ECE445: Bird Box Design Document

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I. INTRODUCTION

I.i. Objective

Observation of animal behaviors and responses to certain audio stimuli can become the backbone for how our technologies are shaped or how our secret codes are constructed. Researchers at the University of Illinois are working to uncover patterns from these behaviors among birds through the means of conditioning. However, researchers are faced with a dire problem -- there is no existing system that would perfectly cater towards their research needs and is cost-efficient. Thus, the near to build a system suitable for their research needs becomes increasingly apparent.

The solution would be a system comprised of a hardware and software interface. The software interface would take parameters fed through a Graphical User Interface (GUI) to construct a unique file (with a certain amount of trials and shams) set by the researcher. The hardware would then respond to the data provided by the researcher in the GUI to play audio sounds for the bird to respond to. The bird would provide responses through color-differentiated buttons and these responses would trigger certain outcomes from the system. At the end of the research period, an excel sheet would be generated documenting the results of each unique response that the bird provided.

I.ii. Background

Modern technology has evolved at an incredible rate and digital signal processing is no exception to this rapid growth. With this growth in technology, it is important to also observe natural aspects regarding the field to draw more inspiration for advancements in signal processing. Thus, the analysis of bird behavior and responses to certain audio stimuli becomes a valuable observation for furthering knowledge in this field of study.

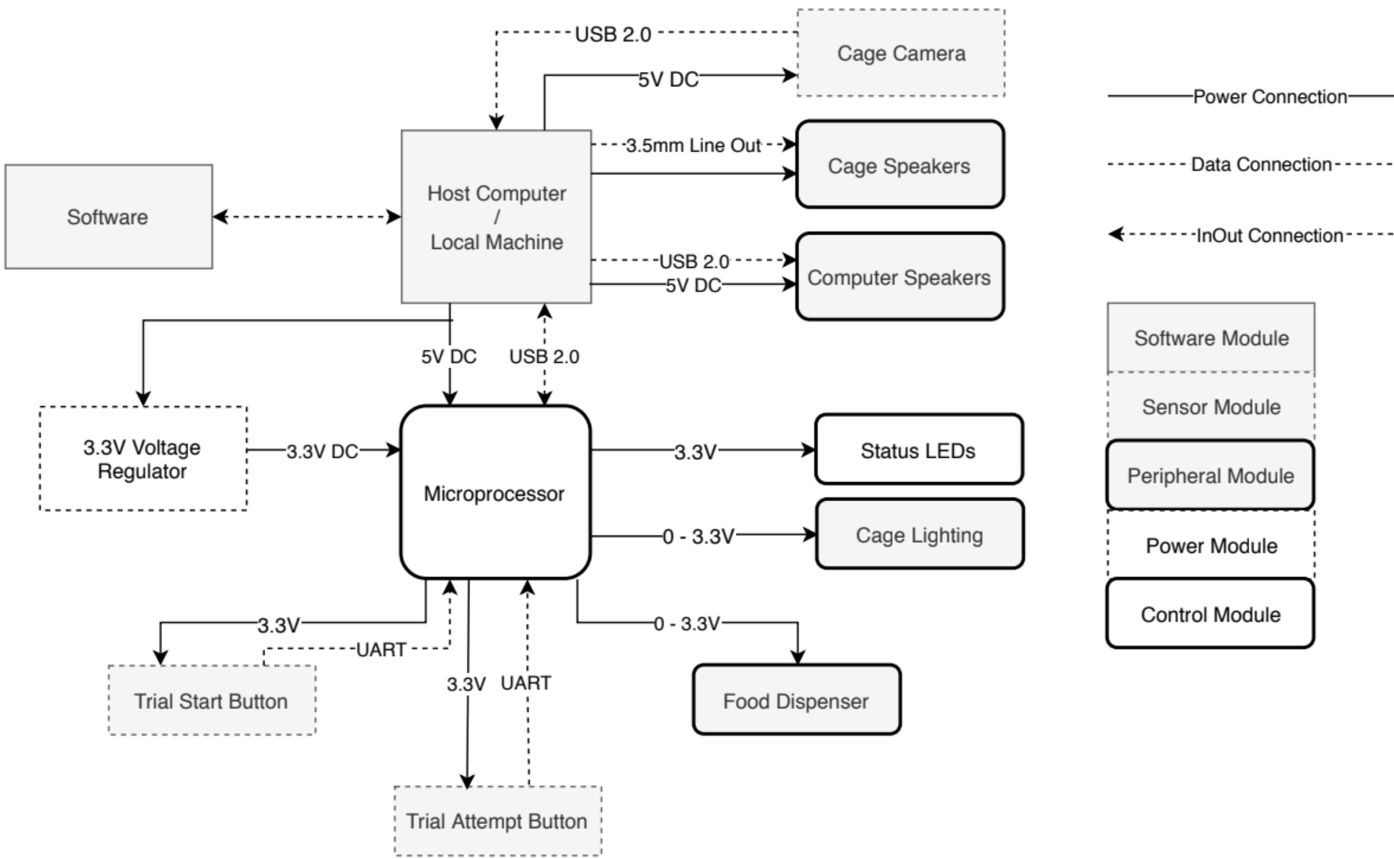
To highlight the problem, there will be varying tiers of impacts to provide emphasis on the scale in which the project contribution can help with understanding in this field. Creating a product to suit the needs of researchers will unlock further contribution towards various insights within the field. The trials the system would help conduct further enables understanding of bird communication, which can be applied to save certain endangered specifies upon identifying a certain cry (from a bird). Or, in a broader sense, this can contribute towards how language is perceived among birds-- how they communicate amongst each other or how certain sounds are assigned meanings [1]. Each of these observations can be used as a converging point for how digital signal processing can evolve in the field of animal sciences and behavior. And conversely, advancements analyzing sounds like this may also influence how digital signals are generated or modulated.

I.iii. High Level Requirements List:

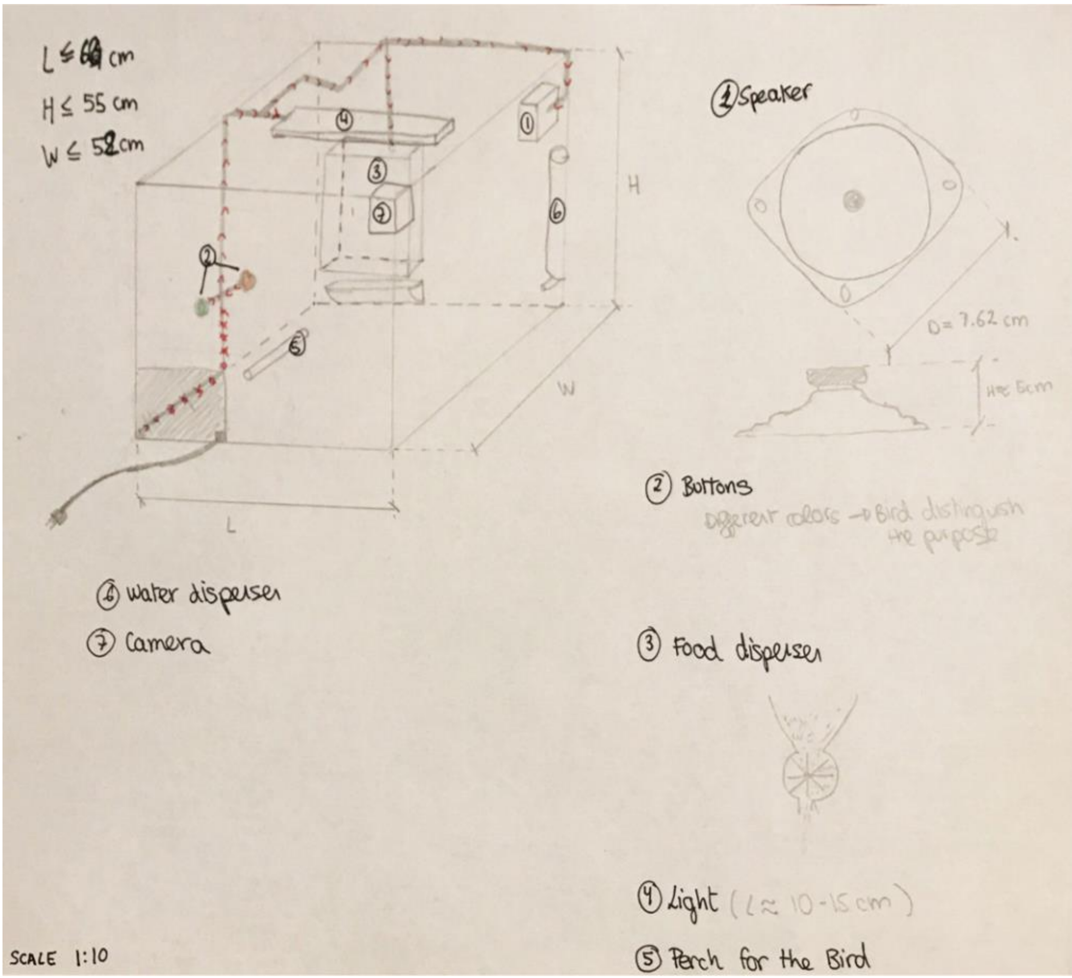
- The software user-interface must create one cohesive excel sheet documenting the results of the trial.
- The project must be capable of running at least 20 consecutive trials/shams for the researcher.
- The project must be cost-efficient and within a $500 budget.

II. DESIGN

II.i. High Level Block Diagram



II.ii. Physical Design



II.iii. Power Module

The power module must convert USB standard 5V, into separate 5V and 3.3V values at all times when connected to an external power source. We assume that the device is always connected to an external power source, and, as such will not consider storing power via battery. Our power consumption budget is averaged around 2.7W with an average of 200mA at 3.3V and 120mA at 5.0V. The 3.3V consumption is mainly through the microcontroller (50±10mA) and the DSP chip (150±25mA) while the 5.0V consumption is solely through the dispenser (120±20mA). These values adhere to the maximum load drawable from a USB 2.0 interface (500mA at 5V)

II.iii.A USB 5V Power Supply

This node is listed separately from the data transfer node for readability, but is responsible for both powering the components of our device as well as facilitating data transfer between host computer and device. For the purpose of the power supply, this block must continuously supply 5V voltage to the regulator while never reaching the maximum draw current for USB 2.0 (500mA). We choose USB 2.0 interface due to its universality as well as the assumption that the host computer will most likely not contain USB 3.0.

Requirements:

- Outputs a maximum of 500mA at 5±0.25V at all times when connected to an external device.

Verification:

- Current sweep of components to ensure overall current is within bounds (< 500mA).
- Measure open-circuit voltage to ensure resulting voltage is standard 5V USB 2.0

II.iii.B Voltage Regulator (3.3V)

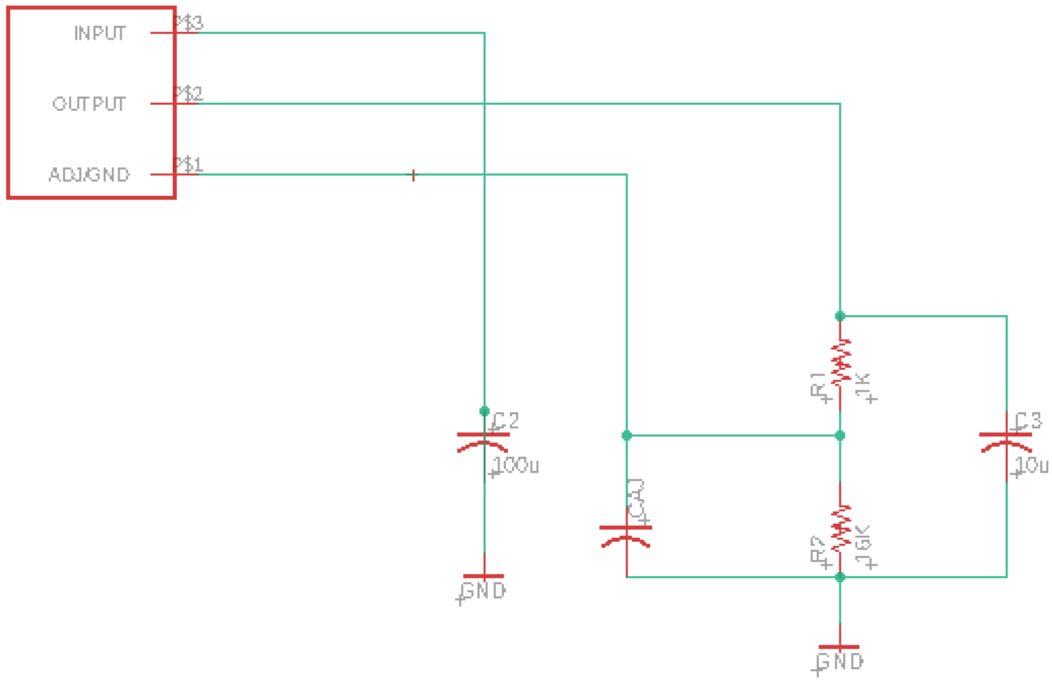
The low dropout regulator supplies 3.3V for the corresponding components in which it is required from an input voltage of 5.0±0.25V. The classic LM1117 must be able to handle an input voltage at the theoretical low for USB 2.0 (4.75V) as well as the maximum (5.25V) at peak current draw (500mA).

Requirements:

- Provides a 3.3V ± 5% output from a 5.0V ± 5% input source
- Operate at currents between 0 - 300mA
- Maintains thermal stability below 80ºC

Verification:

- Use an oscilloscope to measure output voltage to ensure its 3.3V ± 5%
- Use an oscilloscope to measure maximum output current during operation to ensure device is within operating regime
- Use an IR thermometer to ensure device temperature is within specified bounds.



II.iv. Control Module

The control module handles communication between the onboard devices as well as connected devices and software. It is powered by the power module and will disable itself and the device if voltage and current are significantly out of operation bounds or if device temperature is not within safe levels for the chip. This module consumes approximately 50mA ± 5% between its blocks.

II.iv.A Microcontroller

The microcontroller, ATmega16U2 handles processing commands from both input sensors from the sensor module, as well as commands from software to active components in the peripheral module. The communication with the sensor module is done with UART and the communication with the peripheral module is done with SPI. This microcontroller was chosen for its data retainability (20yr 85C) as well as its ability to communicate with a USB 2.0 interface. The chip contains two SPI interfaces for required peripherals and a singular UART interface. Additionally, the microprocessor monitors onboard voltage and current and will disable functionality if out of operational bounds. 16kB of on chip flash allows for programming without an external NAND flash chip.

Requirements:

- USB 2.0 communication
- Temperature stability under 80C
- Detects impulse from sensor module within 10ms

Verification:

- Reserved

II.iv.B Operation LEDs

Status LEDs powered by the microcontroller will display whether or not the circuit is operational during trialing and if the microcontroller is sending data via USB.

Requirements:

- Must be visible from 3m away with a drive current of 10mA

Verification:

- Use an oscilloscope to measure the current that goes through the LED and see if a resistor is needed to control it.
- Ensure that the LED is clearly visible by the viewer.

II.v. Sensor Module

The sensor module receives impulses from the trialed specimen via physical buttons. These buttons must be differentiable to the specimen in addition to easily-pressable. The impulse created by the buttons is detected via UART and sent to the control module. A camera is mounted to the host computer directly via USB 2.0 in order for video footage of the attempted trial to be sent to the researcher in charge of the experiment in order for them to determine whether or no the trial is proceeding as intended or if blocked by some factor.

II.v.A Trial Start Button

Sends a command to the control module that a trial has been requested to begin.

Requirements:

- Distinguishable from the Trial Attempt Button
- Easily-pressable by specimen
- Sizable enough for the specimen to identify and press

Verification:

- Reserved

II.v.B Trial Attempt Button

Sends a command to the control module that an attempt has been made on the current trial. Has no effect outside of testing period.

Requirements:

- Distinguishable from the Trial Start Button
- Easily-pressable by specimen
- Sizable enough for the specimen to identify and press

Verification:

- Reserved

II.v.C USB Mounted Camera

Simple visible spectrum camera placed inside the testing area and interfaced with USB 2.0 with the host computer. This sensor must have a minimum of 20fps in order to ensure adequate video data is presented to logically and cohesively discern whether or not the trialling attempt is proceeding as intended.

Requirements:

- Must provide a continuous, stable data-stream at all times when trialing at 20fps 480p.
- Maximum of 1s of delay between real world action and display
- Must maintain an averaged loss of < 1%

Verification:

- Reserved

II.vi Peripheral Module

This module contains all outputs to the real world. Obtains input signals from SPI interface from the control module as well as 3.5mm and USB 2.0 interface from the host computer. This module is mainly responsible for reward and punishment of the specimen depending on trial results as well as alerting the researcher if the specimen has failed to start he trial within a specified lockout time via audio cue.

II.vi.A Food Dispenser

The food dispenser is made by mounting a 40mm fan over a cut piece of plastic. By sending a current far below the normal operation regime. We can control end amount of seed we deliver to the specimen with a carefully constructed control system.

Requirements:

- Delivers expected food mass within 5% bounds.

Verification:

- Reserved

II.vi.B Cage Speakers

The cage speakers must be high-fidelity and accurately replay the corresponding pitch and timbre of the given audio accurately and swiftly. The expected audio is given in 3s bursts with the average trialling session equating to a total of an hour's worth of time. The speaker must be able to accurately reproduce the given audio with zero breakup or distortion. A spectrogram of the speakers must ensure that a transition from low to high frequency signals is met with zero breakup or distortion as well. Since these is the crux of the entire experiment, this device is given the least tolerance for variation and error. This device will be mounted inside of the cage and connected to the host computer via a grounded 3.5mm jack. We choose to use a grounded 3.5mm jack as a USB 2.0 interface is poorly grounded and contains background noise detrimental to the experiment.

Requirements:

- Reserved

Verification

- Reserved

II.vi.C Cage Light

The cage light is a simple LED strip with all individual electrical components connected in parallel. We choose a LED strip with each of the individual LEDs covered with a yellow phosphor in order to create a soft white light instead of a standard blue white created with a white phosphor. The total current draw of this device is estimated at an average of 200mA ± 5% at 3.3V when operational. Power is supplied by the control module via microcontroller as we wish to either toggle this device based on trial results and subject performance.

Requirements:

- Reserved

Verification:

- Reserved

II.vi.D Host Computer Speakers

Reserved

Requirements:

- Reserved

Verification:

- Reserved

II.vii Software Module

Software is a significant portion of this project. Our software will be solely be run on Windows 10 - 64 bit operating system, and, due to design specifications delivered by our sponsor, will be programmed in Python 3.5.0. The software will contain a user-friendly GUI that someone without programming or computing experience ought to be able to operate. Settings inputted by the researcher will be stored in .ini files on the local machine and input .wav files will be applied to a relevant set of generated trials and then pickled such that the relevant trials can be reattempted on a different subject if wished. Additional information is more low-level and can be found in greater detail on Git or the source files.

Block Name	Specific Components	High Level Requirements
Power Module	AC/DC Converter	• Convert input voltage to desired output within 10% error • Carry up to 5A of current within 10% variance during operation

Control Module	IC Microprocessor	• Detect impulse from sensors within 50ms • Accurately output audio data within a timing difference of no more than 10ms • Accurately receive video data with less than 10% loss
Sensor Module	Trial Start Button Trial Attempt Button Camera	• Button resistance must be low enough for a bird to pecl • Buttons must be differing color in order to distinguish function • Video is accurately recorded
Peripheral Module	Food Dispenser Cage Speakers Cage Light	• Dispenser is consistent as well as accurate to designated amount within 10% mass • Speakers accurately reproduce pitch and volume of data from connection • Light switching latency is less than 30ms
Transfer Module	DSP Chip USB B Protocol	• Must be able to send and receive USB transfer event polls • Able to accurately stream and receive data via USB • Correctly interpret signals from control module to send to software module • Must be able to preserve integrity of transferring signals
Software Module	USB Event Thread Data Transfer Thread Timeout Thread Processing Thread File Outputs GUI Room Speakers	• Must have a maximum run cycle of 10ms • Accurately send and receive signals from transfer module • Output to CSV or Excel • Store user inputted data via dump file • Possess a user friendly GUI

III. COST AND SCHEDULE

III.i Costs Analysis

III.i.A. Labor Costs

We assume that the labor costs of the design would be $45 USD/partner and 10 hours a week. We will consider 63% of the semester’s weeks into this calculation. Thus, labor costs for each partner in this project would be encompassed with the following calculation:

$45/Hour * 3 partners * 10 hours/week * 0.63 * 16 weeks = $13,608 in labor costs

III.i.B. Parts Costs

<make table>

show the excel sheet

https://docs.google.com/spreadsheets/d/1gdevub2tbX148-wMQCY1lsLiYmLWgngAYXDepNYq46M/edit?usp=sharing

III.i.C. Total

Grand total=Labor+Parts=$13,608+$.........=$.........

III.ii SCHEDULE

Week	Objectives	Responsibilities
1 – Feb 18	Finish Design Doc, Finish Circuit Schematics, Place initial Part orders	Kevin- DD, eagle, part orders
		Michael- DD, software
		Maria- DD, Eagle
2 – Feb 25	Power Test the parts, check peripheral modules. Lay out general structure of Software.	Kevin – breadboard assemble parts to test, sensor verification
		Michael – software architecture assignments
		Maria – voltage tests for power module
3 – Mar 4	Prepare for hardware run through with bird	Kevin- Software GUI, System design feedback 1st round preparation
		Michael- Software backend architecture assignments
		Maria- Finalize 1st round PCB Eagle design
4 – Mar 11	Submit first PCB Design, First integrated run through with bird. Meant to do with Hardware only.	Kevin – Review PCB initial submission, submit
		Michael – hardware bird trial verification tests
		Maria – hardware bird trial verification tests
5 – Mar 18	Iterate upon hardware design, prepare for hardware/software integration	Kevin – make adjustments based on hardware issues from bird test

		Michael – link GUI with backend to prepare for hardware integration
		Maria – make adjustments base on hardware issues from bird test
6 – Mar 25	Integrate hardware/software components, perform bird test 2 with the system	Kevin – Link hardware with software
		Michael – Link hardware with software
		Maria – Link hardware with software
7 – Apr 1	Finalize PCB design for submission, debug any additional problems with bird test 2	Kevin—debug integration
		Michael—Debug integration
		Maria – Finalize PCB design
8 – April 8	Final integration with software/hardware, bird test 3, prepare for final demos, leeway week to debug any issues	Kevin—anything the project needs
		Michael—Anything the project needs
		Maria—Anything the project needs
Weeks 9, 10, and 11 are all demo/presentation weeks.		

IV. ETHICS AND SAFETY

Following the ACM code of ethics #2.3: "Know and respect existing rules pertaining to professional work", we need to learn them and make our project according to them. Before any work with animals start it is mandatory to submit IACUC protocols and they adhere to nationwide rules for animal care and research. Our project fulfils all these requirements and has been approved already. The birds are rewarded with specific amount of food for hits, which will ensure all animals get a proper portion of food during the task. To punish the bird, we cut the light which is an ethical way to punish for wrong answers, since it doesn't hurt or stress the bird. Also the There is also an automatic time out if the animal doesn't do anything after a while, which is ethical in making sure the animal isn't in the test for more that it wants to be. This also accords with the ACM code of ethics #1.2: "Avoid harm", we are treating with animals so we need to avoid any harm that we can cause them.

We need to take care about the IEEE code of ethics #6: "To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations". Our project must be used by someone who has knowledge in the birds' field so they know how much food the bird can eat and how much time the light can be off. Following this code, we need to make sure that we have and user friendly interface that everyone without programming knowledge can understand. We need to make sure that our project works good and without any kind of error because it is going to be use by other professionals for their own work so their reputation is at stake following the IEEE code of ethics #9.

V. CITATIONS

[1] R. O. Davis, "Digital signal processing in studies of animal acoustical communication, including human speech", Computer methods and Programs in Biomedicine. https://doi.org/10.1016/0169-2607(86)90050-7

[2] "IEEE Code of Ethics", ieee.org, 2019. [online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[3] ACM.org. (1992). ACM Code of Ethics and Professional Conduct. [online] Available at: https://www.acm.org/code-of-ethics

[4] Illinois Institutional Animal Care and Use Committee (IACUC) [online] Available at: http://research.illinois.edu/regulatory-compliance-safety/iacuc