ECE 445

SENIOR DESIGN LABORATORY

Garden Guardian Final Report

Team 7

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SPRING 2024

Abstract

Our project aims to protect home gardens from animal intrusions through the creation of Garden Guardian, a portable device designed to provide day and night deterrence against any detected movement. The Garden Guardian is equipped with infrared sensors able to identify incoming motion and trigger light and noise deterrents, effectively frightening potential predators away from the garden.

This report outlines the projects' purpose, objectives, design layout, and subsystems. It summarizes our intended requirements, verifications, and project outcomes. Finally, we reflect on the successes and challenges of the semester and the completion of our project.

Contents

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 readjusting the screws in the pole that holds the control box. 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 High Level Requirements

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 180 degrees toward each sensor while rotating at 70 RPM.
3. Solar panel can power the device and all its needs at 5 Volts and 10 Watts, without an external power source. After performing a power analysis, the maximum wattage needed from the battery is 2.5 W.

2 Design

2.1 Block Diagram

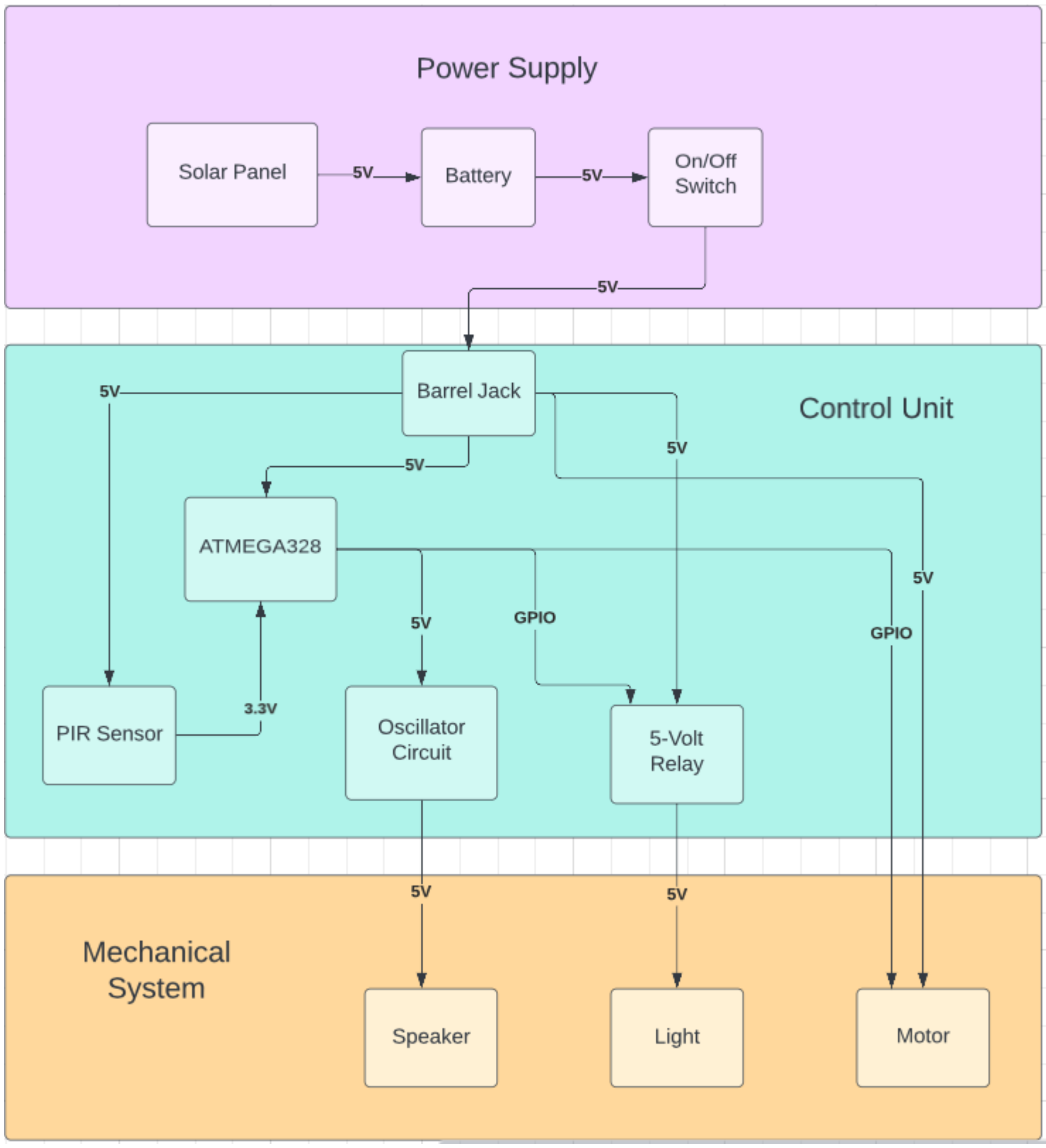

Figure 1: Block Diagram

2.2 Functional Overview

2.2.1 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 10 W and 5 V. When the solar cell is at its peak power, it produces 6.4 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.

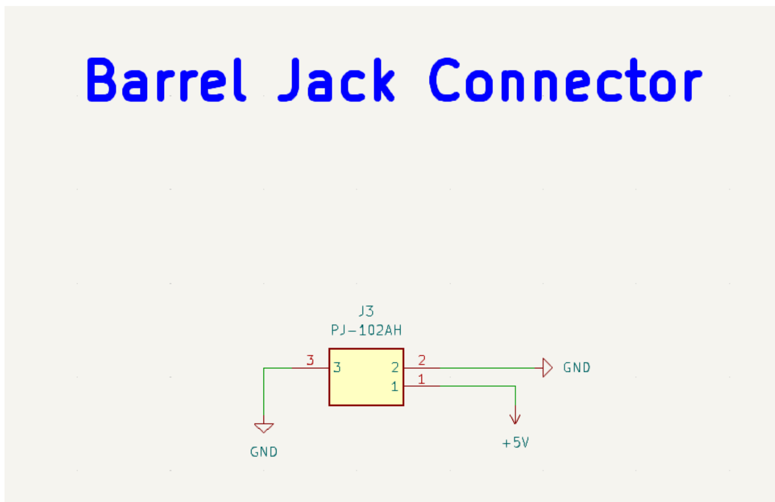

Figure 2: Barrel Jack Connector Schematic

The PCB will be powered through a barrel jack connector. This is connected from a 5-volt USB output to the barrel jack.

2.2.2 Control Unit

The ATmega328P will serve as our control unit and is connected to the power supply. The ATmega328P and PIR sensors both draw 5 volts from the power supply. 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 [2]. For our project, we will want the off-time to be around 1 second. 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 1 second.

To program the PIR sensor, we will need to use the ATmega328P microcontroller chip, which will be programmed by an ISP. The ATmega328P will control what the PIR sensor does. The output of the PIR sensors will feed into a triple OR gate. When any of the PIR sensors send a high signal, the triple OR output will then go back to the ATmega328P. The microcontroller will be controlled to know what to do with receiving high signals from the PIR sensor. The outputs of the ATmega328P chip send three different outputs. The three outputs go to the 5-volt relay, oscillator circuit, and motor.

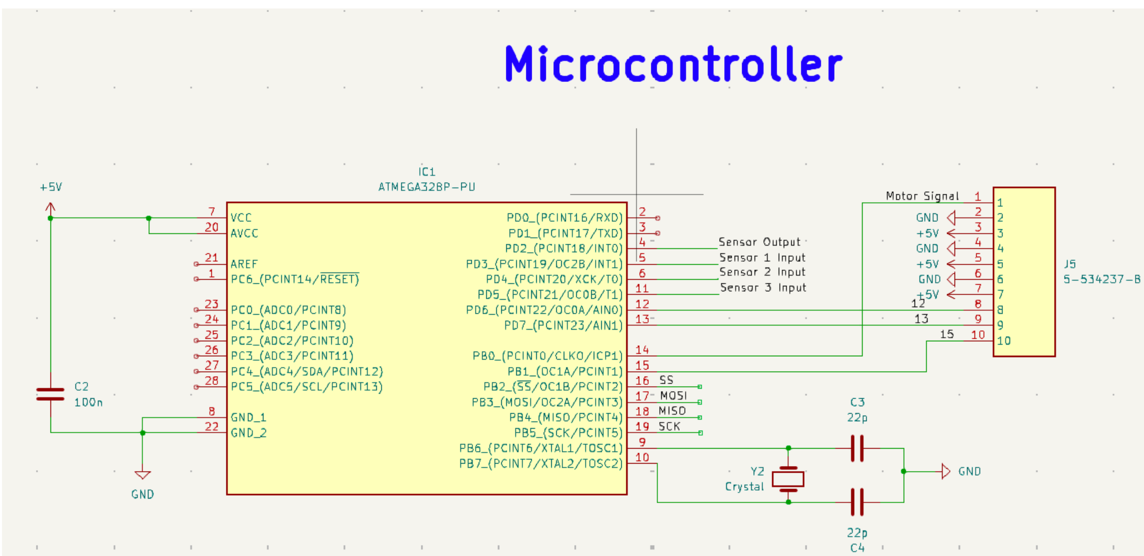

Figure 3: Microcontroller Schematic

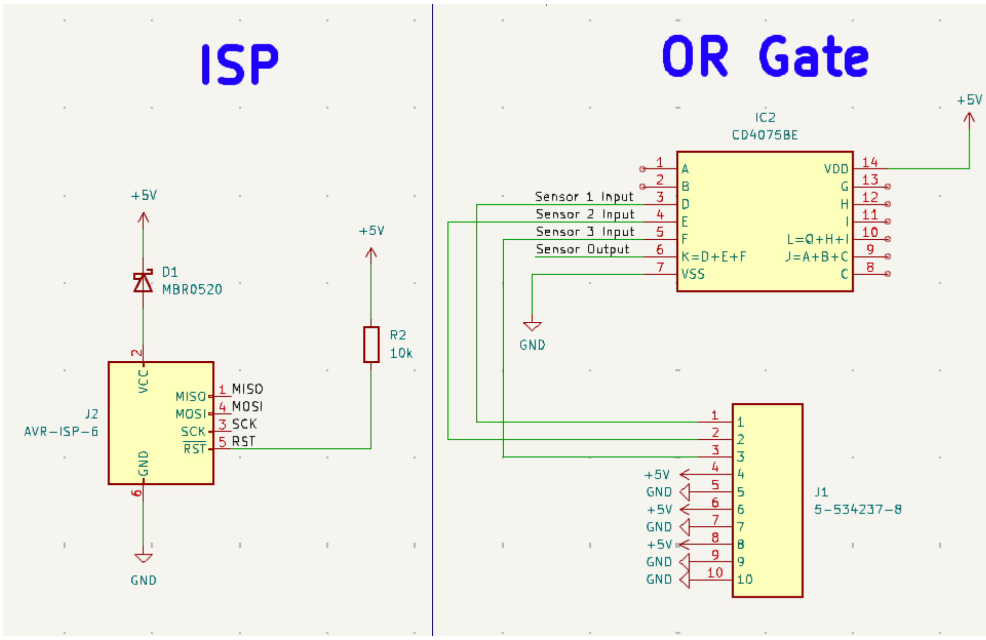

Figure 4: ISP and Triple-Or Gate Schematic

The last part of the control unit is the timer. The use of a timer was our design to successfully switch the type of deterrent triggered based on day or night. To make this work, we relied on the millis() function of Arduino IDE which tracks the current time a program starts in milliseconds. With this tracked time, we applied the modulo operator to keep track of even and odd intervals set based on our needs. For demonstration purposes, we had an interval of 90 seconds but in full application we would increase the interval to 12 hours representing day and 12 for night. With the modulo applied, we could then trigger LEDs for every odd interval and noise buzzers for every even interval. This cycle was nonstop so that the detection and repellent worked throughout the duration of its needs.

2.2.3 Mechanical System

The last main section of our design is the mechanical system. There are three components of the mechanical system. The first component is an oscillator circuit. We opted to use piezoelectric electronic alarms for the noise deterrent, and these alarms necessitate an input of either a sinusoidal or square waveform at a suitable frequency. The transducer will physically deflect in both directions, mirroring the shape of the input waveform, to generate sound [3]. We elected to use a transistor-based square wave oscillator to achieve a proper input to the transducers. This circuit consists of two 2N2222A NPN transistors and opposing RC circuits. When the circuit is powered on, one transistor enters the "cut-off" state, where it doesn't conduct any current. As a result, the collector node charges up to the input voltage. At the same time, the opposing transistor becomes saturated and starts conducting current. Consequently, the capacitor node connected to the base of the first transistor charges up until it enters saturation. Once it reaches saturation, the sudden voltage drop across the capacitor triggers a significant negative response at the base of the opposing transistor, pushing it into cut-off. This alternating push-pull action continues continuously, generating square wave output voltages at the collectors of each transistor. These outputs exhibit square waves with identical frequencies but opposite phases [4]. The next component is the 5-volt relay. When input signal from the ATmega328P is low, the 5-volt relay will remain open and won't power the LED. When the signal is high, the 5-volt relay switches to closed and powers the LED. We chose to use an LED strip that will flash quickly when an input signal is received. 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 by which input of the triple OR gate goes high. The PIR sensor will then know to which PIR sensor to rotate to. There will be three sensors around the control box positioned at degrees 0, 90, and 180. Each sensor is aligned with one of the motor positions. When motion is detected, the motor will rotate the bird to the position of whatever sensor has detected motion.

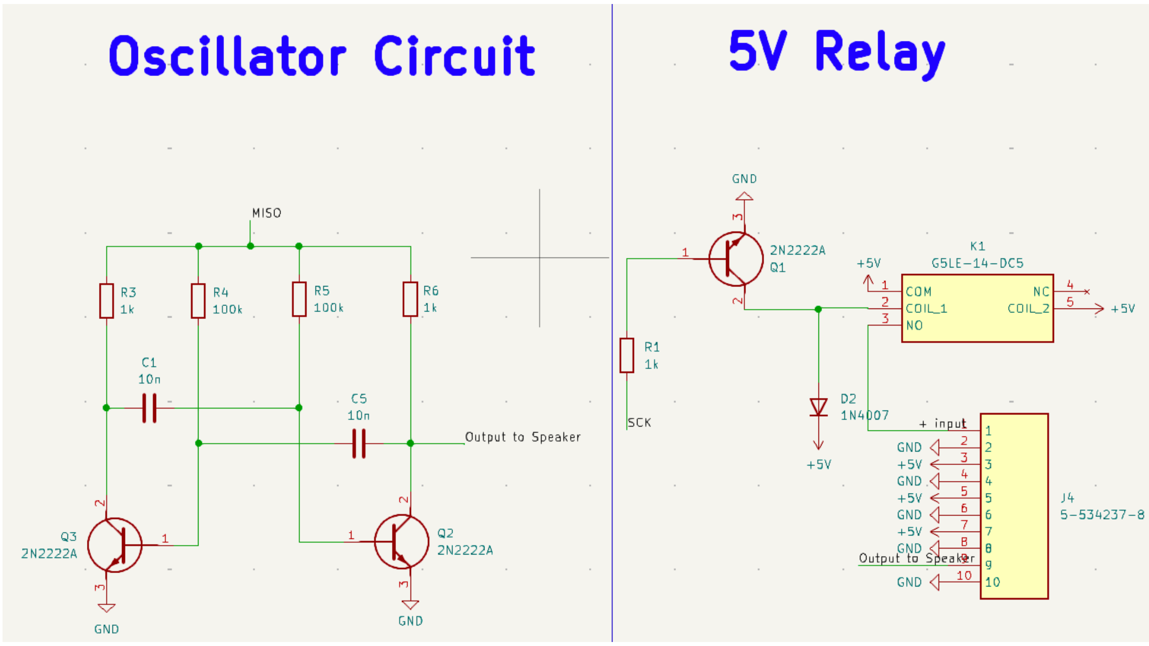

Figure 5: Oscillator Circuit and 5-Volt Relay Schematic

3. Design Verification

All requirements and verifications are shown below and explained in the next sections.

3.1 Power Supply

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 • Use voltmeter to check if solar panel is supplying at least 7 Watts and 3.7 Volts +/- 5% during the prime sunshine hours
• The battery receives and stores power from solar panel and has voltage of at least 3.7V +/- 5%	• Use multimeter to ensure voltage is at least 3.7V +/- 5%
• 3.7V source can provide 5V +/-5%	• Input is connected to a 3.7V source • Use multimeter to check and 5V +/-5%

3.1.1 Solar Panel

The solar panel we used is rated for 10W and 5V. We required the solar panel to be the only outside source for power. It needed to be able to at least generate 7W and be able to deliver it to the battery holder. We were able to do this by using a digital multimeter. When the sun was at its peak, the multimeter read 6.4V at 1.4A. This meant that the solar panel was supplying almost 9W when the Sun was at its peak. This cleared this requirement and was able to power all of the components of the device.

3.1.2 Battery Holder

The battery holder we used held 2 3.7V lithium rechargeable batteries. On the battery holder, there were 2 inputs to charge it. The inputs were micro-USB and USB-C. The solar panel was able to charge this using a USB-C output coming from the solar panel. There were many different types of outputs from the battery holder. It had a 5V USB, 5V output ports and 3.3V output ports. To test the breadboard circuit, we would use the 5V output ports. Once we created the PCB, we used the 5V USB output to the barrel jack. The requirements that needed to be met for the battery holder were that it received at least 3.7V from the solar panel and that it output 5V. Both requirements were met using the multimeter.

3.2 Control Unit

Requirements	Verifications
• PIR sensor can detect motion up to a 7-meter radius away using an adjustable potentiometer	• Ensure nothing is in front of the PIR sensors • Walk in front of the PIR sensors • If LED or noise buzzer go off (depending on timer), then radius is good
• The microcontroller can tell whether it is day or night	• Using a timer in the code • For full functionality, the timer would be 12 hours and switch from light to noise output • For demo, the timer will be switch from light to noise after 90 seconds • Needs to be in a loop to replicate days
• PIR sensor output signal remains high for 1 seconds +/- 5% after	• Walk in front of the PIR sensors • Clear all obstructions in front of PIR sensors and start timer

there is no more motion detected using an adjustable potentiometer	• If LED or noise buzzer go off (depending on timer), then off-time is good

3.2.1 PIR Sensors

The first thing we did to test the PIR sensors was to only use one and use the dead board. By using just one, we were able to individually meet all the requirements that needed to be met. To test if there was a high signal, we would connect an LED diode to a designated pin on the ATmega328P. This way, anytime that there was motion detected, the LED would light up. The first verification needed is for the PIR sensor to detect motion up to seven meters away. We did this by measuring seven meters on the ground and then isolating the PIR sensor to face in that direction. One of us would walk within the 7-meter range and the LED would light up, which meant that motion was detected. The next step could also be done at the same time of the PIR sensor output signal remaining high for one second after motion was not detected anymore. Once one of us left the 7-meter radius range, we would start a timer until the LED turned off. After adjusting the potentiometer on the PIR sensor many times, we were able to get this to be one second [2].

3.2.2 Microcontroller

We used the ATMega328P chip because it was compatible with the PIR sensors that we bought. To test anything in the requirements table, we would upload a test code for that specific function. After this we would isolate the PIR sensor to run the verification. The last major thing that the microcontroller had to do was be able to switch outputs at the designated time.

To distinguish between day and night to trigger between the LEDs and noise buzzers properly, we were able to set an interval of 12 hours in terms of milliseconds and apply the modulo operator. With this, every odd interval of 12 hours would trigger LEDs and every even interval of 12 hours would trigger noise buzzers. By utilizing the modulo operator, we were able to create a continuous back and forth triggering between the two deterrents so that the machine can operate without stopping.

3.3 Mechanical System

Requirements	Verifications
• The device will produce a strobe-noise when motion is detected during the day	• High pitch noise needs to emit from noise buzzer using an oscillator circuit • (For demo, frequency will be reduced to not harm anyone's ears)
• The device will produce a strobe-light when motion is detected during the night	• Look to see if light is going on/off quickly
• 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 can turn toward the motion to have the front of the bird facing it

3.3.1 Motor

The motor was incorporated to rotate the platform with a bird on it to be front facing the detected motion. Through research of various motor types, we recognized that using a Servo motor would best serve our needs as it can be programmable to certain, direct degrees of rotation. We equipped our project with a Servo with 180-degree capability and positioned our three PIR sensors at the 0-, 90-, and 180-degree positions, respectively. To coordinate with our system, when we received signals of detection, we were then able to program the motor to rotate to the correct sensor position.

When testing in the lab, we were having trouble with maintaining the lifetime of the motor as it would constantly just stop working after a few minutes in use. We attributed this to having too much current going through the motor when it was not in use, causing it to overload and give out. To solve this problem, we were able to adjust the code so that when the motor was not in use by the system it was detached from the pin. This way the motor would either be attached or detached to the pin, but never in standby mode. With this solution, we kept one motor working for the entire project's entire needs without needing to replace it.

3.3.2 Oscillator Circuit

The oscillator circuit was utilized to create a square wave input to the noise buzzers. During the initial testing phase, we created the circuit on LTspice to simulate its operation. In the simulation, we altered resistance values easily to view the range of frequency available. For demonstration purposes, we opted to have a 1 kHz frequency output. When testing in the lab, we found that high frequencies were quite disturbing to other groups working around us, so we wanted to minimize the disruption by lowering the pitch. Once we decided on the correct frequency, we built the oscillator circuit on a breadboard with the correct component values for our desired output. We then used the oscilloscope in the lab to ensure we were getting the correct output. The final step of testing the circuit was connecting the transducer to the output to ensure it was generating sound.

3.3.3 5-Volt Relay

The 5-volt relay serves as the controller for toggling the LED strip on and off. Our initial testing phase involved setting up a basic evaluation circuit with the Arduino. This setup comprised components such as a 2N2222A NPN transistor, a 1N4007 diode, an LED diode, and resistors. We uploaded a straightforward blinking test code to the Arduino IDE to comprehend the functionality of this circuit [5]. Once we confirmed the successful operation of the test code, we proceeded to connect the LED strip to verify compatibility. Subsequently, we moved on to integrating the sensor to establish communication with the Arduino, which would then transmit a high signal to activate the relay. After successfully operating the relay with a single sensor, we expanded our setup to incorporate three sensors using a triple OR gate to ensure that the signal was triggered if each of the three sensors were activated.

4. Costs

4.1 Parts

Below is a summary of all the parts and equipment we ordered for our project's completion. In reflection and relating our total cost to the set team budget of $150, we attribute our total cost to being over budget because of part replacements and reorders. A few of the products, such as our solar panel and LEDs, were ordered twice because we were not happy with their initial integration into our product. Additionally, we incurred a cost by ordering a PCB externally from the school order forms.

Part Name	Part Number	Manufacturer	Quantity	Part Cost	Total Cost
Monocrystalline Solar Cell 1W 8.2V	1597-1418-ND (DigiKey)	Seeed Technology Co., LTD	1	$12.30	$12.30
10W Solar Panel Charger	YY-110-01 (Amazon)	Orayafid	1	$21.99	$21.99
Buzzer Piezo 5V 24MM Flange	458-1252-ND (DigiKey)	Mallory Sonalert Products Inc.	3	$1.29	$3.87
Battery Holder 18650 2 Cell	1738-DFR0969-ND (DigiKey)	DFRobot	1	$10.62	$10.62
LED Strip Red 19.69 INCH	2368-69-36R-02-ND (DigiKey)	NTE Electronics, Inc	1	$5.30	$5.30
LED Strip Green 19.69 INCH	2368-69-36G-02-ND (DigiKey)	NTE Electronics, Inc	1	$5.30	$5.30
BATT LITH-ION 3.7V 2.6AH 18650	1568-1488-ND (DigiKey)	SparkFun Electronics	4	$6.62	$26.48
3PCS PIR Motion Sensors	HC-SR501 (Amazon)	Stemedu	1	$7.99	$7.99
Dalen Great Horned Owl Scarecrow Bird Prevent	Great Horned Owl Scarecrow (Lowes)	Lowes	1	$16.97	$16.97
DC Power Connectors Power Jacks	490-PJ-102AH (Mouser)	Cui Devices	1	$0.70	$0.70
Headers & Wire Housings REC 2X10P VRT T/H	571-6-534998-0 (MOUSER)	TE Connectivity	1	$5.12	$5.12
8-bit Microcontrollers - MCU 32KB In-system Flash 20MHz 1.8V-5.5V	556-ATMEGA328P-PU (Mouser)	8-bit Microcontrollers - MCU	1	$2.89	$2.89

9.8 ft. RGB Color Changing Dimmable USB Powered LED	LR431U-7.2X7IR3 (Home Depot)	EcoSmart	1	$5.98	$5.98
PCB	W795587AS2Y5	PCBWay	1	$26.75	$26.75
USB Multimeter USB Voltmeter Ammeter Load Tester	BD07DCSNHNB	MakerHawk	1	$20.99	$20.99
Patriotic Flying Creatures Garden Stakes	05388-2776797	WindyWings	1	$7.99	$7.99
TOTAL					**$181.25**

4.2 Labor

We calculated our total project's labor cost to be $39,492. 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 [6]. With this number, we then divided it by 40 hours per week and by 50 weeks (about 11 and a half months) per year, leaving out 2 weeks for vacations, to get an average hourly rate of $43.88.

$(3\ EE's)\cdot(43.88\ /\ hour)\cdot(12\ hours/\ week)\cdot(10\ weeks)\cdot(2.5\ multipier) = \$\ 39{,}492$

Team Member	Hourly Rate	Hours per Week	Number of Weeks	Multiplier	Total
Aleah Gacek	$43.88	12	10	2.5	$13, 164
Nick Hartmann	$43.88	12	10	2.5	$13, 164
Claire McGrath	$43.88	12	10	2.5	$13, 164
Total					**$39, 492**

5. Conclusion

5.1 Accomplishments

We believe that our project ended up with a lot of success. We were set our high-level requirements at the beginning of the semester and by the end of the semester, we were able to meet all three requirements. Each subsystem worked as intended and they could work with each other as well. Additionally, we gained tremendous experience with the design and troubleshooting in PCB work. Having the hands-on experience to work to create our own PCB was a unique experience that allowed us for a lot of exploration and exposure in a new area. Finally, we were able to work together and collaborate as a group of three with very different backgrounds and strengths to successfully create a working, complete project and at the same time improve our teamwork and communication skills.

5.2 Uncertainties

Some of the uncertainties we still faced at the end of the project included PCB integration and the battery module. We were never fully able to get the PCB to fully work. In our final PCB order, the logic, sensors and LED all worked without issue. However, the noise buzzer and motor were not working as intended. We attribute this to potentially choosing the wrong band widths for the PCB orders. We believe with shorter order times and more time to debug; we would have been able to get a functional PCB by the end of the semester.

5.3 Ethical considerations

Through this project development, our highest priority was considering and addressing all ethical and safety concerns. Our project and its purpose approach the intersection of humans and nature, and we recognize that we are at risk of causing potential damage to those around it.

1. To disclose promptly factors that might endanger the public or the environment. [7]
2. To seek and offer honest criticism of technical work. [7]
3. To improve our technical competence. [7]

Through our completion of this project, we upheld the IEEE Code of Ethics and used them as our framework in maintaining ethical standards. Since our project aims to assist the public with a task, we mainly leaned into the IEEE Code of Ethics [7] to ensure the safety of those using our product as well as the surrounding environment.

5.4 Future work

We believe there are several different ways that our device could evolve. First, changing the noise buzzers to operate in the ultrasonic region would broaden the protection against various other animals and bugs that are beyond human frequencies. Next, for an actual device, we would not build in a blind spot (due to testing/demo purposes). The coverage would be a full 360 degrees, which also would include using a new motor that can cover this range. The last thing that could be expanded on is replacing the switching timing code with a photosensitive sensor. This sensor would detect when the sun is rising and setting to determine which output to switch to. This would eliminate the need for the switching timing code and give better and more precise results when it comes to when the light or noise deterrent should be used.

References

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