Bird Box

ECE 445 Design Document

Chang-Wei Chang, Weihang Liang, Megan Roller
Team 14
TA: Yangge Li
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1 Introduction

1.1 Objective

Birds communicate with each other with different sounds and frequencies. Sometimes they have similar responses to different sounds. Other times, researchers can only understand what the birds hear by observing the surrounding environment. Researchers need better ways to know what can a bird actually hear and what frequencies it can distinguish.

Our solution for determining what the birds can hear is to create a bird box. The bird box is a container that has a speaker to play test sounds, choice buttons for birds to make choices when responding to the test sounds, camera to monitor the bird, a food reward dispenser when the bird makes the correct choice, and a light to turn off for punishment. The box can also run trials autonomously with an automated computer program. The bird box can provide an ideal experiment environment for researchers to test the bird's ability to recognize sounds.

1.2 Background

Songbirds communicate with each other through different songs. They can hear and discriminate among different songs as well as produce them. Research has studied the vocal output (songs) more than the perceptual processes involved in deciphering such calls/songs [1]. Studying what kind of vocalizations songbirds are able to recognize and discriminate between is important as birds communicate with each other using different sounds and frequencies.

Sometimes they have similar responses to different sounds. At other times, researchers can only understand what the birds hear by observing the surrounding environment. Thus, researchers will benefit substantially from improved techniques of determining what birds can actually hear as well as the frequencies that birds are able to distinguish vocalizations [1]. Previous researches and methods have demonstrated that positive reinforcement is an effective way to test the songbirds [1]. Some of the research used computer-based test apparatuses, and our goal is to make a similar but improved apparatus to aid researchers in the study of songbirds.

A previous senior design group initially worked on this project. Their final project displayed accuracy with the peripheral module utilizing a seed-by-seed dispensing feeder and their software followed a user-oriented design (with functionalities requested by the sponsor, such as trial reseeding and bird profile). Additionally, that group abandoned microcontroller choice due to time constraints and uncertainty about its ability to communicate via USB to the final software interface. Finally, that group had not provided a training module as the sponsor preferred that the bird box's core features first be developed and fully functioning [2]. The sponsor ultimately decided that changing the feeder design from a one-seed-at-a-time dispenser to a timed feeder which presented a larger amount of food for specific amounts of time as preferable because it would eliminate some of the functional issues experienced in the first design (described below) and allow researchers to use different types of food [3].

According to our sponsor and graduate researcher, Shelby Lawson, the first group's design attempt was ineffective due to a malfunctioning feeder that only offered one seed at a time; unfortunately, the single seed would often get stuck and cause the feeder to stop working [2]. Another problem with a feeder from a different design was that it moved too fast that it would launch food into the air, and food would get stuck in other parts of the apparatus [3]. Eliminating such issues with the feeder and improving the overall design of the bird box will ultimately save researchers countless hours of observation and add to the body of knowledge regarding avian communication.

1.3 High-Level Requirements

- When the bird performs the correct task (pushing the switch that indicates a change in the sound, when the sound did change), the bird box should give food reward to the bird as the positive reinforcement.

- When the bird performs the wrong task (pushing the switch that indicates a change in the sound, when the sound did not change), the bird box should turn off the light as a negative punishment.

- When the bird does not interact with the box for a long period of time defined by the experimenter, the bird box should warn the experimenter.

2 Design

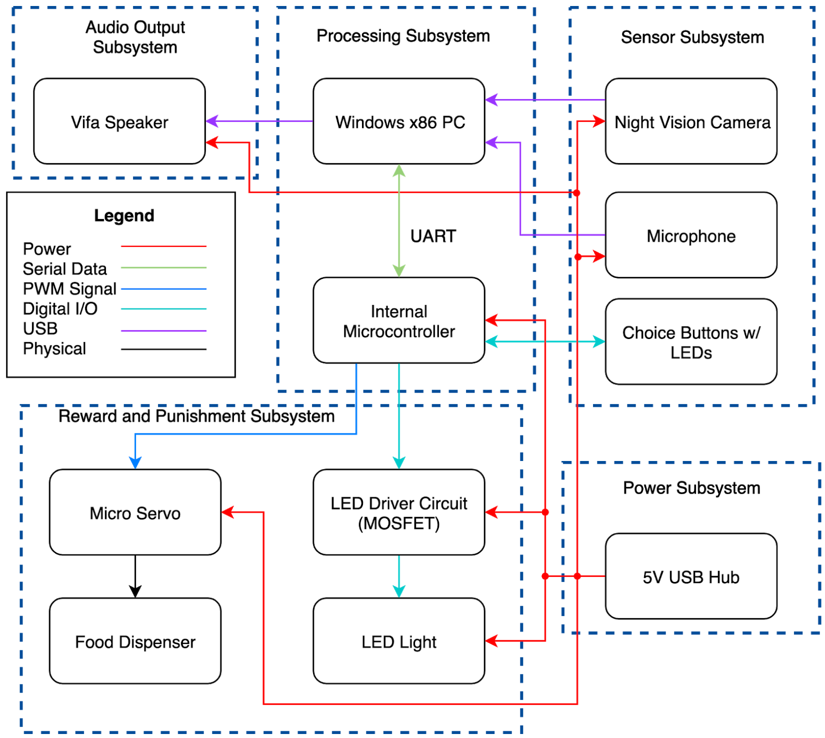

Fig. 1. Block Diagram for Bird Box Design

The overall design of the Bird Box is shown above (Fig. 1). The physical design of the system includes three mechanical parts, the cage, the microswitch panel, and the food dispenser/feeder. The other electrical components are either mounted on one of the three mechanical parts or outside of the page to get out of the reach of the birds.

The cage is a normal bird cage modified to mount our experiment system. The microswitch panel consists of two parts, microswitches and indicator LEDs. The indicator LEDs are mounted on the microswitch lever. The bird would stand on the perch, push the LEDs and activate the microswitches (Fig. 2).

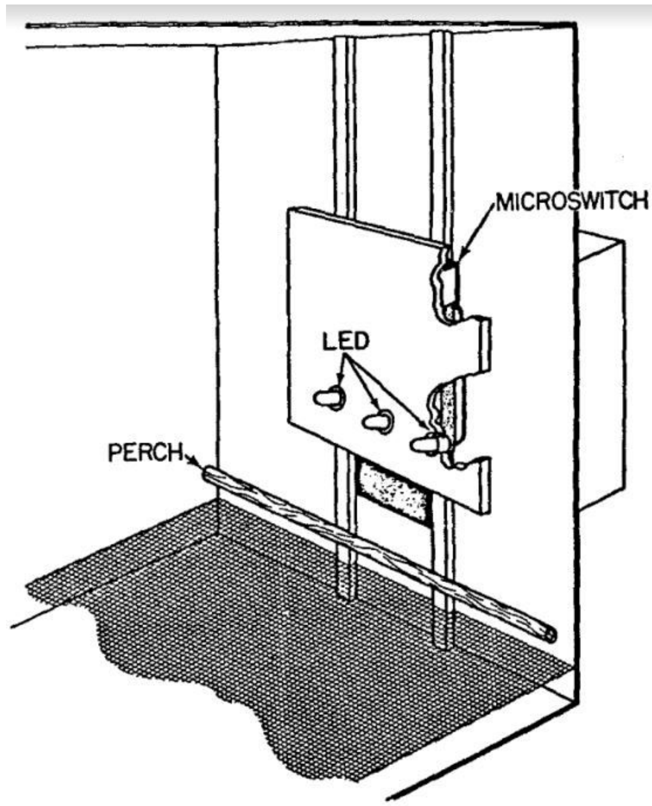

Fig. 2. Microswitch Panel Reference Design from Park's Paper [1]

The food dispenser would also be mounted close to the perch. It consists of three parts, a quarter cup, a micro servo, and a PVC lid. The micro servo can open and close the lid, and the PVC lid is flexible so it is safe for birds. When the experimenter wants to give birds a food reward, the lid quickly opens to let the bird eat from it. When the reward time passes, the lid closes (Fig. 3).

The light bulb is mounted on the top of the cage. The positions of the camera and microphone would be adjusted to give the experimenter a good view inside the cage (Fig. 4).

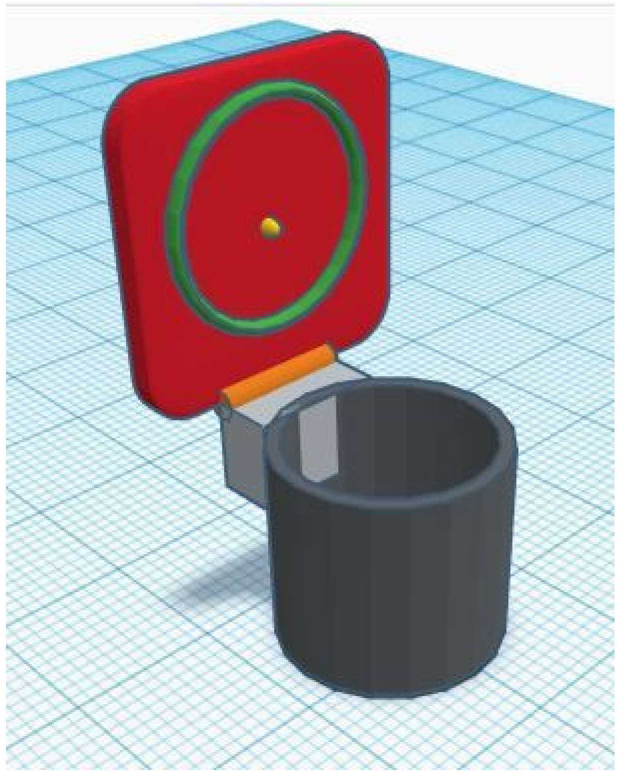

Fig. 3. Feeder Design

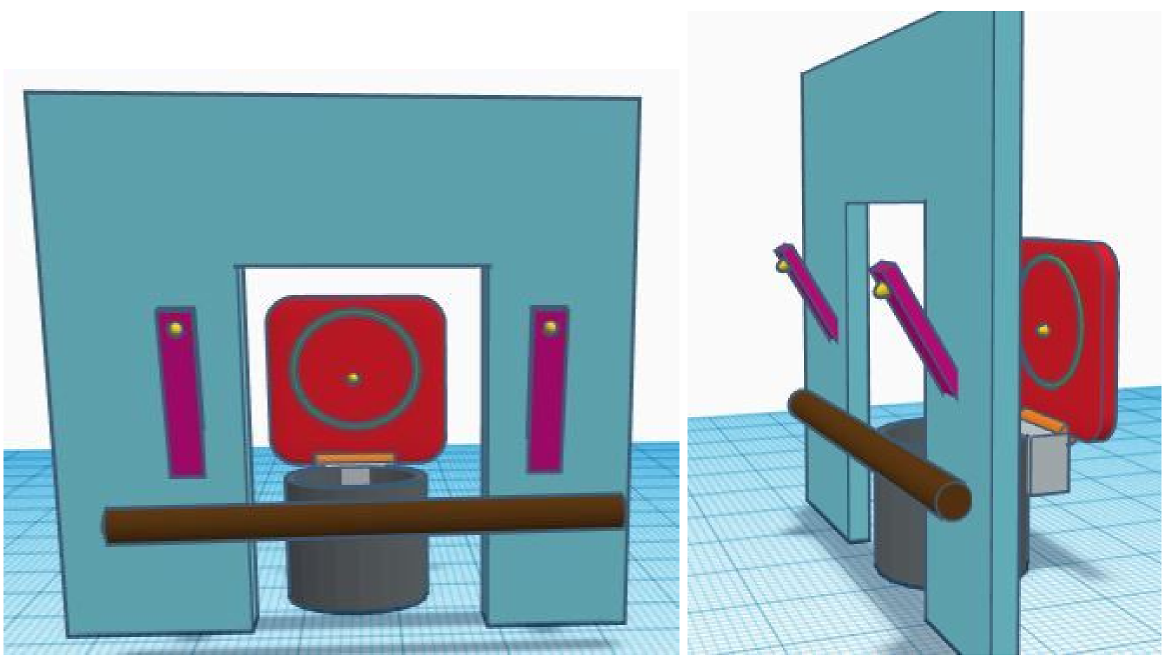

Fig. 4. Overall Design for the Feeder (Not to Scale)

2.1 Audio Output Subsystem

The audio output subsystem only includes the speaker. Since we will be testing the acoustic discrimination on birds, we need a speaker to play the test sounds. The speaker will connect to a Windows x86 PC's audio jack, and the PC will provide the audio output. The power subsystem will provide power through USB. The speaker needs to be either directly powered or charged by the USB power. Our sponsor provided us a Vifa Reykjavik speaker that has a frequency response from 62 Hz to 20 kHz and can be charged by 5 V USB-C. The experimenters would only play sounds within the frequency response of the speaker. The requirement and verification of the audio output subsystem is shown in the table below (Table 1).

Table 1: Requirement and Verification of Audio Output Subsystem

Requirement	Verification
1. Can be powered or charged by 5 V DC. 2. Has the ability to output all the test sounds and frequencies.	1. Charge the speaker through 5 V USB power. Confirm that the speaker gets charged. 2. Play all test sounds and ensure that the speaker actually outputs those sounds.

2.2 Processing Subsystem

2.2.1 Windows x86 PC

All USB sensors from the sensor subsystem as well as the audio output subsystem will be connected to the PC. All sensors and devices connected to the internal microcontroller will be controlled by the PC through USB serial commands. The PC runs the experiment and serves as a workstation for the experimenters. According to our sponsor's requirements, the program that runs on the Windows PC needs to take in the experimenter's input parameters, randomize and run the trials automatically, and output data to an Excel/CSV file. The requirement and verification of the Windows x86 PC is shown in the table on the next page (Table 2).

Table 2: Requirement and Verification of Windows x86 PC

Requirement	Verification
1. Can play the trial sounds. 2. Can communicate with the microcontroller. 3. Can run experiments and output to Excel/CSV file.	1. Run programs to play the trial sounds. 2. Send serial data to and from the microcontroller from the PC and see if both sides get the messages. 3. Run test program to see if the experiments work and check the output files for correctness.

2.2.2 Internal Microcontroller

All digital I/O sensors and outputs (microswitches, LEDs, food dispenser) will connect to the microcontroller. The microcontroller, ATmega328p, communicates with the PC through the UART serial. We picked the microcontroller for its Arduino compatibility and widely available sample designs. Another reason for choosing ATmega328p is that it runs on 5-Volt and has 5-Volt TTL logic levels, which is compatible with our 5 V power supply (Fig. 5).

A USB-UART converter, FT232RL, handles the conversion between USB and UART (Fig. 6). We picked the USB-UART converter for its known compatibility with Arduino bootloader, namely the DTR function.

The microcontroller needs to be able to turn on and off the LEDs and the food dispenser. It also needs to process the button pushes. The microcontroller is programmed through the same FT232RL USB-UART converter by Arduino software.

The requirement and verification of the internal microcontroller is shown in the table on the next pages (Table 3).

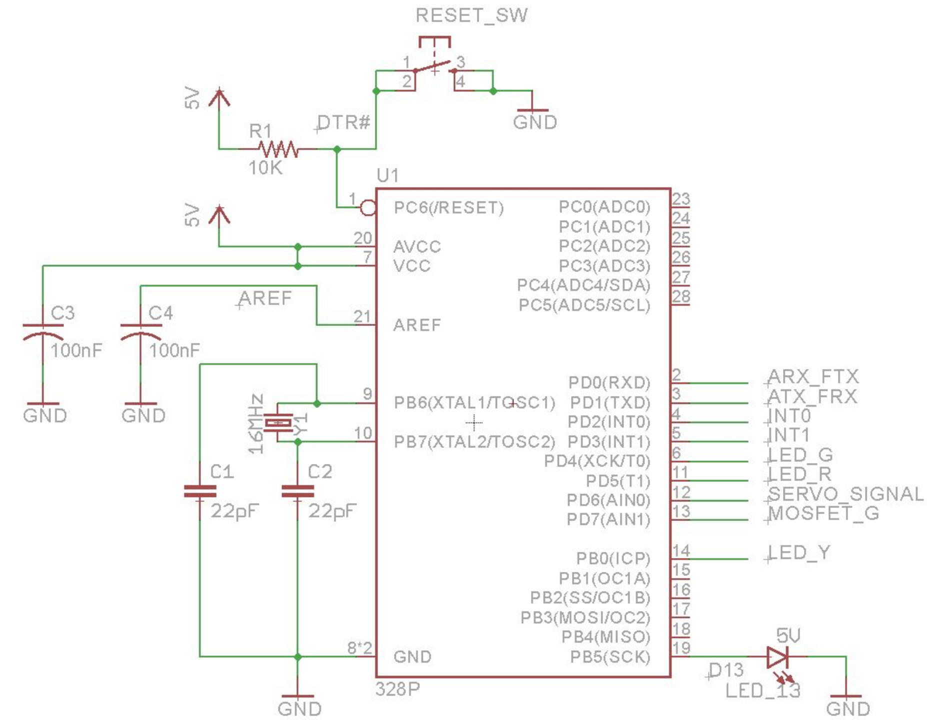

Fig. 5. ATmega328p Circuit

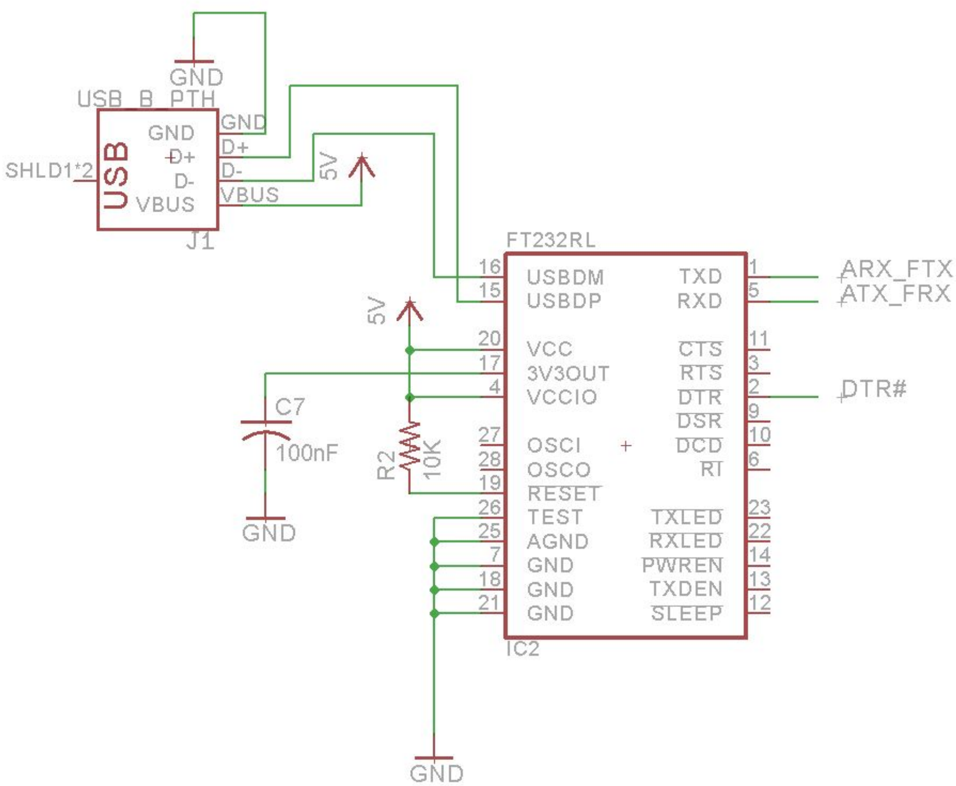

Fig. 6. FT232RL USB-UART Converter Circuit

Table 3: Requirement and Verification of the Internal Microcontroller

Requirement	Verification
1. Able to send and receive serial data to and from the PC. 2. Able to receive interrupts from the microswitches. 3. Able to toggle the indicator LEDs on the microswitches. 4. Able to toggle the LED light bulb. 5. Able to send PWM waves to control the servo on the food dispenser and control it.	1. Send UART serial messages from both the PC and the microcontroller. Check if they both get the messages. 2. Connect the interrupt pins on the microcontroller (PD2, PD3) to the microswitch's debounced output. Push the microswitch and see if the interrupts are received. 3. Toggle the indicator LEDs and see if they turn on and off. 4. Toggle the LED light bulb and see if they turn on and off. 5. Send PWM wave within the range of the operation travel of the servo. Check if the servo turns to the desired positions.

2.3 Sensor Subsystem

2.3.1 Night Vision Camera

The night vision camera will connect to the Windows x86 PC through the USB interface. The experimenter can monitor the experiment through the night vision camera. The camera needs to be able to monitor the birds without the light (during the punishment). We picked the SVPRO camera for its infrared night vision functions. The requirement and verification of the night vision camera is shown in the table below (Table 4).

Table 4: Requirement and Verification of the Night Vision Camera

Requirement	Verification
1. The night vision camera can connect to the PC. 2. The night vision camera can see into the box without light.	1. Connect the PC and the night vision camera and see if it outputs image. 2. Turn off the light and assure the vision in dark is clear.

2.3.2 Microphone

The microphone will connect to the Windows x86 PC through the USB interface. The experimenter can also monitor the experiment through the sound. The microphone needs to pick up the birds' sounds. We picked eBerry XM-B microphone for its affordability. The requirement and verification of the microphone is shown in the table below (Table 5).

Table 5: Requirement and Verification of the Microphone

Requirement	Verification
1. The microphone can connect to the PC. 2. The microphone can record the sounds.	1. Connect to the x86 PC and see if the microphone can input sounds it hears 2. Check if the program can record sounds using the microphone driver

2.3.3 Choice Buttons w/ LEDs

The choice buttons include two parts: the microswitches and the LEDs. One indicator LED will attach directly to each of the microswitches as visual feedback for birds. The choice buttons will interface with the microcontroller under the processing subsystem through digital I/O. The microswitches have to have a very low operating force that the birds can push them easily. We will use an SN74LS279 S-R latch for debouncing the microswitches (Fig. 7). The LEDs have to light up so birds can recognize them as signals. The LEDs will also aid in training the birds to perform the task. The requirement and verification of the choice buttons with LED is shown in the table on the next page (Table 6).

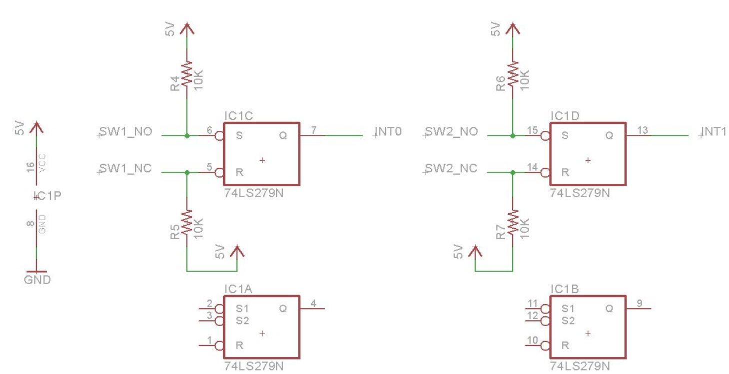

Fig. 7. Microswitch Debounce Circuit

Table 6: Requirement and Verification of the Choice Buttons with LED

Requirement	Verification
1. The microswitch opens or closes the circuit when the birds peck it. 2. The bird is able to push the microswitch. 3. The microswitch has to be debounced. 4. The bird has to be able to see the LED. 5. The LED must be able to operate on or below 5 V.	1. Connect the microswitch to an LED circuit and see if the microswitch turns on and off the LED. 2. Assemble the button and microswitch in front of the bird and make sure the bird can push the button. 3. Check if the microswitches are debounced with the S-R latch through an oscilloscope. 4. Check if birds have responses to the LED stimulus. 5. Connect the LED circuit to the 5 V supply and see if it lights up.

2.4 Reward and Punishment Subsystem

2.4.1 Micro Servo

The micro servo is used to open and close the lid on the food dispenser. When there is a reward, the micro servo needs to open the lid so the bird can eat from the bowl. When the reward time ends, the micro servo needs to close the lid so the bird can go back to react to sounds and choice buttons. For this requirement, the micro servo needs to be powerful enough to turn the lid, but not too powerful that it might injure the birds, and it is designed to run on 5 V. In addition, it should open the lid fast enough that the bird can relate food reward to pushing the correct button. We picked Savox SH-0257MG for its small size, fast speed, and torque within our expected range. The requirement and verification of the micro servo is shown in the table on the next page (Table 7).

Table 7: Requirement and Verification of the Micro Servo

Requirement	Verification
1. The micro servo must be able to open and close the lid. 2. The micro servo must be able to open the lid fast enough when the experimenter/program wants to give birds the reward. 3. The force of the micro servo must not be strong enough to cause injury.	1. Attach the micro servo to the lid and check if it can open and close the lid. 2. Attach the micro servo to the lid and check if it can open the lid in 0.5 seconds. 3. Test if the torque is safe for the birds when attached to the lid by experimenters.

2.4.2 LED Driver Circuit (MOSFET)

The LED Driver Circuit controls the LED light by switching it on and off. We used an N-Channel MOSFET for this purpose. The MOSFET we chose, RFP12N10L, has a drive voltage of 5 V so we can directly control it using the microcontroller (Fig. 8). The maximum current is 12 A, which is much higher than the current drawn by the LED light bulb. The requirement and verification of the LED driver circuit is shown in the table below (Table 8).

Table 8: Requirement and Verification of the LED Driver Circuit

Requirement	Verification
1. The driver circuit can turn on the LED. 2. The driver circuit can turn off the LED.	1. Connect the driver circuit to LED and confirm the LED is on with $V_{GS} = 5$ V. 2. Connect the driver circuit to LED and confirm the LED is off with $V_{GS} = 0$ V.

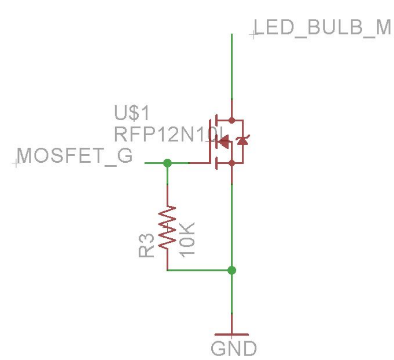

Fig. 8. LED Driver Circuit

2.4.3 LED Light

A soft, non-distracting LED light is used for lighting up the cage and it will turn off as punishment is presented. A common medium base (E26/E27) light bulb runs on 120 V AC. To simplify the power subsystem design, we chose a 5 V - 6 V medium base light bulb from 12Vmonster. It has a 3000 K warm white light. The requirement and verification of the LED light is shown in the table below (Table 9).

Table 9: Requirement and Verification of the LED Light

Requirement	Verification
1. The LED light works under 5 V conditions.	1. Connect the LED light to a 5 V circuit and see if it lights up.

2.5 Power Subsystem

The power subsystem includes a powered USB3.0 Hub that powers every other subsystem. We chose atolla U06K powered USB Hub for its 2.4 A charging port and four USB ports. Since the whole system runs on 5 V, the power subsystem only outputs 5 V through the USB bus. The 2.4 A charging port can charge the Vifa speaker, while three of the four USB ports can each connect to the PCB, the camera, and the microphone. The requirement and verification of the power subsystem is shown in the table below (Table 10).

Table 10: Requirement and Verification of the Power Subsystem

Requirement	Verification
1. Can charge the Vifa speaker. 2. Can power the PCB, camera, and microphone.	1. Connect the Vifa speaker to the charging port and see if it gets charged. 2. Connect the PCB, camera, and microphone to the hub then to the computer, turn them all on, and see if all the systems operate correctly.

2.6 Tolerance Analysis

To avoid injuring the bird, we should include a movable food dispenser to reward the bird. We have taken three designs of the food dispenser into consideration:

- The food is put inside a long tube when food reward is presented, the tip of the tube goes up and food is presented in front of the bird. However, this design takes up too much space if we need a long tube, we will not be able to fit the long tube inside the cabinet where the bird box is placed.

- The food is put inside a small bowl that can move inside and outside of the bird box cage. When food is needed, the bowl will come inside the cage. We discard this design because this is too dangerous when the bird is still eating and the food bowl is taken out of the cage. This may result in catching the bird's head in between the food bowl and the cage's edge.

- The food is put inside a small capped bowl that is placed inside the cage. The lid of the bowl will be made out of an elastic plastic (PVC). When the food reward is given, the lid will open. When the reward time is over, the lid will close. Since the lid is flexible, the force applied to the bird will be safe for the birds.

The lid of the bird food dispenser should be flexible and put a force that is reasonably small if the bird is not leaving the food dispenser to avoid injury.

The lid of the food dispenser is made out of PVC, whose density is 1.3 - 1.45 g/cm^3, and the dimensions of the lid should be cylindrical with a 4 cm radius and around 0.2 cm thick. If we estimate the density to be 1.4 g/cm^3, we could calculate the mass of the lid using the formula below.

$$M = \pi * 4^2 * 0.2 * 1.4 = 36.9\ g$$

With such a small mass, the lid will not be able to hurt the bird when it is closing.

The servo should be able to lift the lid which has a mass of 36.9 g.

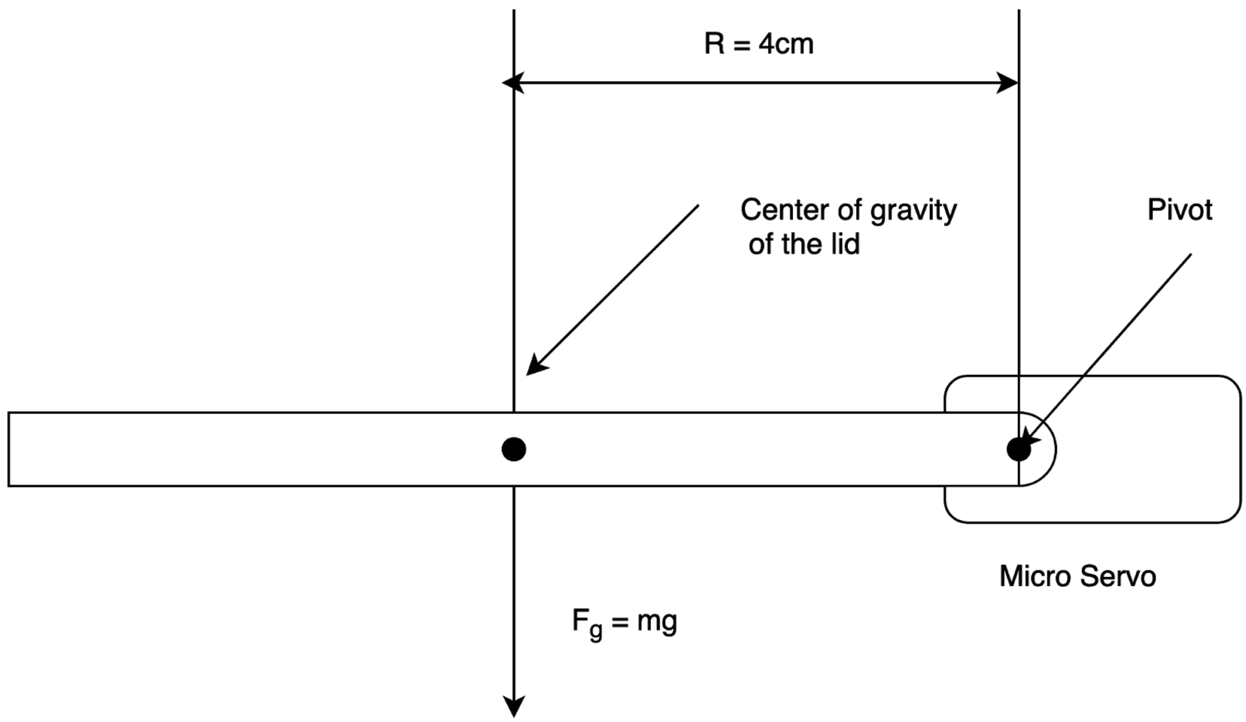

Fig. 9. Servo with lid of the food dispenser

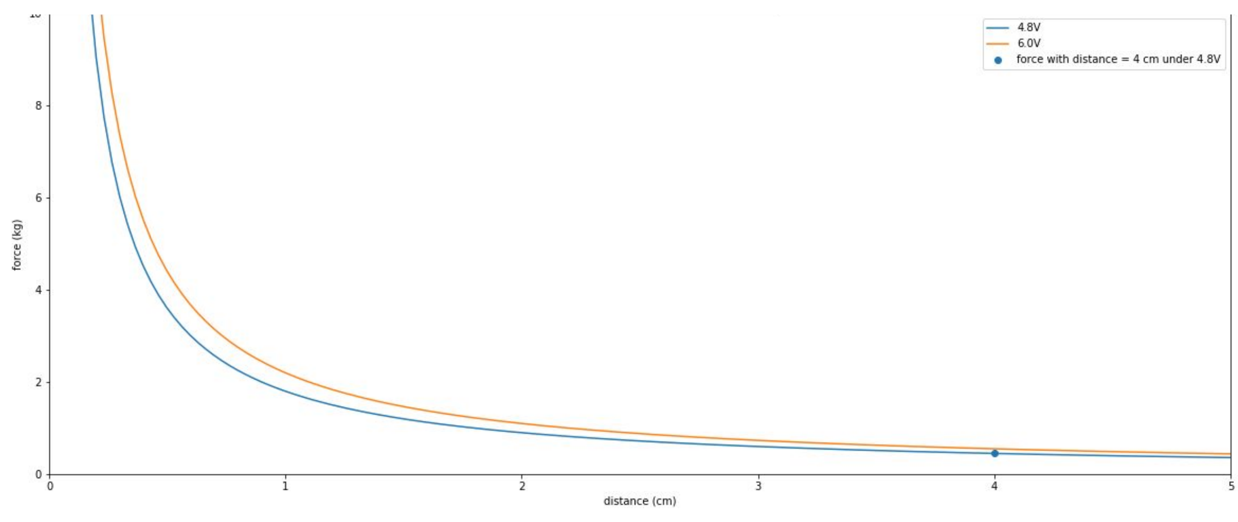

Fig. 10. Distance vs Force at Different Voltages

According to the datasheet of the servo [4] and Figure 9, let τ be the torque when the voltage supply is 4.8 V - 6 V and R be the distance from the pivot to the gravitational center of the lid, we can calculate that the force the servo can apply on the lid would be

$$F = \tau / R / sin(\theta)$$

Then we can calculate the actual force the servo can apply by substituting τ = 1.8 kg/cm and 2.2 kg/cm at 4.8 V and 6.0 V respectively (Fig. 10) and R = 4 cm. θ will be 90 degrees.

Under 4.8 V condition:

$$F = 1.8 / 4 / sin(90°) = 0.45\ kg$$

Under 6.0 V condition:

$$F = 2.2 / 4 / sin(90°) = 0.55\ kg$$

Since the force we can apply on the lid is within 0.45 - 0.55 kg, we are able to lift the lid with the servo listed.

3 Costs

The total expected cost of components and labor is $8,505 excluding the PC.

3.1 Cost of Labor

We assume that all people working on this project are compensated $25 per hour. We will each be working on this project for about 15 hours a week for 7 weeks. The estimated machine shop work time is about 10 man-hours.

$$15 \times 7 \times 3 \times \$25 + 10 \times \$25 = \$8,125$$

3.2 Cost of Parts

The expected cost of components is $380, including the speaker which was provided by the sponsor. The complete parts list is in Appendix A (Table 12).

4 Schedule

Table 11: Proposed Schedule for Each Team Member

Week	Chang-Wei	Weihang	Megan
09/30/19	Write the design document	Write the design document, order parts	Write the design document
10/07/19	GUI design, Python skeleton code	Microcontroller sensor/LED/feeder code (Prioritize feeder code), work on mechanical feeder	PCB design, send the bird cage for testing (feeder and buttons)
10/14/19	GUI design, Python testing mode code, testing	Microcontroller/PC serial code, full system test code, PCB design	PCB design, Python training code
10/21/19	Test testing mode program, test camera, and microphone	Test with birds the code running on the PCB	Breadboard testing, send all for bird testing
10/28/19	Python trial mode code	PCB testing and troubleshooting	PCB testing and troubleshooting
11/04/19	Test trial mode program	Finish the final PCB design	Finish the final PCB design
11/11/19	Complete test on testing and trial mode	Finish final version of PCB Firmware	Integrate the PCB to project (wiring)
11/18/19	Send the whole box for bird testing, Mock demo	Mock demo	Mock demo
11/25/19	Prepare for demo	Prepare for demo	Prepare for demo
12/02/19	Final demo, Final report	Final demo, Final report	Final demo, Final report

Our schedule for the bird box project is shown in the above table (Table 11).

5 Ethics and Safety

We would potentially go against #1.2 in the ACM Code of Ethics [5] and #1 in the IEEE Code of Ethics [6] because we would have to create negative consequences when the birds do the wrong task. However, we will try our best to minimize the discomfort of birds by turning off the lights for the shortest period of time possible while still able to achieve the effects of negative punishment. Due to the usage of the bird box, there are concerns about the safety of the bird during experiment trials.

- Since birds are more vulnerable than humans, most of the components in our project, if broken, pose some potential danger to birds. We will put delicate parts of our projects such as the camera and microphone out of the reach of the birds. If the part has to be within the reach of the birds (outside of the cage), it will be behind a piece of an acrylic panel (Plexiglass).

- Because of the nature of the project, we have to include a food reward dispenser with the moving lid in the bird box. Considering the safety of the bird, the lid of the dispenser will move at a slow pace to allow the birds to dodge the moving dispenser. The lid will be made out of PVC (a type of elastic plastic) board. Even if the bird is not capable of getting out of the range of the food dispenser, the lid will have enough force to push the bird away without hurting the bird. The dispenser also must not have any way of catching and trapping a leg within its moving parts to avoid injuring the bird.

- Since we are “punishing” the birds for performing the wrong task as negative punishment, it is important to keep the birds safe during the “punishment”. We will use a very gentle “punishment”, which is to turn off the lights for a short period of time. This will annoy the birds but not do any actual damage. However, a human experimenter is required to monitor the birds during the experiment in case of any emergencies.

In compliance with #2.1 of the ACM code, we work to make the bird box a professional tool for the experiment when discriminating between the sounds that birds can and cannot hear. We will include different modes for the whole experimenting process: training mode and the trial mode.

We will accept professional advice and give out the corresponding results as stated in the ACM Code of Ethics (#2.4 “Accept and provide appropriate professional review”). During the creation of the bird box, we will meet with our sponsor regularly to assure the bird box is safe, well-designed and professional.

Point #2.6 of ACM code of ethics will be precisely conducted. Whenever an experiment is conducted, an experimenter should monitor the trials through the camera and microphone within the bird box.

Other parts of the bird box should comply with #1 in the IEEE Code of Ethics [6]. All the components in the bird box would be safe for the experimenters under normal use conditions. The bird box and its use protocol are approved by the Institutional Animal Care and Use Committee (IACUC) and the approval is valid through April 2, 2021 [7]. We would work closely with the researchers and experimenters to ensure that the design of the bird box would be safe under the use protocol.

References

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[7] Approval of Animal Use Protocol. (2018). Institutional Animal Care and Use Committee. [Accessed Sep. 19, 2019].

Appendix A: Parts List

Table 12: Parts List

Component	Quantity	Unit Price	Total Price	Description	Manufacturer	Part Number
Audio Output Subsystem						
Vifa Reykjavik Speaker	1	199	199	Speaker	Vifa	VIFA070
Processing Subsystem						
Windows x86 PC	1	0	0	PC		
Microcontroller						
ATmega328 w/ bootloader	1	5.5	5.5	Arduino Uno Chip	Atmel	ATmega328/P
28 pin dip socket	1	0.95	0.95	Socket for microcontroller	Sparkfun	PRT-07942
1K Resistor	1	0.95	0.95	LED & General Resistor	Sparkfun	PRT-14492
10K Resistor	1	1.2	1.2	Reset button resistor	Sparkfun	PRT-14491
16MHz Crystal	1	0.95	0.95	Crystal	Sparkfun	COM-00536
22pF Ceramic Capacitor	2	0.25	0.5	Crystal capactior	Sparkfun	COM-08571
100nF Ceramic Capacitor	5	0.15	0.75	Power decoupling circuit	Vishay BC Components	K104K15X7RF5TL2
0.47uF Ceramic Capacitor	2	0.4	0.8	Power decoupling circuit	KEMET	C315C474K5R5TA7303
1uF Ceramic Capacitor	1	0.34	0.34	Power decoupling circuit	TDK Corporation	FG18X7R1E105KRT06
47uF Ceramic Capacitor	1	1.2	1.2	Power decoupling circuit	TDK Corporation	FG16X5R1E476MRT06
Tactile Swtich	1	0.35	0.35	Reset button	Sparkfun	COM-00097
5V Yellow LED	1	0.6	0.6	LED Indicator	Kingbright	WP7113YD5V

Table 12: Parts List (Continued)

USB UART						
USB Type B Socket	1	1.25	1.25	USB B Header for serial	Mouser	154-2442
FT232RL USB to UART	1	4.5	4.5	USB-UART converter	FTDI, Future Technology Devices International Ltd	FT232RL
Connectors						
TE GI 2 Pin White Housing	1	0.17	0.17	White LED Connector	TE Connectivity AMP Connectors	2-1971793-1
TE GI 2 Pin White Header	1	0.25	0.25	White LED Board Header	TE Connectivity AMP Connectors	2-1971800-1
TE GI 2 Pin Blue Housing	1	0.28	0.28	Green LED Connector	TE Connectivity AMP Connectors	2-1971793-2
TE GI 2 Pin Blue Header	1	0.23	0.23	Green LED Board Header	TE Connectivity AMP Connectors	2-1971800-2
TE GI 2 Pin Red Housing	1	0.28	0.28	Red LED Connector	TE Connectivity AMP Connectors	2-1971793-3
TE GI 2 Pin Red Header	1	0.23	0.23	Red LED Board Header	TE Connectivity AMP Connectors	2-1971800-3
TE GI 2 Pin Yellow Housing	1	0.28	0.28	Yellow LED Connector	TE Connectivity AMP Connectors	2-1971793-4
TE GI 2 Pin Yellow Header	1	0.23	0.23	Yellow LED Board Header	TE Connectivity AMP Connectors	2-1971800-4
TE GI 3 Pin Yellow Housing	1	0.29	0.29	Micro Actuator Connector	TE Connectivity AMP Connectors	3-1971793-4
TE GI 3 Pin Yellow Header	1	0.37	0.37	Micro Actuator Board Header	TE Connectivity AMP Connectors	3-1971800-4
TE GI 3 Pin Blue Housing	1	0.35	0.35	Green Switch Connector	TE Connectivity AMP Connectors	3-1971793-2
TE GI 3 Pin Blue Header	1	0.38	0.38	Green Switch Board Header	TE Connectivity AMP Connectors	3-1971800-2
TE GI 3 Pin Red Housing	1	0.29	0.29	Red Switch Connector	TE Connectivity AMP Connectors	3-1971793-3
TE GI 3 Pin Red Header	1	0.38	0.38	Red Switch Board Header	TE Connectivity AMP Connectors	3-1971800-3
TE GI Contact	15	0.062	0.93	Contact for GI connectors	TE Connectivity AMP Connectors	1971795-1

Table 12: Parts List (Continued)

Sensor Subsystem						
Night Vision Camera	1	52.99	52.99	Camera	SVPRO	SV-USBFHD05MT-KL36IR
Microphone	1	7.99	7.99	Microphone	eBerry	XM-B
Choice Buttons						
Microswitch	2	5.58	11.16	Bird Push Button	Honeywell Sensing and Productivity Solutions	V7-5F17D8-336
5V Red LED	1	0.64	0.64	Red Switch LED	Kingbright	WP7113ID5V
5V Green LED	1	0.51	0.51	Green Switch LED	Kingbright	WP7113SGD5V
S-R Latch	1	1.31	1.31	Debounce Circuit	Texas Instruments	SN74LS279AN
16 DIP Socket	1	0.51	0.51	Socket for Latch	3M	4816-3000-CP
Molex Insulkrimp 1.87x0.02	6	0.66	3.96	Quick Connect Terminals	Molex	190030067
Reward and Punishment Subsystem						
Micro Servo	1	31.41	31.41	Food Dispenser Actuator	Savox	SH-0257MG
5V Yellow LED	1	0.6	0.6	LED Indicator	Kingbright	WP7113YD5V
N-Channel MOSFET	1	1.04	1.04	LED Driver Circuit	ON Semiconductor	RFP12N10L
5V 6V Medium Base LED	1	11.99	11.99	Punishment LED	12Vmonster	P-3W-E27-WW-6V
Medium Base Socket	1	3.88	3.88	LED Bulb Socket	Pass Seymour	S752WCC10
Power Subsystem						
USB 3.0 Hub with Power	1	16.14	16.14	Connects to everything and provides power	atolla	U06K
USB-C Cable	1	6.99	6.99	Power the Vifa Speaker	AmazonBasics	L6LUC009-CS-R
USB-B Cable	1	5.1	5.1	Power the PCB	AmazonBasics	7HUA
Sum			380			