

**Screws Loose**

Project Deliverable E - Project Plan and Cost Estimate

**Group 9**

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**1. Introduction**

To support the conservation of endangered bat species in Ontario, Tiree has tasked us with developing a monitoring system to evaluate the effectiveness of bat boxes. In this deliverable, we present a detailed design drawing and concept summary based on the selected Global Concept from Deliverable D. We then provide a comprehensive bill of materials (BOM), listing all necessary components and equipment for the design. Additionally, we outlined a detailed prototyping plan, which includes a task breakdown with estimated durations and assigned responsibilities for each task. Our plan also specifies a detailed testing process. Furthermore, we provided a list of the significant project risks, with corresponding contingency plans to mitigate the critical risks deemed probable.

**2. Design Drawing and Concept Summary**

***Electronic components***

Originally, our chosen global concept involved using a Raspberry Pi Zero 2W, 2 Passive infrared (PIR) sensors, load cell, an amplifier (for the load cell), and an NFC module. However, upon further research we decided to use a SAMD21 over the Raspberry Pi Zero 2W, due to the SAMD21’s high efficiency and low power consumption. For example, with a 3.7 V battery, the Raspberry Pi Zero 2W consumes approximately 0.2775 W of power, while the SAMD21 consumes around 0.0185 W of power (based on values in the appendix and using P = VI, where P is power, V is voltage, and I is current). This reduction in power consumption allows the use of a smaller, more readily available battery. However, since the SAMD21 lacks a built-in microSD card slot, a microSD breakout board will be required.

The sensors chosen remain the same: two PIR sensors and a load cell with an amplifier. PIR sensors are used to detect thermal energy emitted from various animals and objects (Cook, 2018). Bats being warmblooded mammals, allows them to be easily detected by the PIR sensors. A load cell converts an applied force (tension, compression, weight, etc.) into a change in electrical resistance, which can then be measured to determine any changes in weight for the bat box (Strain Gauges, n.d.). An amplifier will be used alongside the load cell to amplify the change in electrical resistance.

Together, the PIR sensors and load cell will determine whether a bat has entered or exited the bat box. One PIR sensor will be placed outside the bat box, while the other will be mounted on the inside (refer to Figure 1.0). The load cell will be placed on the back side of the bat box. If the PIR sensor on the outside of the bat box is triggered before the inside one, and the load cell detects an increase in weight, that indicates that a bat has entered the bat box. Conversely, if the inside PIR sensor is triggered before the outside one, and the load cell detects a decrease in weight, that indicates that a bat has left the bat box. However, one new addition to the device is a temperature sensor, which will be used to monitor the internal temperature of the bat box.

The microSD breakout board will enable us to use a microSD card to store large datasets in a **.txt** file format over time. The collected data will include the rate of entry and exits, the maximum number of bats inside the bat box and the maximum weight of the bat box over a period of one month.

An NFC module (**PN532**) will be used to provide a quick and convenient way for maintenance teams to access the bat house’s data. Data from the SD card is uploaded to the NFC chip in a simple .txt file format. When a data collector scans the NFC chip with an NFC-enabled device, the file automatically opens, displaying the processed information in the format shown in Figure 2.0.

The device will be powered by a 3.7V 9000mAh Lithium ion battery pack, which will give the device an operating time of roughly 35 days. This was determined using the calculations in Table 1.0. Additionally, we have included a bi-directional voltage booster to raise the system’s output voltage to the necessary 5V for other components.

**Table 1.0**

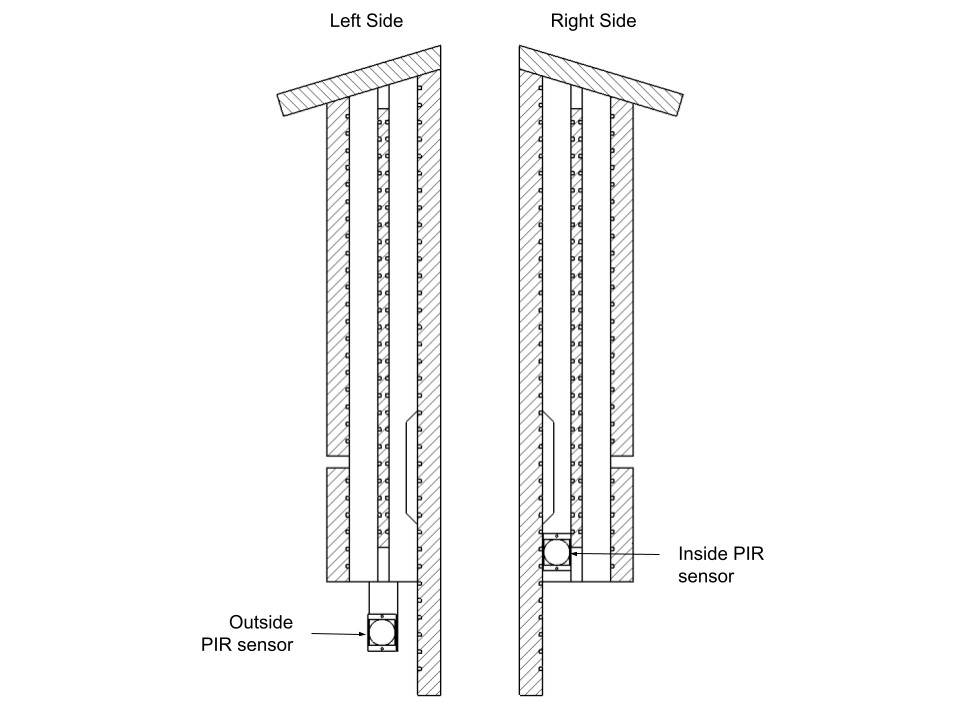
*Battery Capacity Calculations*

|  | (840 hours = 35 Days) |
| --- | --- |
|
|

*Note.* Values taken from the appendix. The bi-directional voltage booster is not included due to its high efficiency.

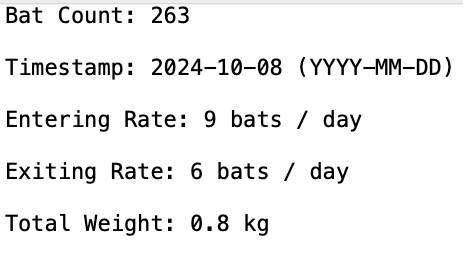
**Figure 1.0**

*Diagram of the placement of the PIR sensors*



*Note.* Created by J’afar Assaf on October 26th, 2024

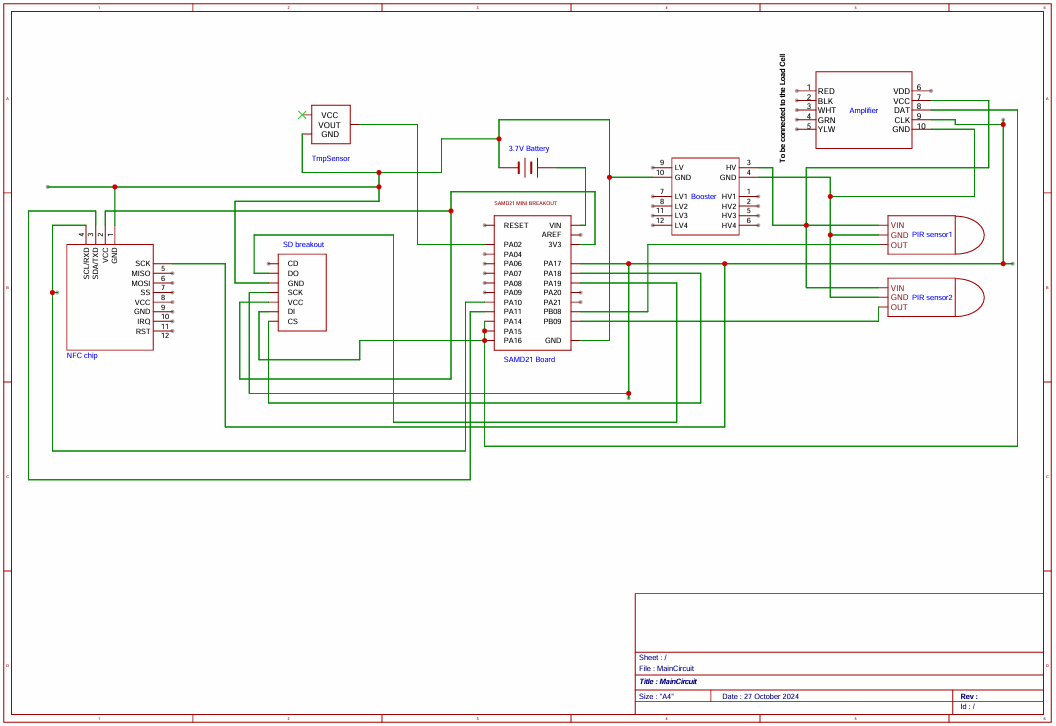
**Figure 2.0**

*Format of processed information*

*Note.* Created by Hossam on October 8th, 2024

**Figure 3.0**

*Schematic showing the circuit of the device*

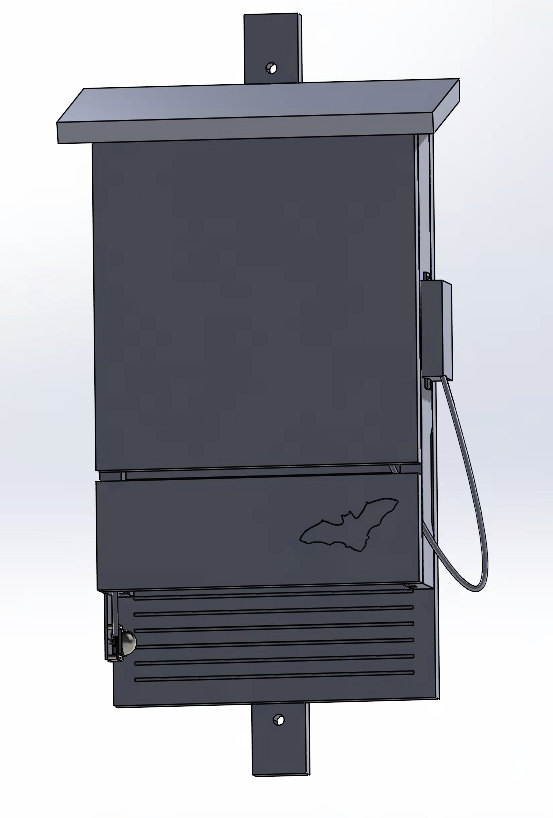
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*Note:* There are uncertainties, more to find during testing/building. Some assumptions were made, such as that since both NFC and temperature sensors can both operate on a voltage between 3.3 and 5V, then we may connect them directly to the SAMD21 board without using a logic shifter (i.e. booster). Created by Amin on October 27th, 2024.

***Enclosure and Mounting***

All critical components (SAMD21, battery, NFC chip, etc.) are housed in a 3D printed container, made out of ABS, that will be securely screwed to the side of the bat box. For ease of access, the enclosure features a buckle mechanism, similar to ones used on mason jars. The buckle mechanism will be made with the same material as the container, and it should reduce the likelihood for water to enter the container. All cables running out of the enclosure will be run down the side of the bat box in a “V” shape, allowing for any moisture or condensation to drip directly off of the cables and onto the ground instead of into any sensitive electronics. From there the wires will be routed into small holes through the side of the bat box and soldered directly onto the pins of each sensor, leaving enough slack for strain relief during maintenance.

**Figure 4.0**

*Images of the container with its dimensions and a representation of how the wires will be organised on the bat box*

*Note.* We will be designing a custom container for the device, so the provided image of the container is only a representation of what the container would look like. Created by Waleed on October 26th, 2024.

| BOM Level | Parts and Components | Part Number | Unit Cost | Quantity | Total Cost |
| --- | --- | --- | --- | --- | --- |
| 2 | [Passive Infrared Motion Sensor](https://www.pishop.ca/product/hc-sr501-pyroelectric-infrared-pir-motion-sensor-detector-module/) | HC-SR501 | $ 3.95 | 2 | $ 7.90 |
| 2 | [Load Cell](https://www.amazon.ca/Bridge-Digital-Amplifier-Arduino-DIYmalls/dp/B086ZHXNJH/ref=pd_sbs_d_sccl_2_2/138-3904992-8608018?pd_rd_w=hPXKX&content-id=amzn1.sym.6ad16f3c-18e0-4f22-ab86-1fc3330d8164&pf_rd_p=6ad16f3c-18e0-4f22-ab86-1fc3330d8164&pf_rd_r=63A5P5HXPR0KJP7T57CN&pd_rd_wg=nVFN2&pd_rd_r=661fe043-3687-4b71-8af3-f57dc95169b9&pd_rd_i=B086ZHXNJH&psc=1) | SEN-10245 | $ 12.98 | 4 | $ 12.98 |
| 2 | [Amplifier](https://www.amazon.ca/Bridge-Digital-Amplifier-Arduino-DIYmalls/dp/B086ZHXNJH/ref=pd_sbs_d_sccl_2_2/138-3904992-8608018?pd_rd_w=hPXKX&content-id=amzn1.sym.6ad16f3c-18e0-4f22-ab86-1fc3330d8164&pf_rd_p=6ad16f3c-18e0-4f22-ab86-1fc3330d8164&pf_rd_r=63A5P5HXPR0KJP7T57CN&pd_rd_wg=nVFN2&pd_rd_r=661fe043-3687-4b71-8af3-f57dc95169b9&pd_rd_i=B086ZHXNJH&psc=1) | HX711 | 1 |
| 1 | [SAMD21 Microcontroller](https://www.amazon.ca/gp/product/B0CBSYZKRF/ref=ewc_pr_img_1?smid=A33HV3N1GS7LPU&psc=1) | DEV13664 | $ 39.06 | 1 | $ 39.06 |
| 2 | [MicroSD Card Breakout Board](https://www.pishop.ca/product/microsd-card-breakout-board/) | ADF-101 | $ 11.95 | 1 | $ 11.95 |
| 2 | [Bi-Directional Voltage Booster](https://www.pishop.ca/product/4-channel-i2c-safe-bi-directional-logic-level-converter-bss138/) | ADF-100 | $ 5.45 | 1 | $ 5.45 |
| 1 | [3.7V 9000mAh Lithium Ion Battery Pack](https://www.aliexpress.com/item/1005007348720830.html?spm=a2g0o.productlist.main.45.1f904NSB4NSBBz&algo_pvid=7e193194-c09a-4757-b303-b0c1624b3504&algo_exp_id=7e193194-c09a-4757-b303-b0c1624b3504-22&pdp_npi=4%40dis%21CAD%2110.24%218.19%21%21%2151.53%2141.22%21%4021030ea417298962135003816e1950%2112000040366349780%21sea%21CA%210%21ABX&curPageLogUid=xK1vLOKedbai&utparam-url=scene%3Asearch%7Cquery_from%3A) | GL-18650 | $ 10.28 | 1 | $ 10.28 |
| 2 | [TMP36 Temperature Sensor](https://www.pishop.ca/product/temperature-sensor-tmp36/) | SEN-10988 | $ 2.95 | 1 | $ 2.95 |
| 3 | [ABS Filament (Container, Buckle)](https://www.pishop.ca/product/abs-1-75mm-filament-silver-1kg/) | ABS-2069 | $ 0.02 | 100 | $ 2.50 |
| 1 | [Wire Spool](https://www.pishop.ca/product/solid-core-wire-spool-25ft-22awg-yellow/) | ADF-1658 | $ 3.95 | 1 | $ 3.95 |
| 1 | [Battery Connector](https://www.pishop.ca/product/jst-to-breadboard-jumper-3-pin/) | SF1552 | $ 2.77 | 1 | $ 2.77 |

**3. Bill of Materials***Note.* For the ABS filament, the quantity is in grams. The table excludes any taxes. Created by Mohammed on October 26th, 2024

**4. Prototype Plan (Types: Structural: Integrity/Cable Management & EOA, Core function: Sensors/Microcontroller/System )**

| **Prototypes** | | | | **Tests** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Type** | **Objective** | **Priority (1-3, Higher is more important)** | **Method** | **Expected Results** | **Duration** | **Team member(s)** |
| 1 | Core Function: Microcontroller | Does the microcontroller program run as intended | 3 | Run the program on the microcontroller | Program runs without producing errors | ~30-50 min | Amin  Mohammed  Waleed |
|
|
| 2 | Core Function: Sensors | Do the individual sensors function as expected | 3 | Set up the system as intended. Model a bat to mimic movements in and out of the box | Observe if sensors detect movement accurately | ~30-50 min |
|
|
| **Prototypes** | | | | **Tests** | | | |
| **ID** | **Type** | **Objective** | **Priority** | **Method** | **Expected Results** | **Duration** | **Team member(s)** |
| 3 | Core Function: Sensors | Do the sensors work as expected, in tandem. | 3 | Set up the series of sensors as intended. Use the same bat model from Prototype 2 | Observe if all sensors detect movement in the expected order, under varying conditions | ~1-2 hrs | Amin  Mohammed  Waleed |
| 4 | Core Function: Data Processing | Does the system log data in the correct format on the micro SD card and NFC module | 3 | Use sensors from Prototype 3 to log data to SD card | Check file structure and formatting to work as listed in Fig. 2 | ~1-2 hrs | Amin  Mohammed  Waleed |
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| 5 | Core Function: System | Verify Accuracy, Precision, and error bounds | 2 | Test system's output against known standards or simulated bat data | Data output matches expected precision and accuracy | ~1 hr | Hossam  J’afar |
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|
| 6 | Structural:  Enclosure Integrity | Inspect for weaknesses, potential points of failure, and waterproofing | 3 | Evaluate enclosure in various simulated environmental conditions | Enclosure maintains integrity without leaks or damage | ~24-48 hrs | Hossam  J’afar |
|
|
| 7 | Structural:  Cable Management and Ease of Access | Verify speed of replacement and check cable channel options | 2 | Test cable arrangement options and inspect ease of access during battery replacement | Cables are secure, the battery is easily replaceable, and safely routed within the time frame | ~30 min | Hossam  J’afar |

*Table outlining the necessary equipment for each prototype stage*

| **Prototype ID** | **Equipment Needed** | |
| --- | --- | --- |
| **1** | * SAMD21 microcontroller * Breadboard * Jumper wires * Power supply (5V) * Arduino IDE |  |
| **2** | * SAMD21 microcontroller * 2 PIR sensors * Model of a bat (for movement simulation) * Breadboard * Jumper wires | * Load cell with HX711 amplifier * Boost Converter * Arduino IDE * Power supply (3.7V) |
| **3** | * SAMD21 microcontroller * 2 PIR sensors * Model of a bat (for movement simulation) * Breadboard * Jumper wires | * Load cell with HX711 amplifier * Boost converter * Arduino IDE * Power supply (3.7V) |
| **4** | * SAMD21 microcontroller * Micro SD card and breakout board * NFC PN532 chip * Breadboard * Jumper wires | * Arduino IDE * Boost Converter * Power supply (3.7V) |
| **5** | * SAMD21 microcontroller * 2 PIR sensors * Model of a bat (for movement simulation) * Breadboard * Jumper wires | * Load cell with HX711 amplifier * Boost converter * Arduino IDE * Power supply (3.7V) |
| **6** | * Enclosure (made of ABS material) * Sprinkler * Paper towel * Fridge | * Heater |
| **7** | * Battery * Enclosure (made of ABS material) * Cables * Bat box model | |

**5. Project Risk Assessment and Contingency Plans**

| **Risks** | **Likelihood** | **Impact** | **Contingency** |
| --- | --- | --- | --- |
| Team member unable to complete task | Low | Moderate | Divide the task amongst other group members |
| Unable to complete feature in time | Moderate | High | Schedule more time if permitted or simplify/omit parts or all of the feature |
| A project feature is not feasible | Low | High | Arrange group meeting to reevaluate design to be more functional |
| Team conflict arises | Low | High | Arrange a group meeting to discuss conflict and reach a compromise. Otherwise, choose resolution through majority vote. |
| Sensor malfunction or inaccuracy | Moderate | High | Keep backup sensors on hand for replacement, and run |
| Power system failure | Low | High | Ensure easy access for battery replacements or repairs during maintenance checks |
| Documentation is incomplete or unclear | Moderate | Low | Assign a team member to review and finalise documentation regularly |

**Work Cited:**

Cook, J. S. (2022, October 13). *Understanding Active & Passive Infrared Sensors (PIR) and their uses*. Arrow.com. <https://www.arrow.com/en/research-and-events/articles/understanding-active-and-passive-infrared-sensors>

Omega Engineering. (2023, May 27). *Strain gauges*. Omega.ca <https://www.omega.ca/en/resources/strain-gages>

**Appendix**

| **Component** | **Rough Current Draw at 5V** |
| --- | --- |
| Raspberry Pi | ~75 mA |
| SAMD21 | ~5 mA |
| NFC PN532 | ~0.045mA |
| TMP36 | ~0.5 μA |
| PIR | ~0.050 mA |
| Load Cell and Amplifier | ~1.6 mA |

Raspberry Pi: <https://www.cnx-software.com/2021/12/09/raspberry-pi-zero-2-w-power-consumption/>

SAMD21: [SparkFun SAMD21 Mini Breakout - DEV-13664 - SparkFun Electronics](https://www.sparkfun.com/products/13664)

PIR: <https://www.mpja.com/download/31227sc.pdf>

Amplifier: [Load Cell Amplifier- HX711 - HX711MOD (tinytronics.nl)](https://www.tinytronics.nl/en/sensors/weight-pressure-force/load-cells/load-cell-amplifier-hx711#:~:text=Nominal%20power%20consumption%3A%201.6mA)

NFC chip (PN532): <https://www.elechouse.com/elechouse/images/product/PN532_module_V3/PN532_%20Manual_V3.pdf>

TMP36: <https://cdn.shopify.com/s/files/1/0015/7571/4865/files/datasheet_TMP35_36_37.pdf?298>