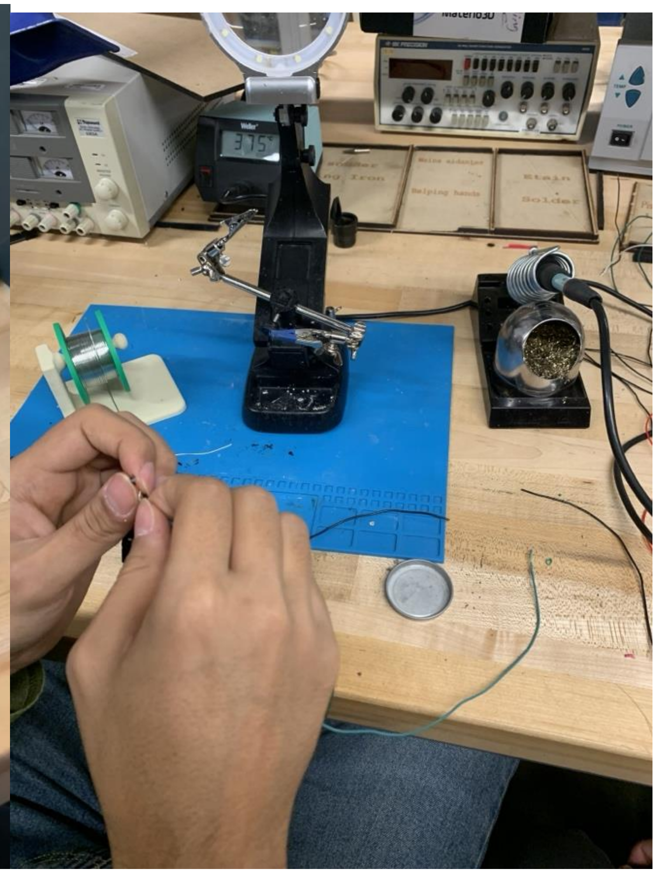
- **SD Card**: An SD card module was used to store the data recorded by the sensors. This allows researchers to download and analyze the data remotely. The SD card was chosen for its storage capacity and ease of integration with the Arduino.

Wiring and Connections

All components were connected according to the circuit diagram, ensuring proper power distribution and signal transmission. The Arduino was connected to the IR sensors, the SD card, and the power supply using jumper wires and a breadboard during testing. The final prototype used a more permanent wiring solution with soldered connections and a custom PCB to minimize loose connections and improve reliability.





6.3 Software Design

The software design focuses on programming the Arduino microcontroller to process sensor input and store data on the SD card. The code is written in C/C++ using the Arduino IDE.

Main Program Functions

1. **Sensor Reading**: The code continuously monitors the IR sensors for any interruptions in the IR beam. When a bat enters or exits the bat box, the code logs the event along with a timestamp.
2. **Data Logging**: The data is written to a file on the SD card in CSV format, which can later be retrieved for analysis. The data includes the time of entry/exit and sensor status.

3. **Power Management**: To conserve battery, the code includes sleep modes when the system is not actively detecting bat movement. This ensures the system runs as efficiently as possible.

Challenges and Solutions

During the development of the software, we encountered issues with the SD card not writing data properly. This was traced to a conflict between the IR sensor reading and the SD card writing process. To address this, we added delays in the code to ensure the sensor readings were processed before attempting to write to the SD card.

7.1. Subsystems of Prototype

7.1.1. BOM (Bill of Materials)

Item	Total Cost	Link for product
IR Break Beam Sensors (x2)	$6.67	https://learn.adafruit.com/ir-breakbeam-sensors/arduino
Screws	$4.44	https://www.homedepot.ca/product/leviton-white-replacement-wallplate-screws-packed-10-units/1001532514
Rechargeable 9v	$5.60	https://www.homedepot.ca/product/leviton-white-replacement-wallplate-screws-packed-10-units/1001532514
5ft of Black Wires	$1.81	https://makerstore.ca/shop/ols/products/5ft-hook-up-wire-22awg-black
Arduino UNO	$10.17	https://makerstore.ca/shop/ols/products/arduino-uno-r3-clone
USB Cable	$3.11	https://makerstore.ca/shop/ols/products/usb-type-a-b-cables
SD Card	$8.80	https://shorturl.at/RGKqS
SD Card Adapter	$2.83	https://edu-makerlab.odoo.com/shop/microsd-adaptor-2168?search=adapter
MDF (x2)	$6.78	https://makerstore.ca/shop/ols/products/mdf/v/M003-1-8-18-NCH

Wood Glue		$7.42	https://edu-makerlab.odoo.com/shop/nails-2177?search=nails&order=name+asc#attr=1070
Mounting Brackets (x2)		$5.62	https://www.homedepot.ca/product/unbranded-universal-mount-shade-brackets-silver-2-pc
Soldering Wire		$8.90	https://shorturl.at/RNkKt
9v Battery Snap Connector		$2.26	https://makerstore.ca/shop/ols/products/9v-battery-clip-connector
DIY Power Jack Shell		$2.49	https://www.amazon.ca/uxcell-Plastic-Cover-Power-Connector/dp/B0711R4LWP
Forest Green Paint		$7.53	https://shorturl.at/Ch44a
Male-Female Jumper Wire		$1.13	https://makerstore.ca/shop/ols/products/jumper-cables-pack-of-10
Total Cost of Prototype	$85.55		

7.1.2. Equipment List

Equipment	Purpose
CO_2 Laser Cutter	Cut the pieces of MDF into proper sizes arcuately
Breadboard	Used to test functionality of code before soldering all wires together
Soldering Iron	Melt the soldering wire that's used to attach wires together
Electric Drill	Drill the ventilation holes and screw holes used for the brackets and IR break beams
Arduino IDE	Program Arduino for handling sensor data and storing it on the SD card
Serial Monitor (in Arduino IDE)	Real-time data monitoring for debugging.
Data Analysis System (e.g. Excel)	Analyze data collected on the SD card

7.1.3. Instructions

7.2. Testing & Validation

Tested System	Conducted Test	Results
Entry/Exit Accuracy	Simulated bats entering and leaving the bat box by interrupting both the exit and entrance systems	Functions properly with very limited miss tracks and no double positives were detected
Distinguishment between Guano and Bat Exit	Put simulated guano near exit and compared to exit of bat	Sensor was able to ignore majority of the guano that was placed through, however if fallen directly in the middle, guano interfered
SD Card Data Logging	Ran test with sensor and then proceeded to connect SD card to computer to view if data tracking was accuracy	Was successful with all of the entrance/exit detections being stored
Battery Power Consumption	Measure power consumption during normal operation over a test period to ensure the system remains efficient and battery life is sustainable.	Plan for battery optimization or consider alternative power sources if needed for extended operation.
Box durability and Weather Resistance	Dropped the box from various heights and accessed the damage, if any, that the box received Walked through pouring rain with the box exposed	Small dents were visible once dropped from waist height, but overall quality remained sturdy. The interior of the box received some unwanted water; however, the electronics compartment was secure and dry.

8. Conclusions and Recommendations for Future Work

This project provided valuable insights into both the engineering and design aspects of creating a functional bat box equipped with tracking sensors. Throughout the development process, we gained experience in prototyping, sensor integration, and software development, while also learning how to balance functionality, cost, and environmental sustainability. The work involved significant testing and iteration, especially with the sensor setup, battery life, and ensuring that the box would be weatherproof and safe for bats.

One key lesson learned was the importance of power management. Although the initial 9V battery setup worked for early tests, its limited lifespan highlighted the need for more sustainable power solutions. Future work should focus on optimizing the power system, possibly integrating solar panels or higher-capacity batteries to extend the system's operational time in remote locations. Additionally, further refinement of the software to handle large data sets and improve user accessibility would enhance the system's usefulness for researchers.

If given more time, a few areas would be prioritized:

1. **Power Efficiency**: As mentioned, improving the battery life with a rechargeable battery system would make the product more reliable and cost-effective in the long term.
2. **Advanced Data Analysis**: Implementing real-time data analysis and wireless data transmission (e.g., via Bluetooth or Wi-Fi) would allow researchers to access data remotely, eliminating the need to manually retrieve the SD card.
3. **Improved Weatherproofing**: While the current design addresses basic weatherproofing, further testing under harsher conditions could uncover areas for improvement, such as more robust sealing and materials to ensure the longevity of the prototype.

Overall, while this prototype meets the basic requirements for tracking bat movements, there is significant room for enhancement. With additional time, integrating more advanced technologies, refining the design, and expanding the system's capabilities would result in a more versatile and durable tool for bat conservation research.

9. Bibliography

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10. Appendices

The documents listed in the table below are all relevant to the development and design of the Bat Box and Tracking System (BBT) prototype. This user manual serves as a summary of the entire design process, encapsulating the key decisions, iterations, and outcomes from the early planning stages to the final prototype testing. Each referenced document represents a critical phase of the project, starting with the conceptual design and project planning, followed by prototyping, feedback collection, and the refinement of the system.

These deliverables include detailed information on the design considerations, cost estimates, materials used, and the evolution of the prototype, which were all instrumental in shaping the final product. As the manual summarizes the key aspects of the BBT system, the referenced documents provide supporting documentation for each phase of the project. Together, they offer a comprehensive overview of the work completed, ensuring that future users and developers can understand the rationale behind design choices, testing results, and areas for future improvement.

Document Name	Document Location and/or URL	Issuance Date
GNG 1103 Group 2 - Project Deliverable B	https://docs.google.com/document/d/107ywqV-Dxf7pregVAxXMuSsuunD1WvOULJqX5zxh24w/edit?usp=sharing	September 29, 2024
Project Deliverable C	https://docs.google.com/document/d/1wAad_kAGbdzMzPzlgvRICAzBjbd-_BFD2vuGhRXkxog/edit?usp=sharing	October 6, 2024
Deliverable D - Conceptual Design	Deliverable D - Conceptual Design.docx	October 17, 2024
Deliverable E - Project Plan and Cost Estimate	Deliverable E - Project Plan and Cost Estimate.docx	October 27, 2024
BOM	Project deliverable E.xlsx	October 27, 2024

Deliverable F - Prototype I and Customer Feedback	Deliverable F - Prototype I and Customer Feedback.docx	November 3, 2024
Deliverable G - Prototype II and Customer Feedback	Deliverable G - Prototype II and Customer Feedback.docx	November 10, 2024
Deliverable H - Prototype III and Customer Feedback	Deliverable H - Prototype III and Customer Feedback.docx	November 24, 2024

MakerRepo Link: https://makerepo.com/SaherAli/2153.gng-1103c-group-2-macs-makerepo-repository