ECE 445

SENIOR DESIGN LABORATORY

Garden Guardian Design Document

Team 7

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1 Introduction

1.1 Problem

Gardening has experienced a significant increase in popularity across the United States, with over 55% of US households currently maintaining a garden. In total, this comes out to around 71.5 million households for a total of 185 million people [1]. While this hobby is a great, rewarding way to connect with nature and produce an assortment of vegetables and plants, it also comes with many challenges, specifically the impact of animals on gardens. Animals ranging from sizes as big as deer to as little as rabbits can cause much damage to the plants carefully and diligently planted by homeowners. Gardeners are constantly adapting new and unique methods to protect their produce from animals. Some common strategies implemented include fencing, repellents, and traps, but each with their own limits. Fences, for example, are limited to protection from ground animals, as they cannot keep out birds or climbing animals, and are a high cost to put up. Traps and repellants both typically only work against the exact animal that it is intended for and are costly to keep up with restocking. Additionally, adding traps or fences can cause many gardens to look visually unappealing, which is a main concern for many gardeners.

1.2 Solution

Our solution is to create a device that will identify, locate, and deter all animals that approach a person's garden. This device will be easily mobile and can be placed anywhere in one's garden so that any approaching animal will be spotted. The device uses a PIR sensor to pick up on any infrared motion which will activate a signal if triggered. The device will then turn toward the detected animal and make a loud, alarming noise during the day or a strobe-like light at night to deter the animal. The reason we chose to use noise during the day and a light at night is that we did not see the light as very effective during the day due to the sun being out and we did not want noise going off at night to disrupt any neighbors. Any animal that experiences a loud noise or flashing light will quickly run away from the source, which will be positioned in the garden.

This device is very beneficial towards garden owners because it is very easy to move and set up anywhere in one's garden. The device will be height adjustable and have a bird on the top to be able to 'blend in' with the garden. The height is adjustable by adding poles at the end of the device. The device is also adjustable with the render distance depending on the size of the

garden. Our goal is to create a device that everyone can place in their garden and adjust to their own preference to match their needs and keep out all animals.

1.3 Visual Aid

Figure 1: An average garden surrounded by a fence [3].

Figure 1 is an example of what a common garden might look like in someone's backyard. Some key things to point out are the visually unappealing green fence around the garden. The fence creates several issues. One issue is the accessibility of the garden. A gardener will have to jump over the fence to work on his garden. This action causes potential danger to the gardener and to their plants. Another issue is that birds can easily fly over, and some animals can climb over the fence making the fence pointless. Without the fence, the garden would visually look better as well as preventing any jumping injury to the owner.
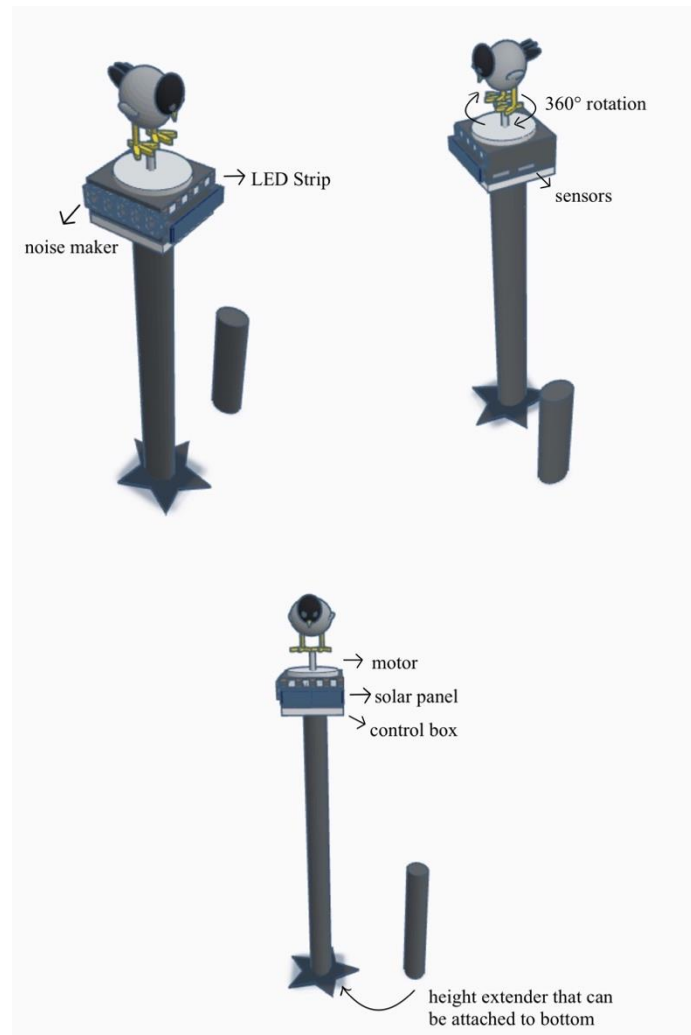
Figure 2: Garden Guardian Model

Working from bottom to top, the Garden Guardian can add extra height to the device by adding an additional part of the pole to the bottom as seen in Figure 2. The next component would be the control box. All the major components would be placed within this box, with the PIR sensors attached to the outsides of the control box. Above this will be the solar panel. The solar panel will power all the components of the device. The next level will have a strobe light and noise maker. Above this will be the motor, which will be able to fully rotate the bird placed on it in a 360-degree rotation.

1.4 High Level Requirements

Our project will be considered successful if these requirements are met:

1. Garden Guardian can detect motion up to a seven-meter radius and then sends a signal to turn on the noise/light deterrent.
2. Garden Guardian determines where the motion is coming from, rotates the bird on top of the Garden Guardian the correct number of degrees (this will change due to moving animals) so that it faces the animal directly, and is able to rotate the full 360 degrees while rotating at 10 RPM.
3. Solar panel can power the device and all its needs at 8.2 volts and 1 Watt, without an external power source.
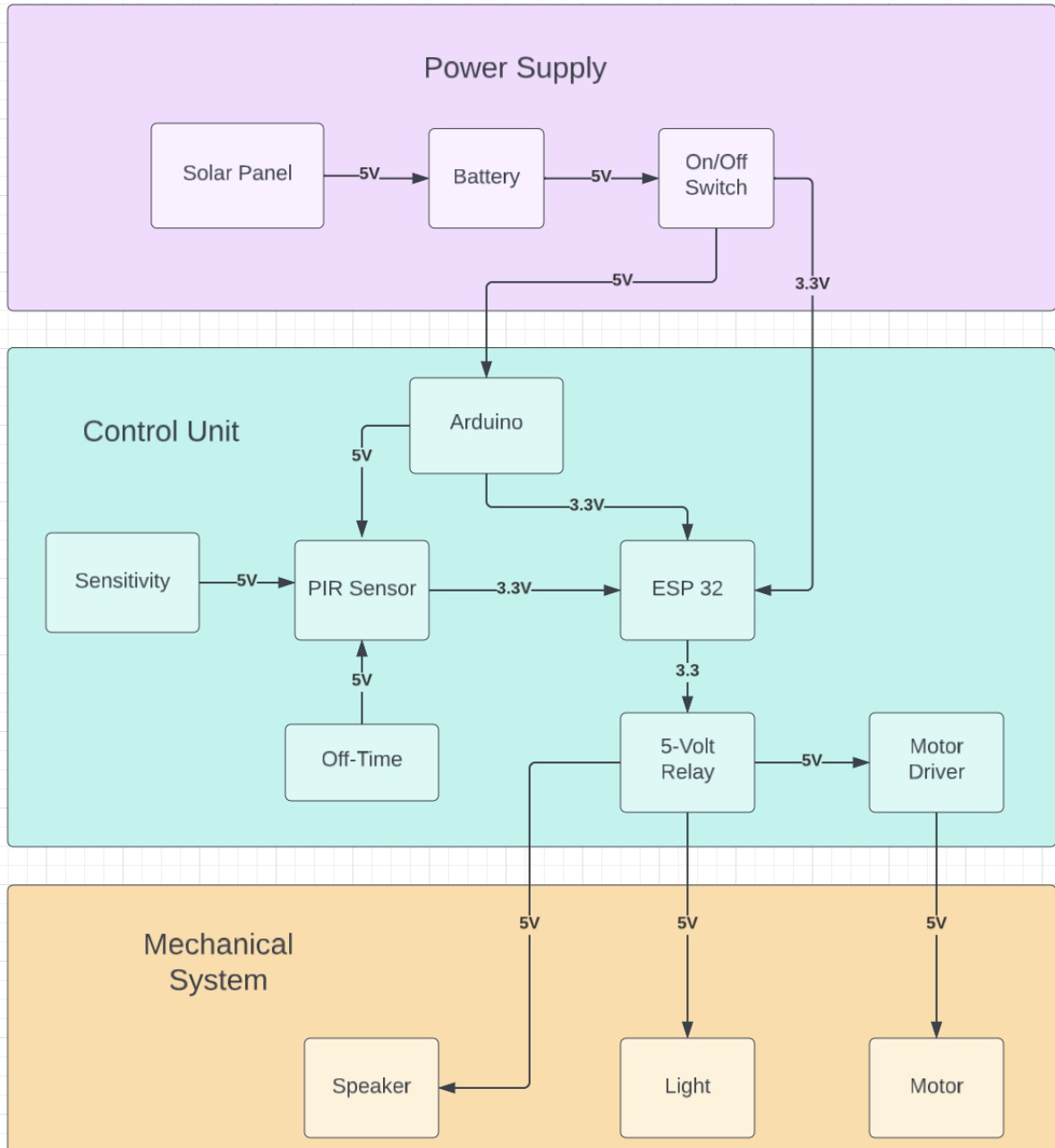
2 Design

2.1 Block Diagram

Figure 3: Block Diagram

2.2 Physical Design

To sense if there is movement, we will strategically place 3 different PIR sensors around the control box as shown in Figure 2. In Figure 2, only the front sensor can be seen. This sensor is to be aligned with where the bird is looking forward at. The LED strips will be wrapped around the pole right below the base of the motor. The noise producer will be placed underneath the LED strips. The on/off switch will be underneath the control box. Any additional height can be added and subtracted to the bottom part of the pole by adding on to the base.

2.3 Functional Overview

2.3.1 Power Supply

The power supply is responsible for supplying all the power that is needed for the entire device. The first step begins with a solar panel generating the power needed for the entire system. We are using the monocrystalline solar cell which has a max amperage of 1 W and 8.2 V. When the solar cell is at its peak power, it produces 5.5 volts, which is more than sufficient for our device. This is sent to the battery which holds the voltage until it is needed to use. Two rechargeable 3.7 volts lithium batteries will be placed into the 2-cell battery holder. This battery holder has an off/on switch so that the device owner can turn on and off the device when they please. The battery holder has multiple different outputs that will be used. The outputs include 3.3V and 5V port outputs. Because of this, no voltage divider from the battery will be necessary. This will also regulate the amount of voltage that will be delivered to the rest of the device.
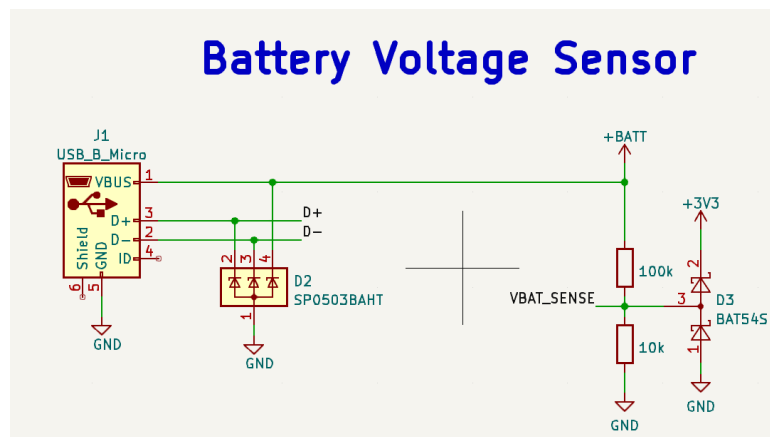

Figure 4: Battery Voltage Sensor Schematic

The schematic for the battery voltage sensor was sourced from the ECE 445 WIKI [4]. We subsequently incorporated a micro-USB port as the input to gauge the voltage from the battery cell holder, equipped with a USB output port. In this design, a circuit is integrated to measure the input voltage, utilizing two Schottky diodes to limit the voltage at the divider output. This configuration serves to safeguard the Analog-to-Digital Converter (ADC) from voltages exceeding 3.3 V or falling below ground level.

Requirements	Verifications
• The solar panel must be able to supply all power needed for the device	• Ensure that all components of the device are fully working • Isolate each individual component and use voltmeter to see if its getting power from battery
• The battery receives and stores power from solar panel and has voltage of 3.7V +/- 5%	• Discharge battery at 50mA • Use voltmeter to ensure voltage is 3.7V
• 3.7V source with currents at 0-170 mA can provide 3.3V +/-5% and 5V +/-5%	• Input is connected to a 3.7V source and drawing that maximum of 170mA • Use multimeter to check for 3.3V +/- 5% and 5V +/-5%

2.3.2 Control Unit

Two components of the control unit are connected to the power supply: the Arduino board and the ESP32. The Arduino board draws 5 volts from the power supply to then power the PIR sensor. The PIR sensor we are using is the HC-SR501 PIR. PIR sensors detect motion by measuring the infrared radiation that is emitted from objects. PIR sensors have strips of pyroelectric material that have an electric current running through them when exposed to infrared light. The sensor compares the strips that are next to each other. If there is a positive differential change between two of the strips, there is motion detected and a high signal is sent to the microcontroller. This specific sensor is adjustable in two different ways. The sensitivity is adjustable on the underside of the PIR sensor with a potentiometer. The distance can change from two to up to seven meters. The off-time is also adjustable for 0.3 seconds and up to 5 minutes. The off-time means that once the high signal from the PIR sensor turns low, the signal

to the proceeding components will still be high until the off-time has passed [8]. For our project, we will want the off-time to be around 3 seconds. This means that once the animal has left the vicinity of the garden, the device will still be making the noise/light for an additional 3 seconds.

To program the PIR sensor, we will need to use an Arduino board. The Arduino board will power and control what the PIR sensor does. The output of the PIR sensor will then go to the ESP32. The ESP32 will be controlled to know what to do with receiving high signals from the PIR sensor. All the output signals needing to go to the next system will run through the 5-volt relay. One signal from the 5-volt relay will go to the motor driver. The motor driver controls the movement and direction of the motor.
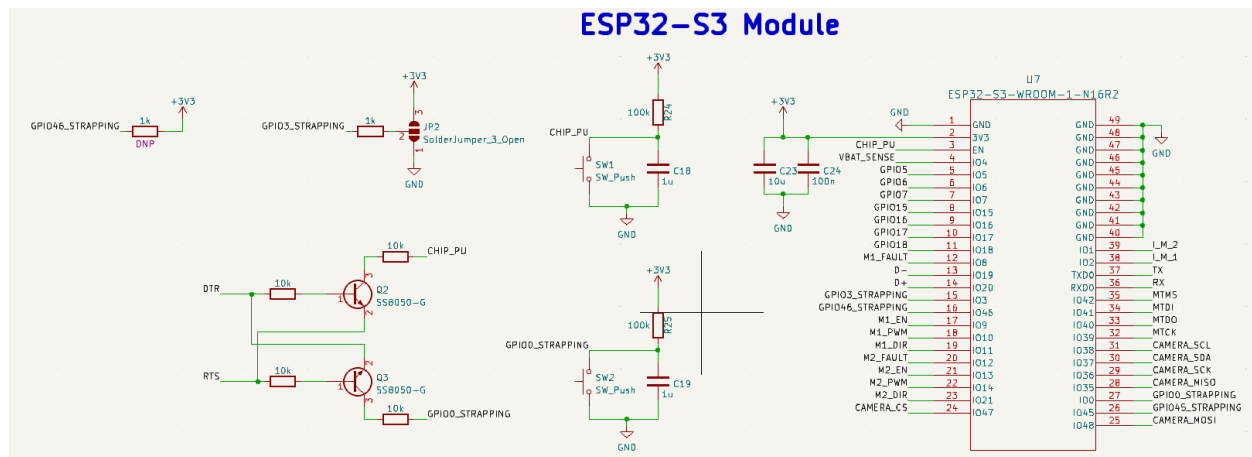

Figure 5: ESP32-S3 Module Schematic

We obtained the schematic for the ESP32-S3 Module from the ECE 445 Wiki [4]. Essential features for the ESP32 include a reset button, exposed strapping pins, and a programming circuit. Strapping pins play a crucial role in determining the IC behavior during startup, with the exception of GPIO45. Connecting all strapping pins is advised, as they govern essential module functions. Notably, Pin #0 activates "Download Mode" for flashing program memory, and it's crucial to leave Pin #45 unconnected to prevent voltage fluctuations in the internal SPI memory IC. Moreover, the ESP32 is Arduino-compatible and will serve as the controller for our motor driver and sensors.
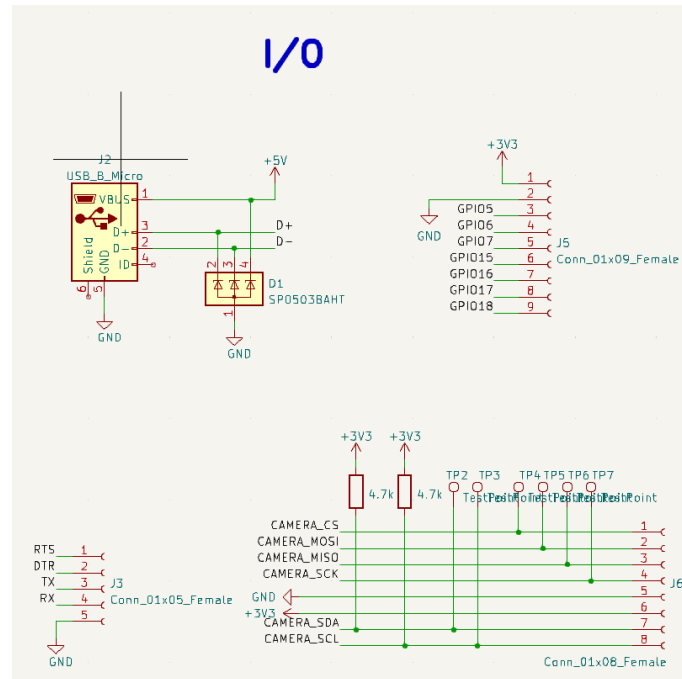
Figure 6: ESP32 I/O Schematic

The I/O schematic portion of the ESP controller, sourced from the ECE 445 WIKI [4], outlines crucial connections and functionalities for interfacing with external components. It includes GPIO pins for versatile input and output, communication interfaces for connecting with other devices, analog input pins for reading variable signals from sensors, and power supply connections. Additionally, special function pins, pull-up/pull-down resistors, and protection components contribute to stable and secure interactions. This schematic is essential for configuring the ESP controller's behavior during startup and ensuring reliable communication and control with peripherals in embedded systems or IoT applications.

Requirements	Verifications
• PIR sensor is able to detect motion up to a 7-meter radius away	• Ensure nothing is in front of the PIR sensors • Walk in front of the PIR sensors • Connect ammeter to output of the PIR senser to see if there is an output signal
• The microcontroller is able to tell whether it is day or night	• Use ammeter to check amperage coming out of solar panel • If amperage below 25mA then signal should be sent to light • If amperage above 25mA then signal should be sent to noise buzzer
• PIR sensor output signal remains high for 3 seconds +/- 5% after there is no more motion detected	• Walk in front of the PIR sensors • Clear all obstructions in front of PIR sensors and start timer • Connect ammeter to output of the PIR senser to see if there is an output signal and time for how long it remains on after no more obstruction

2.3.3 Mechanical System

There are three components of the mechanical system. The first component is the noise producing buzzer. When the buzzer receives an input signal, the buzzer produces a sound up to 90dB. The next component is the strobe-light. We chose to use two different colored LED strips that will rapidly receive reversed input signals. This opposite input signal will cause the appearance of strobe-like lights. The signals coming from the Control Unit to the light and noise buzzer will be at a 50% duty cycle to create the noise and light needed to deter animals. The noise buzzer will be used during the day and the light will be used the night.

The last component is the motor. The motor will receive inputs on which way to rotate and how far to rotate. The speed of the motor is constant. The way that the motor will be able to know

how far to turn is to program the PIR sensor. The PIR sensor will be programmed to have it center any type of motion it picks up within the strips of pyroelectric material on the sensor. There will be three sensors around the control box that each can scan an angle of 120 degrees for a total of 360 degrees. One PIR sensor will be positioned on the front facing part of the control box to be parallel with the bird. The other two sensors will be positioned on the back left and back right part of the control box. If there is motion detected in sensor #1, the motor will turn toward that motion. If motion is detected in sensor #2 or sensor #3, the motor will turn toward the motion plus +/- 120 degrees, depending on which sensor is picking up motion. This way, we can program the motor to always center to the bird.

Requirements	Verifications
• The device will produce a strobe-noise when motion is detected during the day	• Use a 50% duty cycle input for the noise buzzer • Listen if noise buzzer is going on/off quickly • Use ammeter to check if amperage is above 25mA in solar panel
• The device will produce a strobe-light when motion is detected during the night	• Use a 50% duty cycle input for the noise buzzer • Look to see if light is going on/off quickly • Use ammeter to check if amperage is below 25mA in solar panel
• Front of device rotates to face where the motion is coming from	• Ensure nothing is in front of the PIR sensors • Walk in front of the PIR sensors • Motor is able to turn toward the motion to have the bird facing it • PIR sensor senses motion and

2.4 Tolerance Analysis

The power supply system for our project needs to be carefully designed to ensure stable voltage regulation for all its subsystems. There are a couple considerations when using a linear voltage regulator: the dropout voltage and thermal performance. The dropout voltage ($V_{dropout}$) is the minimum voltage between the input and output required for the regulator to operate. One example from our design is that we are inputting 5 V to the voltage regulator and want to output 3.3 V to the microcontroller. We should take our maximum input to be 4.8 V to account for the maximum amount of ripple. In this case, $V_{dropout}$ must be greater than or equal to 1.5 V. The thermal concerns can be addressed by determining the power dissipation (P_D). If too much power is dissipated, then the regulator will overheat. We can calculate the power dissipated using the expression $P_D = i_{out} * (v_{in} - v_{out})$. To find i_{out}, we must perform ohms law on the thermal circuit [6]. Using the simple thermal circuit from the wiki page, we can solve ohms law and find that the junction temperature, $T_j = i_{out} * (v_{in} - v_{out})(\theta_{jc} + \theta_{ca}) + T_a$.

Variable	Value	Comment
Maximum Operating Temperature (T_j)	125 ℃	From LM317 datasheet
Ambient Temperature (T_a)	38 ℃	Assuming warm board as they did in the example on the wiki
i_{out}	171 mA	Maximum current drawn from 3.3 V components
v_{in}	4.8 V	Assuming input voltage to be 5 V, choose 4.8 V to account for ripple
v_{out}	3.3 V	Desired output
Junction-to-Case Thermal Resistance (θ_{jc})	4.2 ℃/W	From LM317 datasheet

Case-to-Ambient Thermal Resistance (θ_{ca})	50 ºC/W	From LM317 datasheet

With these selected values, we can solve for the junction temperature, T_j = 51.9 ºC which is less than the maximum operating temperature of 125 ºC, so our linear voltage regulator should operate correctly for our design [7].

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor Costs

We calculated our total project's labor cost to be $32, 910. All members of our group are Electrical Engineering students. Referencing the Grainger College of Engineering Electrical & Computer Engineering admissions page on salary averages, the average starting salary for an entry level Electrical Engineer is $87,769 as of the Academic Year 2021-2022 [9]. With this number, we then divided it by 40 hours per week and by 50 weeks per year, leaving out 2 weeks for vacations, to get an average hourly rate of $43.88.

$$(3 \, EE's) \cdot \left(\frac{43.88}{hour}\right) \cdot \left(10 \, \frac{hours}{week}\right) \cdot (10 \, weeks) \cdot (2.5 \, multipier) = \ 32,910$$

Team Member	Hourly Rate	Hours per Week	Number of Weeks	Multiplier	Total
Aleah Gacek	$43.88	10	10	2.5	$10, 970
Nick Hartmann	$43.88	10	10	2.5	$10, 970

Claire McGrath	$43.88	10	10	2.5	$10, 970
Total					**$32, 910**

3.1.2 Parts Costs

Part Name	Part Number	Manufacturer	Quantity	Part Cost
Monocrystalline Solar Cell 1W 8.2V	1597-1418-ND (DigiKey)	Seeed Technology Co., LTD	1	$12.30
Buzzer Piezo 5V 24MM Flange	458-1252-ND (DigiKey)	Mallory Sonalert Products Inc.	3	$1.29
Battery Holder 18650 2 Cell	1738-DFR0969-ND (DigiKey)	DFRobot	1	$10.62
LED Strip Red 19.69 INCH	2368-69-36R-02-ND (DigiKey)	NTE Electronics, Inc	1	$5.30
LED Strip Green 19.69 INCH	2368-69-36G-02-ND (DigiKey)	NTE Electronics, Inc	1	$5.30
BATT LITH-ION 3.7V 2.6AH 18650	1568-1488-ND (DigiKey)	SparkFun Electronics	4	$6.62
3PCS PIR Motion Sensors	HC-SR501 (Amazon)	Stemedu	1	$7.99
Decoy Bird	Bird-B-Gone Bird Deterrent Decoy	Bird-B-Gone Bird Deterrent Decoy For Red Tailed Hawks Ace Hardware	1	$19.99
TOTAL				**$69.41**

In total, summing up labor and parts costs, we reached a grand total of $32,979.41.

3.2 Schedule

Week	Nick	Claire	Aleah
2/19/24	Order parts, collect and review	Schematic design and visual aids	Proposal corrections.
2/26/24	Work on PCB design & schematics	Finalize PCB schematic	Last check-in with machine shop.
3/4/24	Finalize PCB design and order it.		Work on Arduino coding.
3/11/24	Spring Break		
3/18/24	Assemble PCB and verify functionality, debug and review and order 2nd PCB if necessary		
3/25/24	Continue PCB assembly & finalize design		Day/night differentiation with solar panel and mechanical systems.
4/1/24	Check with machine shop and test device for functionality and accuracy	Double check soldering of components.	PIR sensor tracking movement code.
4/8/24	Last finalization on device, debug any necessary issues		
4/15/24	Prepare for Final Demo	Prepare for Final Demo	Prepare for Final Demo
4/22/24	Write Final Report	Write Final Report	Write Final Report
4/29/24	Presentation preparation and rehearsal	Presentation preparation and rehearsal	Presentation preparation and rehearsal

4 Ethics and Safety

4.1 Ethics

Through this project development, our highest priority is considering and addressing all ethical and safety concerns. Our project is one that approaches the intersection of humans and nature, and we recognize that we are at risk of causing potential damage.

1. To disclose promptly factors that might endanger the public or the environment. [5]
2. To seek and offer honest criticism of technical work. [5]
3. To improve our technical competence. [5]

While completing this project, we will strive to uphold the IEEE Code of Ethics and use it as our framework in maintaining ethical standards. Since our project aims to assist the public with a task, we will be mainly upholding the IEEE Code of Ethics [4] to ensure the safety of those using our product as well as the surrounding environment.

4.2 Safety

Our project poses minimal safety concerns since it operates as a standalone device moving only rotationally and alternating between noise or light repellent. However, we have identified potential safety hazards and listed them below. By remaining attentive about these concerns and strictly following all lab and general safety protocols, we will ensure the overall safety of our project.

4.2.1 Solar Panel

The primary safety consideration revolves around the solar panel. Given its continuous activity, there is a potential risk of electrical shock that demands careful handling and adherence to safety protocols.

4.2.2 Motor

Our use of a motor introduces another safety consideration, as there is a potential risk of being pinched during its operation. By following all proper lab safety and PPE regulations, we will ensure that we will not be injured throughout the process of our project assembly.

4.2.3 Battery Safety

An issue that can present itself is working with rechargeable lithium-ion batteries. If not maintained properly, lithium-ion batteries present themselves as a potential fire hazard. Ways to prevent exposure to any type of hazard include frequently checking the batteries to see if there is any type of change in odor, color, or temperature. This will be achievable in our project by keeping the battery holder accessible in the control box [2].

4.2.4 Seizure Warning

Any individual with epilepsy may experience seizures caused by the flashing red and green light produced by the LED strips attached to our device for overnight protection. We plan to have the light emitting frequency at 50 percent duty ratio, with half being red and the other half being green. To prevent any issues of this concern, we plan to include attaching a hazard sticker on the main box of our device.

5 References

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[6] *LM317 3-Terminal Adjustable Regulator Datasheet (Rev. Y)*, Texas Instruments Incorporated, 18 Oct. 2023, www.ti.com/lit/ds/symlink/lm317.pdf.

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