Automated pet cage

ECE 445 Design Document

Christina Hejny
Avram Fouad
Saurav Kumar

Group 16

Professor: Arne Fliflet
TA: Hanyin Shao

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1. Introduction

1.1 Problem & solution overview:

As every good rat owner knows, rats and many other pet rodents need plenty of daily enrichment time outside their cage to stay healthy. This time commitment often prevents people with busy schedules from owning pet rats. A way to let the pets out of their cage and receive daily enrichment time without the owner present would both reduce the time commitment for the rat owner as well as make rat ownership more accessible to people with busy schedules. Our solution to this problem is an automated rat cage. It will be a device assembled into the cage that will open the cage door at a user specified time every day. Then after two hours, the device will alert the rat to re-enter the cage and close the door once the rat is inside. This will ensure that the pet rat will receive its daily enrichment time every day even if the owner is too busy to let them out.

The device operates in a simple to understand sequence. After the device is assembled into the cage and turned on, the user will first use a keypad to enter the current time to set the device's clock. Then the owner will enter the specific time that the cage will open daily. At the specific time every day, the cage door will open letting the pet out. The device will wait two hours, after which it will beep, signaling to the pet that it is time to re-enter the cage. The pet will re-enter the cage and stand on a pressure sensor to inform the device that it is back inside the cage. In response to the sensor's input, the device will then close the cage door and dispense a treat from a feeder inside the cage. This process will occur daily at the same time. The reasoning behind the beep and feeder is to help train the rat to come inside the cage through positive reinforcement. Rats are famously very easy to train and capable of learning complex tasks. An owner could quickly and easily train this behavior, even to young rats. The device will also feature a motion detector that will stop the cage door from closing if something is in the doorway, similar to a garage door sensor.

1.2 Visual Aid:

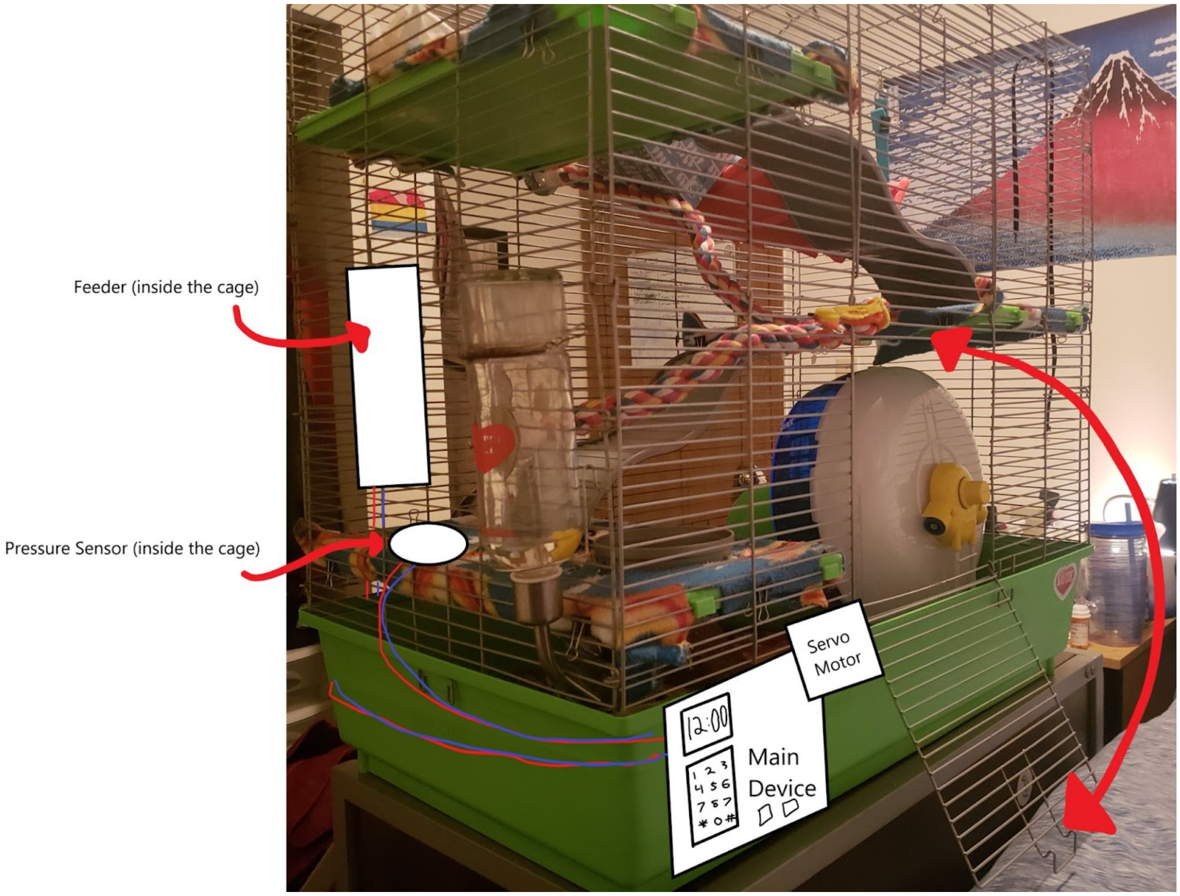

Figure #1: Visual Aid of Solution

1.3 High-level Requirements

- If the cage has been open for at least 2 hours [+/- 1 minute], the door must close within 3 seconds of the thin film pressure sensor becoming activated by the rodent. This is to ensure that the rodent does not leave the cage before the door closes.

- The "beep" sound generated by the speaker should be between 60-70 dBA with a frequency between 250-20000 Hz. This will ensure that the rodent can hear the "beep" generated by the speaker when it is time to return to the cage.

- The cage should not close during the designated 2 hour open-cage period under any circumstance unless the emergency "close" button is pressed. This strict requirement will guarantee that the rodent is never locked out of the cage.

2. Design

2.1 Block Diagram

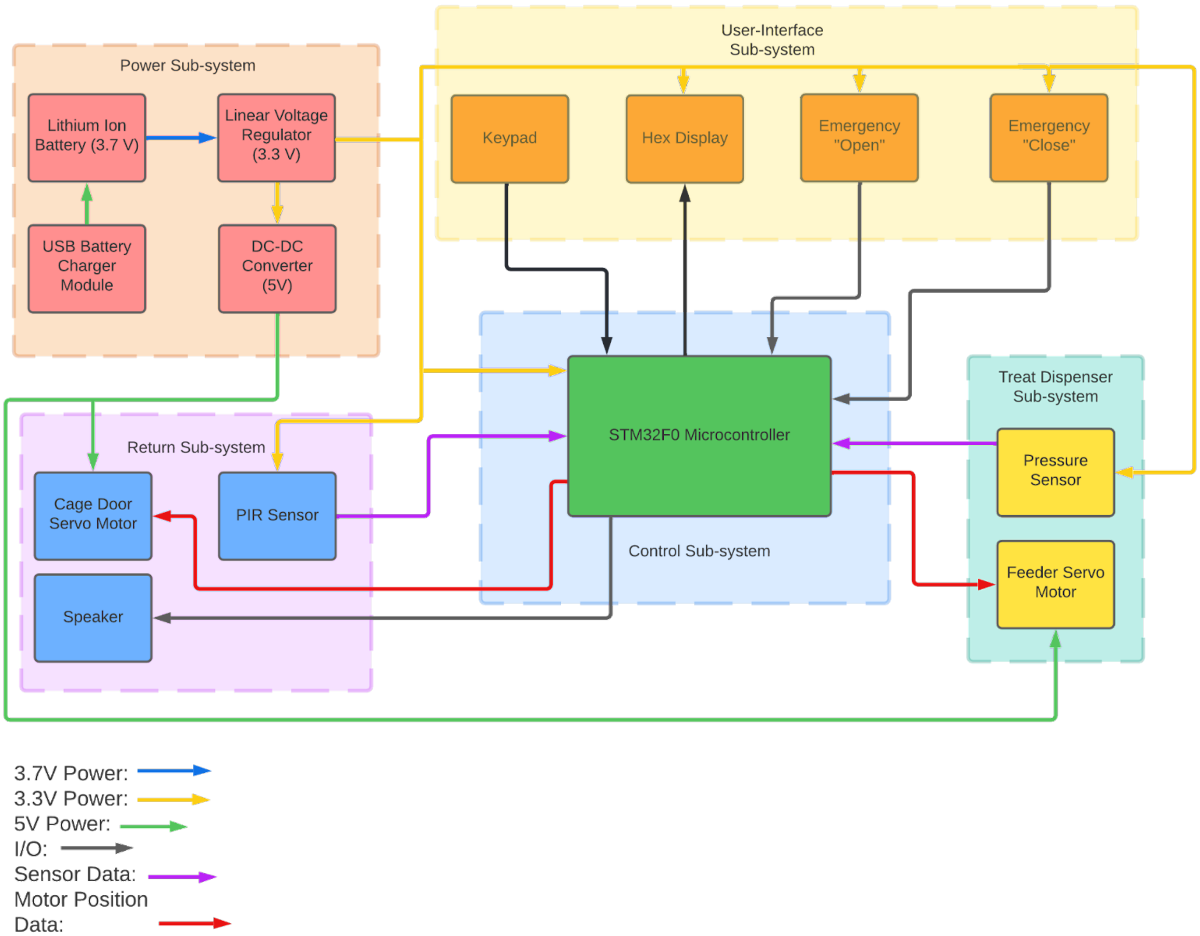

Figure #2: Block Diagram of Overall Design

The Power subsystem provides power to all other subsystems via 3.3V and 5V outputs. The User-Interface subsystem provides the time data input by the user via a keypad and displays the specified time on a 7-segment display. The Return subsystem operates the cage door via a servo motor and PIR sensor and also produces the "beep". The Treat Dispenser subsystem checks if the rat has returned to the cage and dispenses the treat to it via the feeder when required. The Control subsystem consists of just a microcontroller. It processes all the input and sensor data and outputs the motor position data for the Return and Treat Dispenser subsystems. It also outputs I/O voltages to the 7-segment display and speaker.

2.2 Physical Diagram

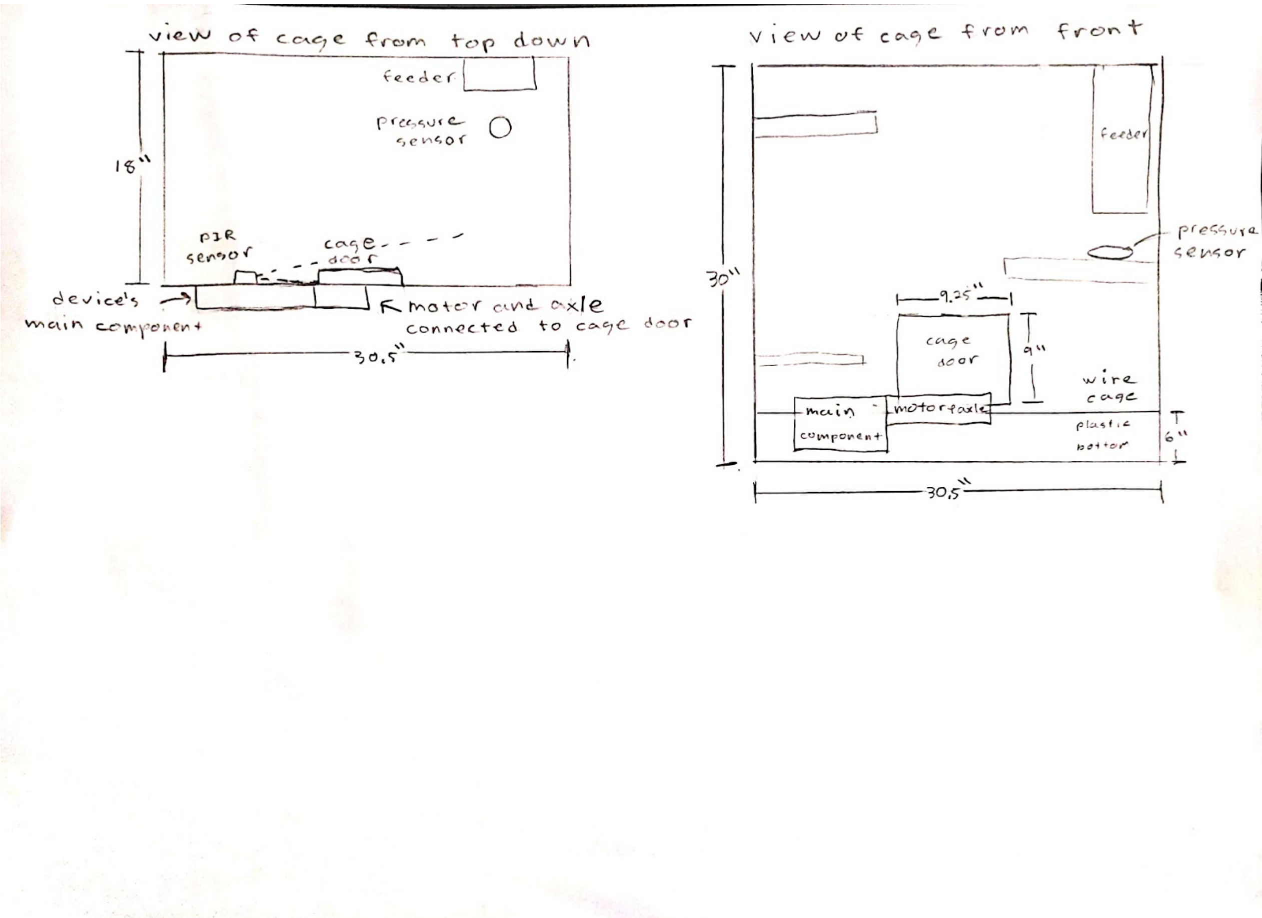

Figure #3: Mechanical Drawing of Proposed Cage

As seen above in Figure 3, the pressure sensor is placed right in front of the feeder because we intend to train the pet to step on the pressure sensor to get the treat. Furthermore, the placement of the feeder is meant to be as further away from the door as possible, to prevent a scenario where the pet learns to step on the sensor, get the treat and run back out. We also attached a PIR sensor to detect motion inside the cage and checks if the pet is in the door's way. The sensor sends a signal to the control system when movement is detected in order to prevent a scenario where the door causes injury to the pet. Finally, the main components such as the user-interface subsystem are placed on the front of the cage for the users' convenience.

2.3 Subsystem Requirements

2.3.1 Power Subsystem:

The power sub-system is necessary for powering the various components utilized in our solution. A 3.7 V Lithium-ion battery will be used as an input to a Linear Voltage Regulator. The regulator will step the 3.7 V down to 3.3 V. The 3.3 V regulator output will then be used to power a 7-segment Display, a microcontroller, a pressure sensor, and a PIR sensor. A DC-DC converter will be used to step up the 3.3 V to 5 V in order to supply the appropriate voltage for two servo motors. An external MCP73831 Battery Charging module will be used to charge the Lithium-ion via USB connection. The Power Sub-system interfaces with every other sub-system in our solution and ensures that each component in a specific sub-system receives the appropriate supply voltage without exceeding the rated current.

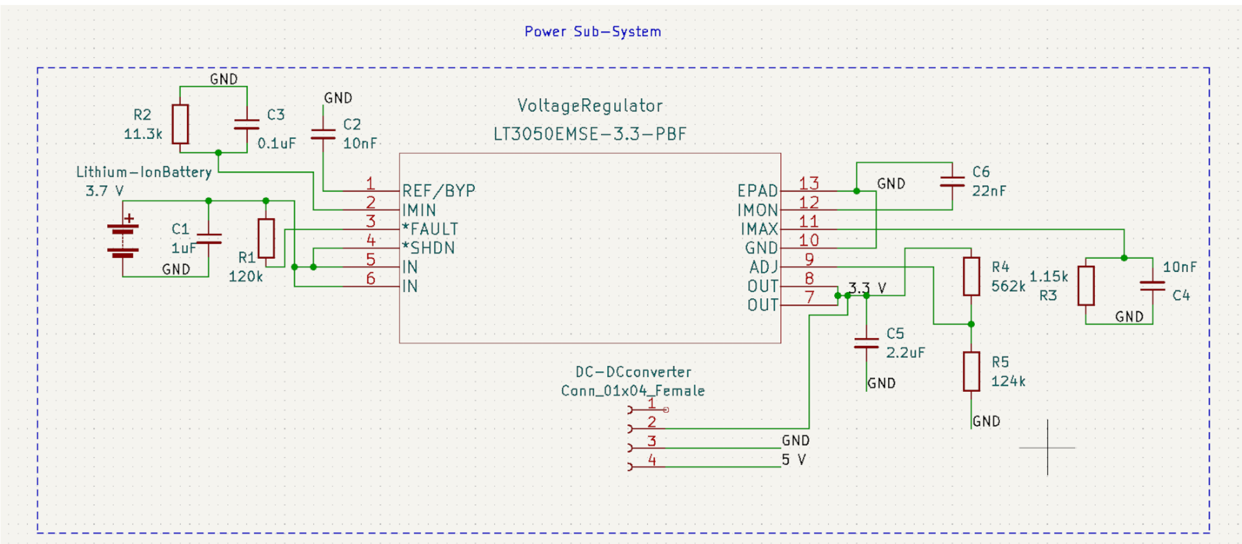

Figure #4: Power Sub-System Schematic

System-Level Requirements:

- The measured output voltage of the linear regulator must be 3.3 V +/- 0.2 V.
- The output voltage of the DC-DC converter must be 5 V +/- 0.4 V.
- The Linear Regulator should supply up to 200 mA to the microcontroller.
- The DC-DC converter should not supply more than 3 A to each servo motor

Requirements	Verification
1. Provide 3.3V +/- 6% from a 3.7 V battery source. 2. Provide 5V +/- 8% from a 3.7 V battery source. 3. Can supply the microprocessor with up to 200 mA current. 4. Do not provide more than 3 A to each servo motor.	1A. Measure the output voltage of the linear regulator using an oscilloscope. Monitor the output to confirm that the output voltage stays within 6% of 3.3 V. 2A. Measure the output voltage of the DC-DC converter using an oscilloscope. Monitor the output to confirm that the output voltage stays within 8% of 5 V. 3A. Connect the 3.3V output to a 100 Ω potentiometer and ground it’s other side. 3B. Measure the current through the resistor using a multimeter. Adjust the resistance of the potentiometer until it’s current reads 200 mA. 3C. Measure the output voltage using an oscilloscope and confirm the voltage stays within 6% of 3.3V. 4A. Use a multimeter to measure the current being delivered to each motor from the DC-DC converter output.

2.3.2 User-Interface Subsystem

The User-Interface sub-system allows the user to manually enter the desired time they would like the cage to open. The user will first enter the current time on a keypad using the following format: “HHMM” where “HH" represents the hour and “MM” represents the exact minute. Then the user will enter the specific cage door opening time in the same format. The “*” button on the keypad will reset the initial input time that was entered. This allows the user to change their selected input time in case new circumstances arise. Furthermore, the “#” key allows the user to immediately open or close the cage. If “#” is pressed while the door is open, the door will immediately close and vice versa. This function will allow the user to manually override the scheduled “open” time in case of any emergency event. This sub-system interacts with the Controller sub-system by sending the appropriate keys that were pressed to the microcontroller. The microcontroller will then process the data and determine the correct “open time” and whether the cage door needs to be opened/closed immediately. The User-Interface sub-system also includes a seven-segment display module. This component interfaces with the Controller sub-system by receiving the appropriate digital input voltage values to each pin such that the correct “open” time selected by the user is displayed in the same format as mentioned above.

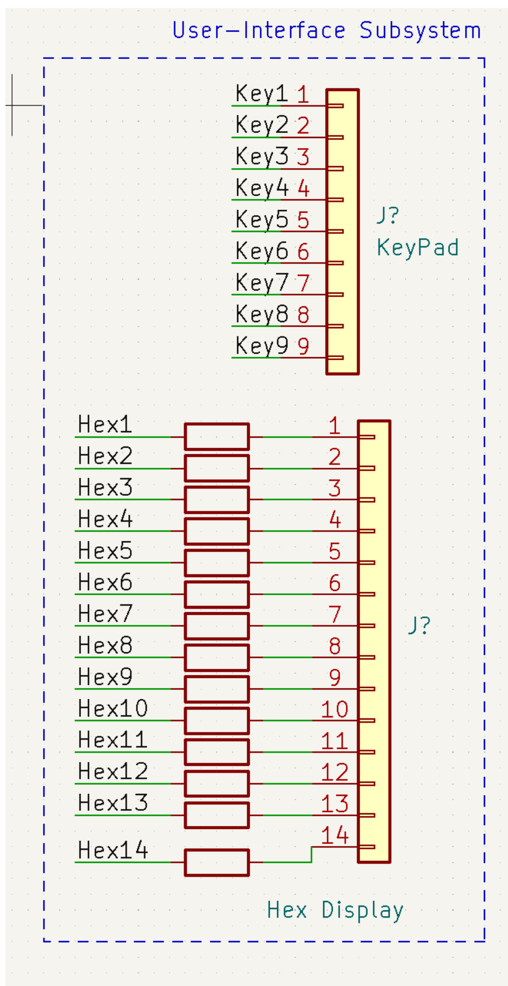

Figure #5: User-Interface Sub-System Schematic

System-Level Requirements:

- The user must be able to reset/clear the selected “open” time by pressing the “*” button.
- The keypad must send the correct time entered by the user to the microcontroller.
- The seven-segment display must be able to display the selected time input processed by the microcontroller.

Requirements	**Verification**
1. The “*” button must be able to reset the selected “open” time. 2. The keypad must output the time entered to the microcontroller. 3. Seven segment display must be able to display the selected time input processed by the microcontroller	1A. First enter an arbitrary time like 12:30 by pressing the 1, 2, 3, and 0 buttons on the keypad. 1B. Press the “*” button on the keypad and check the contents of the seven-segment display. If this works, the display should reveal nothing which means the initial time entered has been reset. 2A. Wire each pin of the keypad to a separate I/O pin in the microcontroller. 2B. Create an array in software that takes in values from the microcontroller I/O pins being used for this test. 2C. Download a keypad matrix library online. 2D. Press an arbitrary key sequence of 1, 2, 5, 0. This represents an “open” time of 12:50. Check the serial monitor to see if the array matches the key sequence that was pressed. 3A. First verify that the 2nd requirement is met such that the microcontroller is able to correctly receive the time entered in the keypad. 3B. Using the datasheet for the seven-segment display module, wire the appropriate pins from the microcontroller to the seven-segment display. Use a 200 Ω resistor in series for each connection. 3C. Power the seven-segment display and examine if the correct time is displayed on the module.

2.3.3 Control Subsystem

The control sub-system consists of just a microcontroller. The microcontroller features a real time clock that is calibrated using a 32.768 MHz crystal. The real time clock and its associated timers are used to determine when the device opens the cage door, and to keep track of the two-hour open cage period. The microcontroller interfaces with the User-Interface sub-system by using the I/O data from the keypad to set the real time clock and specified opening time. It will also send I/O data to display the specified opening time on the seven-segment display. In addition, the microcontroller also interfaces with the Return sub-system by sending the correct position data to the servo motor attached on the cage door so that the door can open or close. The microcontroller will also send position data to the servo motor in the feeder so that food can be dispensed at the appropriate time. To create the “beep”, the microcontroller will send an output signal to the speaker using the tone function. While closing the door, the microcontroller also reads the passive infrared sensor output voltage to determine if an object is in the cage doorway. If motion is sensed, the microcontroller will immediately stop the cage door servo motor to prevent an object from getting caught in between the door and doorway. In addition, the microcontroller also interacts with the Treat-Dispenser sub-system by reading the pressure sensor output voltage to determine when to start closing. The microcontroller converts the pressure senser output voltage from an analog value to digital by utilizing an internal A/D converter. Then, based on the digital value, the microcontroller determines whether the cage door should close and if the feeder should dispense food.

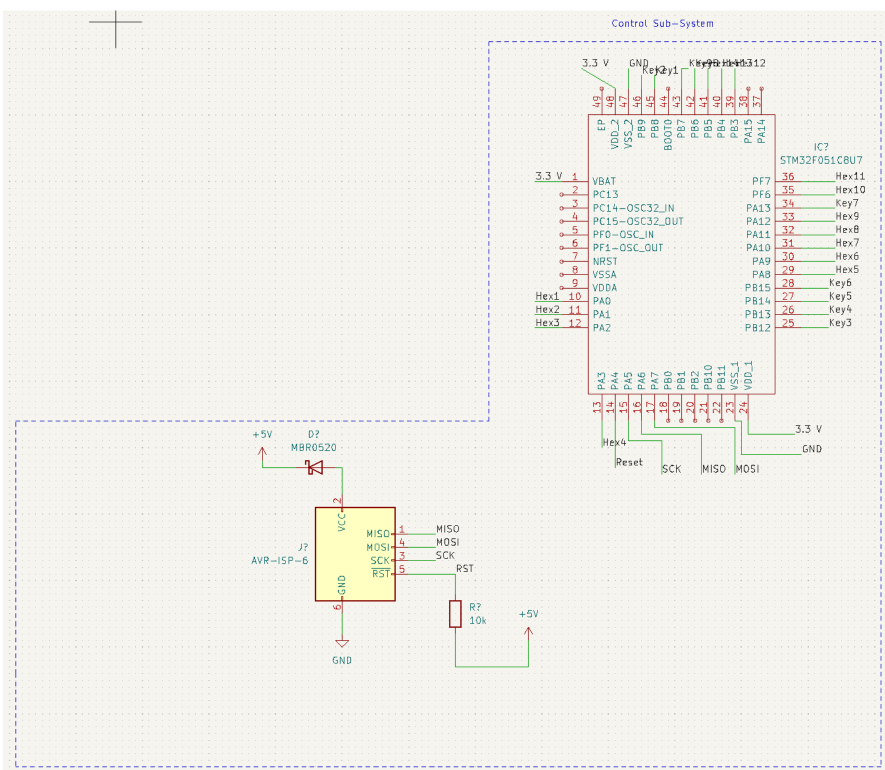

Figure #6: Control Sub-System Schematic

System-Level Requirements:

- The control subsystem must be able to set and keep track of the real time ± 1 minute.
- The control subsystem must send a digital high signal to the speaker 2 hours ± 1 minute after the programmed time has been reached.
- The microcontroller should only check if the pressure sensor is triggered until after the two hours timer has finished. If the pressure sensor is triggered before the two hours are over, nothing should happen.

Requirements	**Verification**
1. The microcontroller should only check if the pressure sensor is triggered after the two hours timer has finished. 2. The control subsystem must send a digital high signal to the speaker 2 hours ± 1 minute after the programmed time. 3. The control subsystem must be able to set and keep track of the real time ± 1 minute.	1A. Place a 250 g weight on the pressure sensor before the two hours are done and make sure the door doesn't move and the feeder doesn't release any food. 2A. Set a desired time for the cage to open and ensure the speaker beeps two hours after the door opens. 3A. Make sure time displayed on seven segment display is coherent with real time. 3B. If for some reason the seven-segment display is not working, use the serial monitor in software to print the time read by the microcontroller and compare with the actual time. .

2.3.4 Treat Dispenser Subsystem

The Treat Dispenser sub-system is comprised of a thin-film pressure sensor pad and a feeder. The pressure sensor is placed inside the cage between the feeder and the door as shown in Figure 1. The pressure sensor acts as a Force Sensitive Resistor (FSR). As the force applied on the pad increases, the resistances decrease [2]. The FSR will be included in a voltage divider circuit. When the rodent is not stepping on the pressure pad, the FSR resistance and voltage will be at a maximum. Once the rodent steps on the pad, the resistance will quickly decrease, and the voltage will reach a sufficiently low threshold voltage. The Control system interacts with the Treat Dispenser sub-system by reading the analog voltage of the FSR output. The microcontroller than converts this to a digital value using an internal A/D converter. If more than 2 hours have passed since the cage was first opened and if the FSR threshold voltage has been reached, the microcontroller will send a pulse to the feeder motor which will then dispense a treat for the rodent. The feeder consists of a food container attached above a plastic wheel. The food container and the wheel will both have a hole drilled through their structures. The feeder servo motor will control the position of the wheel. Therefore, when food needs to be dispensed, the servo motor will position the wheel such that its hole lines up with the food container's hole, allowing the food to fall into a bowl. We will use Cheerios as the choice of food. This option is perfectly safe and ethical for a rodent to consume [4]. Furthermore, the feeder will dispense at least 20 grams of food each day since rodents consume anywhere from 15-20 grams of food in a given day.

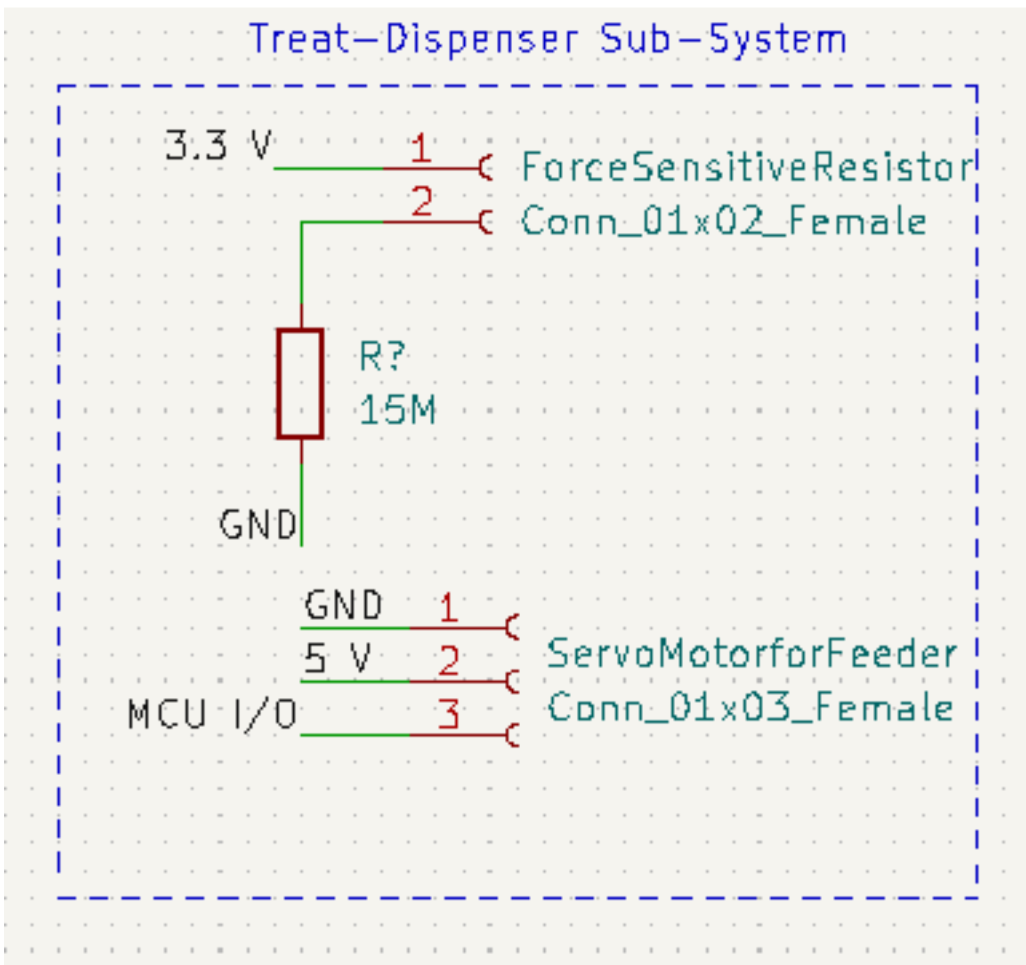

Figure #7: Treat-Dispenser Sub-System Schematic

System-Level Requirements:

- The feeder should be able to dispense at least 20 grams of food.
- The sub-system must be sensitive enough to detect a 250–500-gram rodent.
- The feeder should not dispense food at all if any force below 225 grams (+/- 3 g) is applied to the pressure sensor.

Requirements	**Verification**
1. The feeder should be able to dispense at least 20 grams of food. 2. The sub-system must be sensitive enough to detect a 250–500-gram rodent. 3. The feeder should not dispense food at all if any force below 225 grams (+/- 3 g) is applied to the sensor	1A. Enter an arbitrary "open" time using the keypad. 1B. Once 2 hours after the "open" time has been reached, place a 300 g weight on the pressure sensor. 1C. If the feeder correctly dispenses the cheerios, measure the weight of the food using a scale. 2A. Once again enter an arbitrary "open" time using the keypad. 2B. Once 2 hours after the "open" time has been reached, place a 250 g weight on the pressure sensor. Confirm whether the cage door closes as it should. 2C. Repeat steps 2A and 2B using heavier weights up to 500 g. 3A. Repeat step 2A. Once 2 hours after the "open" time has been reached, place a 100-gram weight on the pressure sensor. 3B. Observe whether the feeder dispenses food. If it doesn't, the system has worked correctly. 3C. Repeat steps 3A and 3B for various weights between 0-225 grams.

2.3.5 Return Subsystem

The Return Sub-System has three main components: a servo motor, a piezoelectric speaker, and a passive infrared sensor. The servo motor will be mounted to the cage with an axle and is used to open and close the cage door. The Control sub-system interfaces with the Return sub-system by controlling the position of the servo motor through the use of a PWM pulse which will allow the cage to open or close. After the designated two hour open cage period, the microcontroller will send an audio output to the speaker. The audio will play a “beep” noise so that the rodent knows to return. The passive infrared sensor will be positioned to sense movement along a plain near and parallel to the cage doorway. While the cage door is closing, the microcontroller will check the output of the sensor and immediately stop the motor if any motion is detected. This will prevent anyone or anything from blocking the cage door and getting pinched between the cage door and doorway. Finally, the Power sub-system also interacts with the Return sub-system by supplying the appropriate voltages to power each device. The servo motor will be powered by the 5 V DC-DC converter output while the PIR sensor will be powered by the 3.3 V output of the linear regulator.

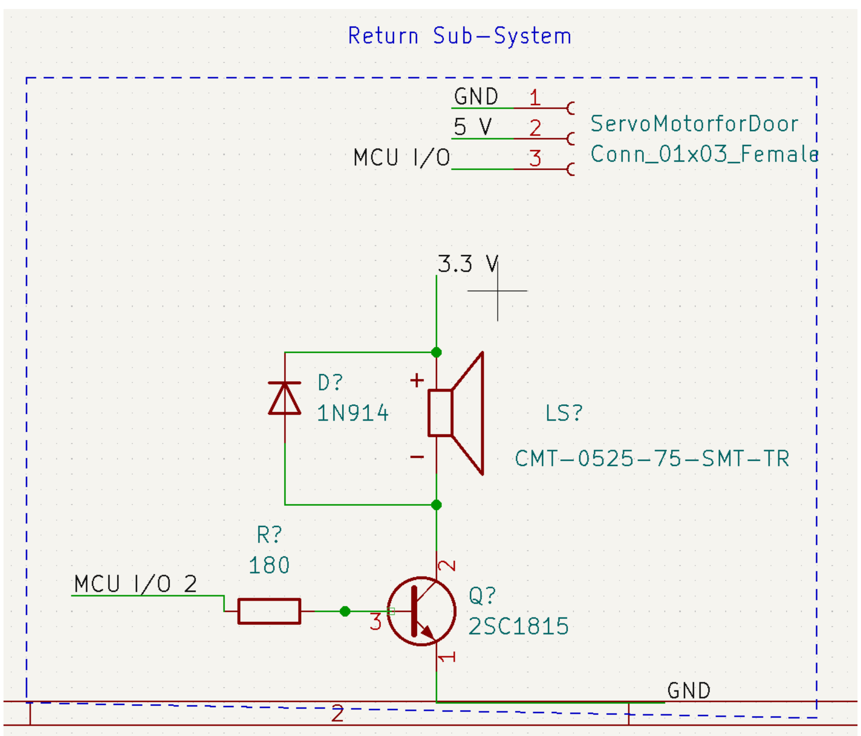

Figure #8: Return Sub-System Schematic

System-Level Requirements:

- The servo motor must be able to rotate the door such that it completely opens or closes. If the door is to be open, it should not obstruct the rodent in any way. Similarly, if the door should be closed, there should be no way for the rodent to leave the cage.
- After 2 hours [+/- 1 minute] of the cage door opening, the speaker must play a 2 second [+/- 20 ms] “beep” every 15 minutes [+/- 1 minute] until the pet triggers the pressure sensor.
- The passive infrared sensor must detect if an object is in the cage’s doorway during closing without fail. This is to ensure the safety of the user and the pet.

Requirements	Verification
1. The servo motor must rotate between positions θ_{Open}** and θ_{Closed}** within +/- 3° with commands from the microprocessor. 2. The servo motor must completely open or close the cage door, from θ_{Open} to θ_{Closed} and θ_{Closed} to θ_{Open}, within 3 seconds +/- 0.5 second. 3. The servo motor must support up to 1 kg of weight on top of the cage door while remaining in the position +/- 3° of θ_{Open}. 4. The speaker must output a tone between 60 - 70 dBA measured at a distance of 3 m from the speaker. ****(Note that exact degree values for θ_{Open} and θ_{Closed} are unknown until the axel is built by the machine shop. These values will be determined experimentally once that part of the device is built and edited into this requirement. For now, understand that θ_{Open} represents the angle of the motor where the cage door is fully open and θ_{Closed} represents the angle of the motor where the cage door is fully closed.)**	1A. Set the time on the device so that the cage door will open soon. Verify that the position of the motor is at +/- 3°of θ_{Closed} using a protractor. 1B. Once the cage door opens, verify that the position of the motor is at +/- 3°of θ_{Open} using a protractor. 1C. When the cage door closes, verify that the position of the motor is back to +/- 3°of θ_{Closed} using a protractor. 2A. While completing verification 1, measure the time from when the motor starts rotating to when it finishes in position θ_{Open} using a stopwatch. 2B. As the cage door closes, measure the time from when the motor starts rotating to when it finishes in position θ_{Closed} using a stopwatch. 3A. Set the time on the device to open the cage door. Once the motor is in the θ_{Open} position, place a 250 g weight on top of the opened cage door. Measure the angle of the motor using a protractor to verify it remains at position +/- 3° of $\theta_{Open.}$ 3B. Continue adding 250 g weights on top of the opened cage door until the total weight is 1 kg. Each time, measure the angle of the motor using a protractor to verify it remains at position +/- 3° of $\theta_{Open.}$ 4A. Set the device up so that the cage door is about to close (this can be done while completing verifications 1 & 2). Place a decibel meter 3 m away from the speaker. Measure the dBA of the ambient noise as a reference. 4B. While the device beeps, measure the reading of the meter and verify that the speaker's beep is between 60-70 dBA.

2.4 Schematics

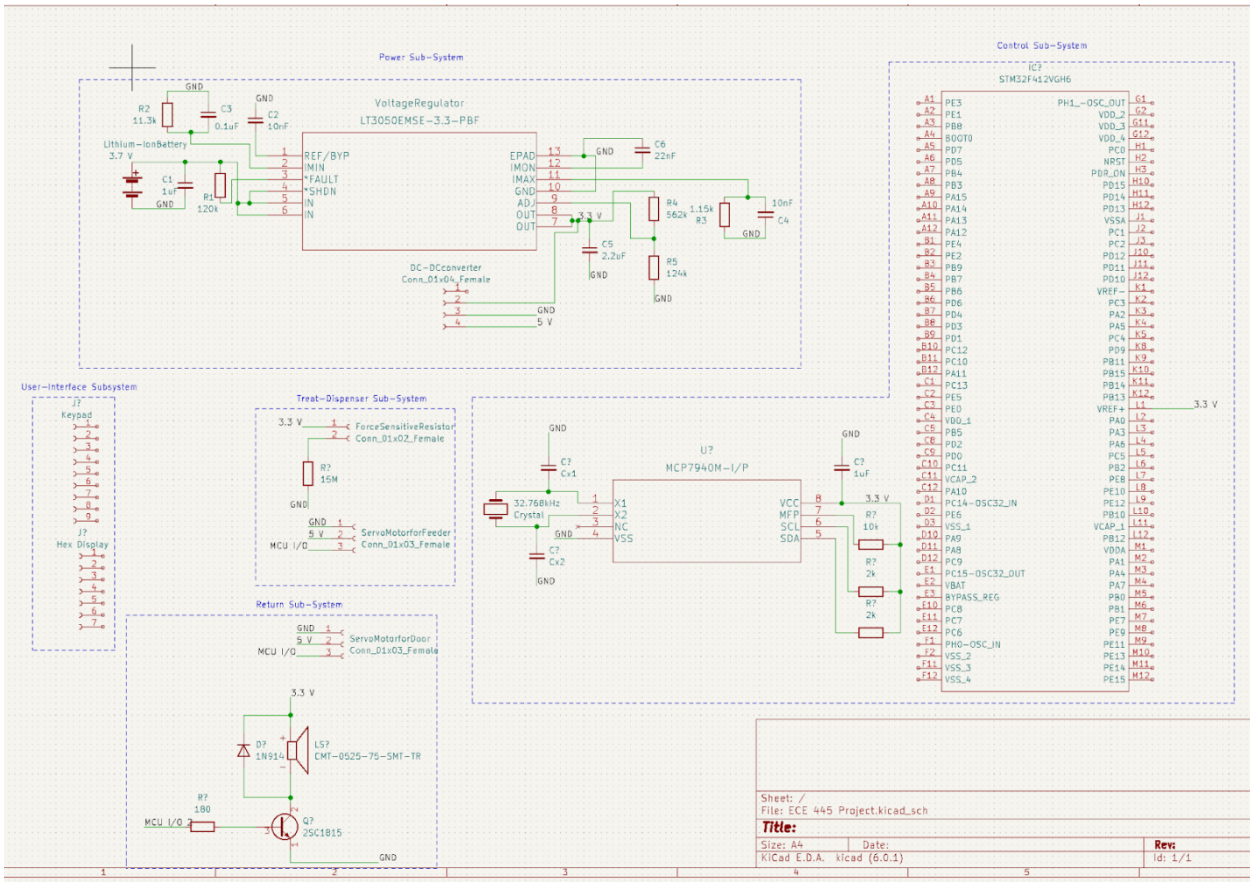

Fig 9: Overall Schematic

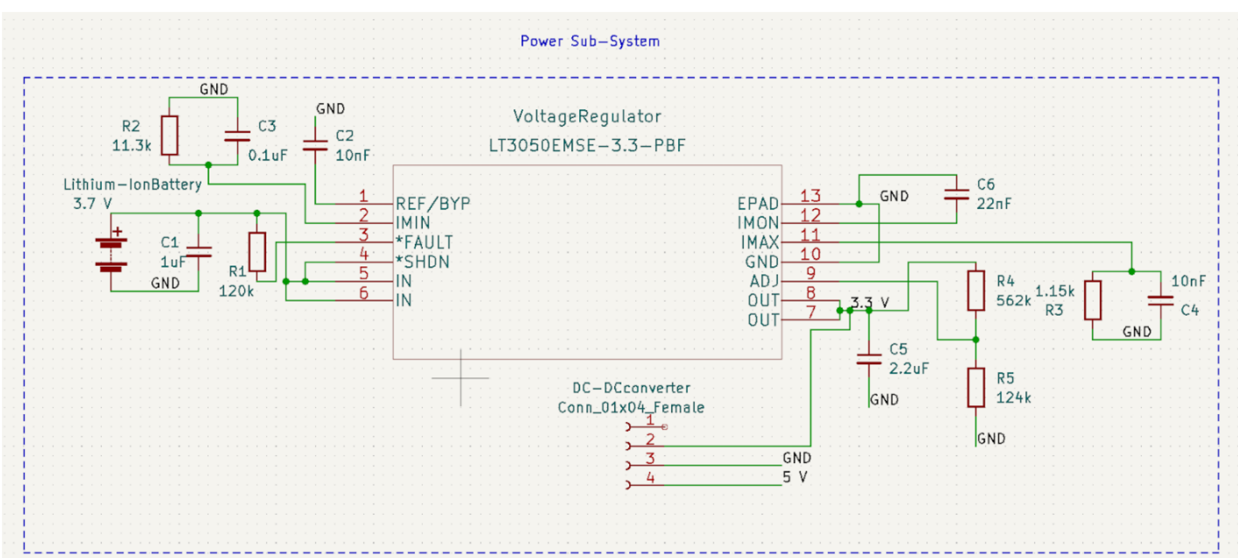

Figure 10: Power Sub-System Schematic

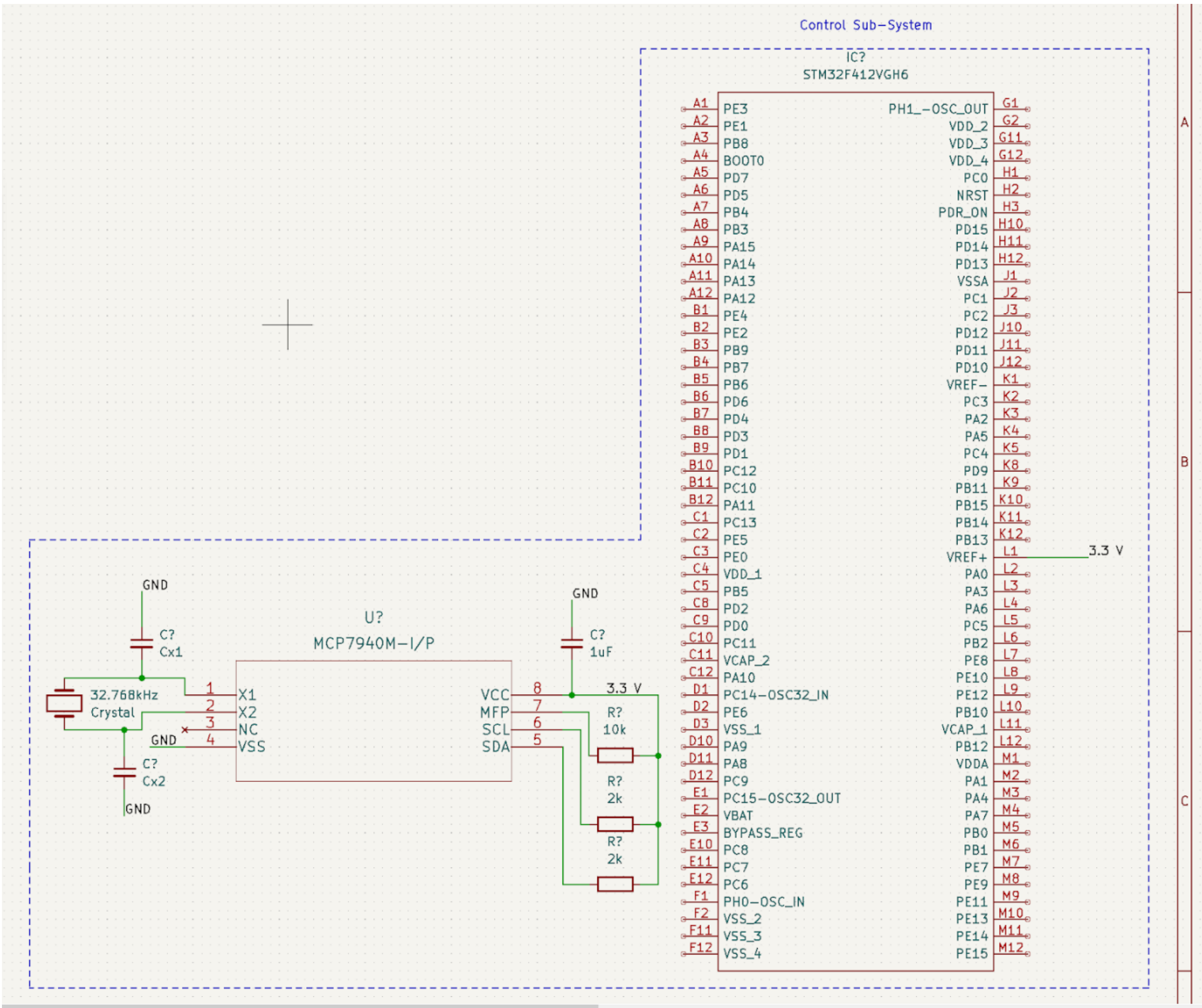

Figure 12: Control Sub-System Schematic

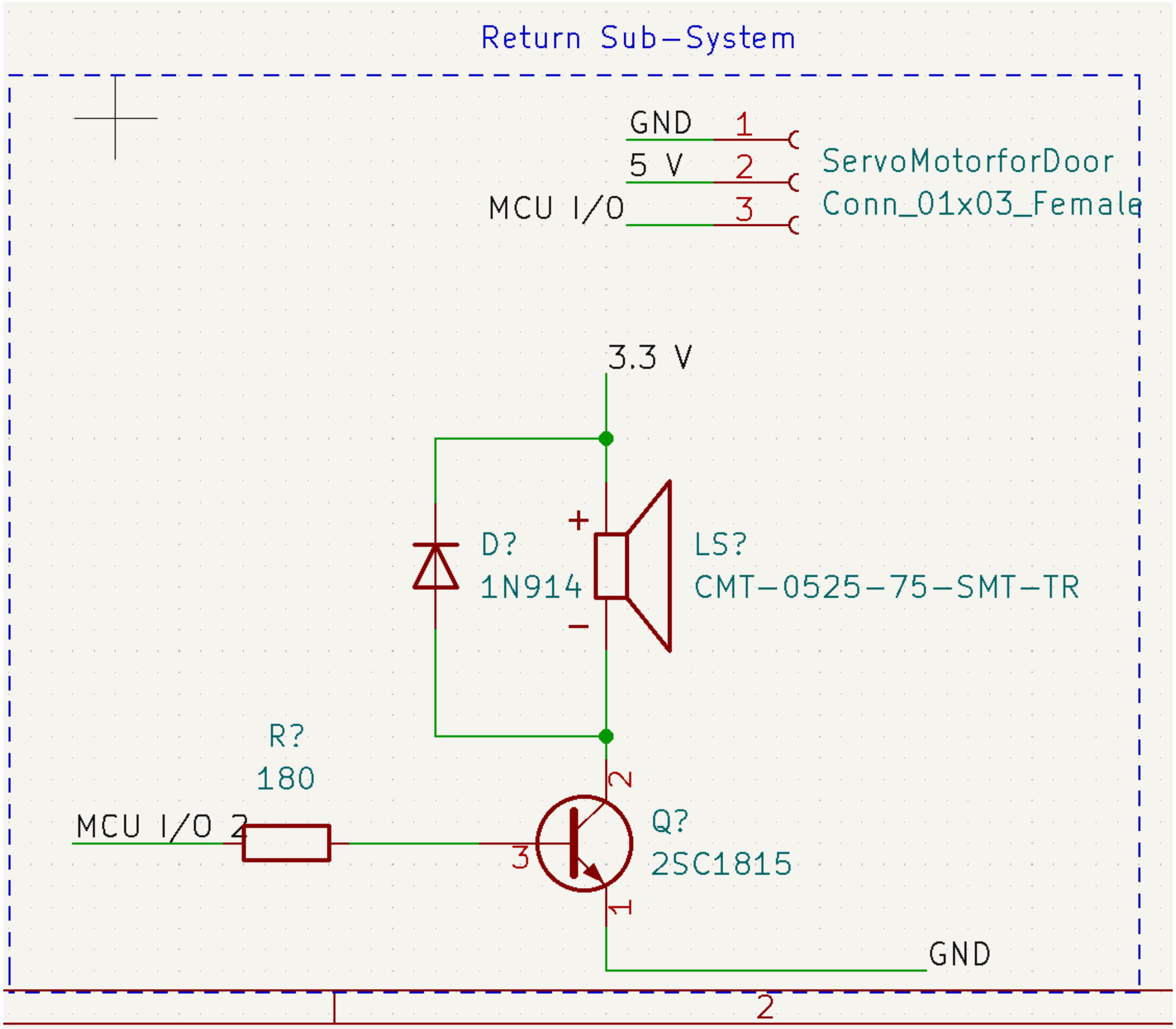

Figure 13: Return Sub-System Schematic

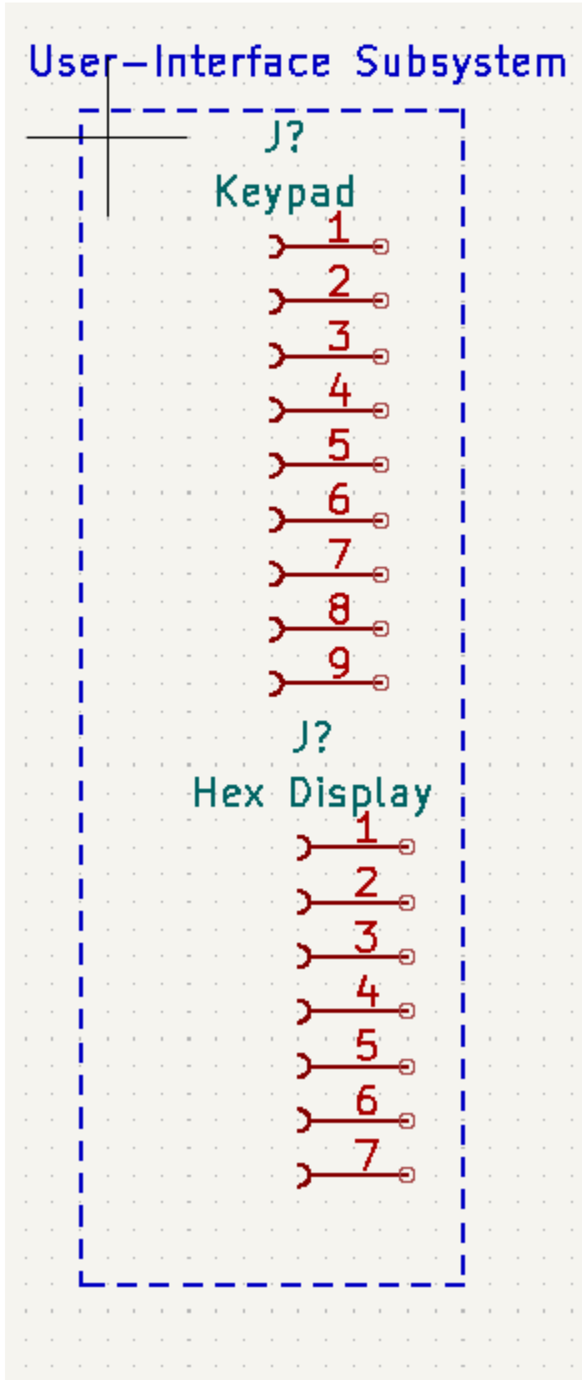

Figure 14: User-Interface Subsystem

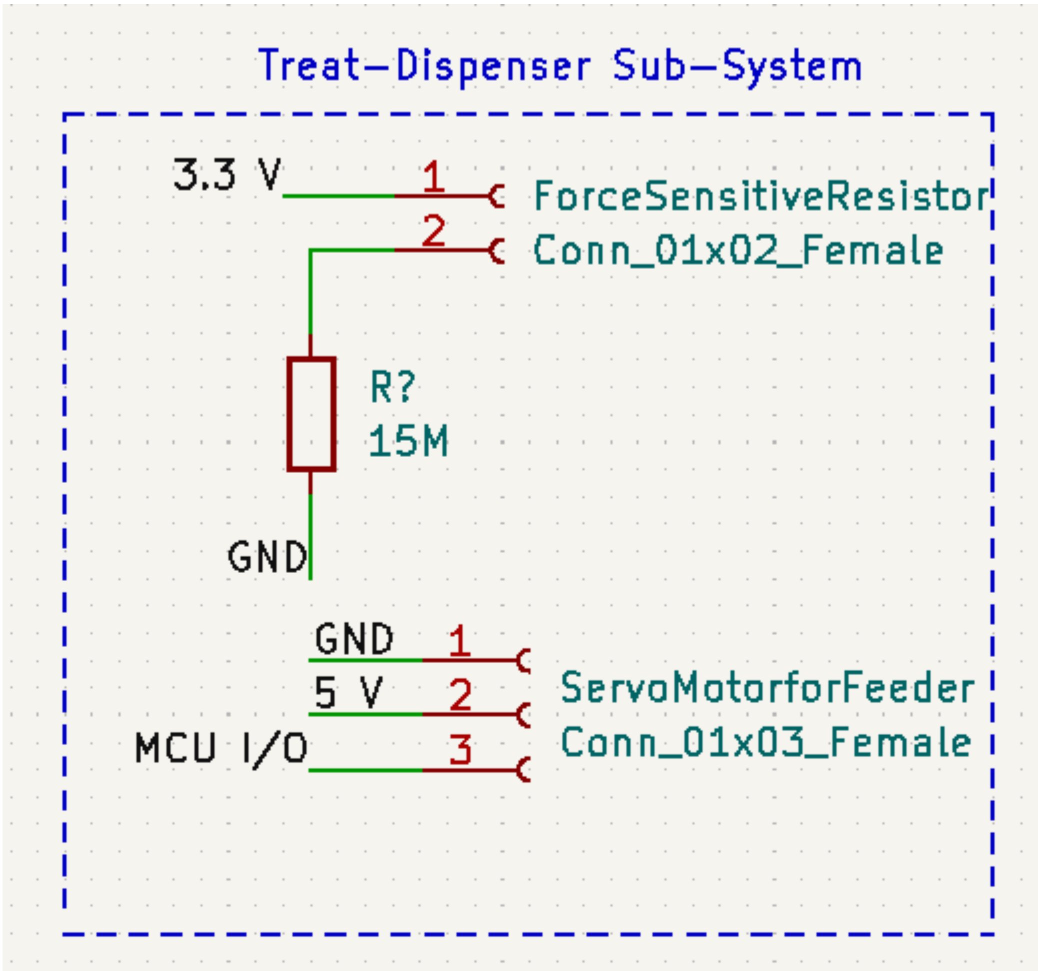

Figure 15: Treat Dispenser Sub-System

Tolerance Analysis:

One feature that may pose a risk for the project is the voltage divider circuit that is used with the FSR pressure sensor. Careful consideration should be placed into selecting a resistor value in parallel with the FSR. A "false alarm" scenario in which the control system determines the pressure sensor has been activated even though the rodent is not located on top of the pressure pad could be disastrous and would cause the rodent to be locked out of the cage. For our solution, we have decided to utilize the SEN0294 thin-film pressure sensor. The initial output resistance with no force applied is around 10 MΩ. Figure #10 displays a graph of the output resistance vs the weight applied. The resistance, measured in MΩ, is related to the weight, in grams, according to the following equation:

$$\text{Output Resistance} = 153.18(\text{Weight})\text{-}0.699$$

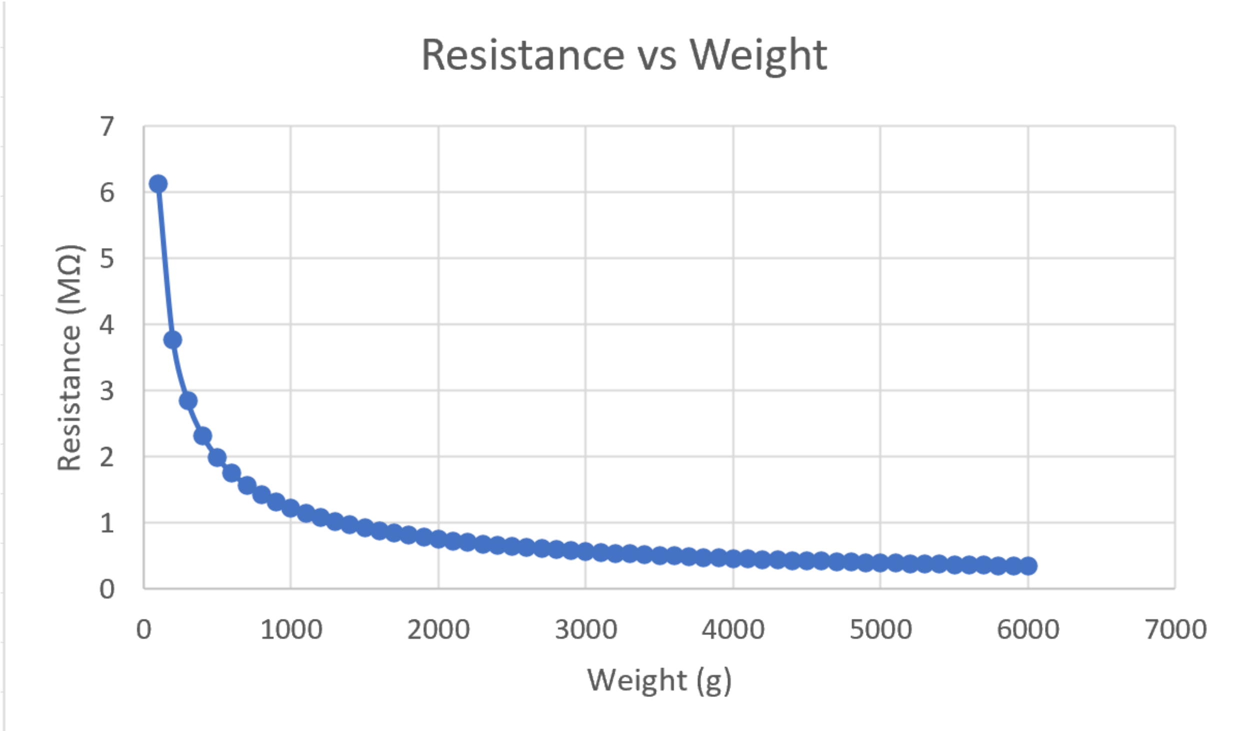

Figure #16: FSR Resistance vs Weight

The average weight of an adult rat is between 250-500 grams [1]. Using the lower bound of 250 grams, we see that the maximum output resistance with the rodent on the pressure pad will be around 3.23 MΩ. If we design a voltage divider using the output resistance in parallel with a resistor, we can use the output voltage across the FSR to determine whether the rodent has activated the sensor. If we take 20% of V_{DD} to be the “trigger” voltage, we see that any voltage appearing across the FSR below 0.66 V (.20*3.3 V = 0.66 V) will mean that the rodent has activated the sensor. Therefore, we can solve for the minimum resistance needed by using the voltage divider equation:

$$0.66\ V = 3.3\ V*(3.23\ M\Omega)3.23\ M\Omega + R$$

After solving the equation, we get R = 12.92 MΩ meaning any resistor above this value will work. The microcontroller will convert the analog voltage across the FSR into a 12 bit digital value using an internal A/D converter and will check if this value is below 819 (0.2*(212-1)). From these calculations, we have observed that the pressure sensor should correctly identify whether or not the rodent has returned inside the cage as long as we use an appropriate resistor calculated above.

3. Cost and Schedule

Cost Analysis:

The average salary of an Electrical Engineering graduate from the University of Illinois at Urbana-Champaign was $79,714 in the 2018-2019 school year [3]. This is equivalent to an hourly pay of about $38.32. We plan on working for an average of 12 hours each week. Since there are 14 weeks in a semester we can calculate the total labor cost for each person.

Labor Cost = (Hourly Pay)*(Average Hours per Week)*(Total Weeks in Semester)

Labor Cost =($38.32)*(12 hours/week)*(14 week) = $6,437.76

Name	Hourly Pay	Total Hours	Total Cost
Saurav Kumar	$38.32	168	$6,437.76
Christina Hejny	$38.32	168	$6,437.76
Avram Fouad	$38.32	168	$6,437.76
			$19,313.28

Parts:

Name	**Description**	**Manufacturer**	**Part #**	**Quantity**	**Cost**	**Ext Cost**
Keypad	COM-14662 KEYPAD - 12 BUTTON	SparkFun Electronics	1568-1856-ND	1	$4.50	$4.50

Pressure Sensor	RP-C18.3-ST THIN FILM PRESSURE S	DFRobot	1738-SEN0294-ND	2	$5.00	$10.00
Microcontroller	ARM Microcontrollers - MCU Mainstream Arm Cortex-M0 Access line MCU 64 Kbytes of Flash 48 MHz CPU, motor co	STMicroelectronics	511-STM32F051C8U7	1	$4.28	$4.28
7-Segment Display	1001 DISP 7SEG 0.56" QUAD WHT 14DIP	Adafruit Industries LLC	1528-1513-ND	1	$4.95	$4.95
Lithium Battery	BATTERY LITHIUM 3.7V 2.5AH	Adafruit Industries LLC	1528-1840-ND	1	$14.95	$14.95
DC-DC converter	DC DC CONVERTER 5V 5.6W	Pololu Corporation	2183-2123-ND	1	$10.61	$10.61
Voltage Regulator	IC REG LINEAR 3.3V 100MA 12MSOP	Analog Devices Inc.	LT3050EMSE-3.3#PBF-ND	1	$4.72	$4.72
USB battery charger	LI-ION LI-POLYMER CHARGER BOARD	Adafruit Industries LLC	1528-1833-ND	1	$6.95	$6.95
Servo Motor	SERVOMOTOR 6V FEETECH HI-TORQUE	Pololu Corporation	2183-3426-ND	2	$19.45	$38.90
Speaker	BUZZER MAGNETIC 3V 5X5MM SMD	CUI Devices	102-CMT-0525-75-SMT-TR-ND - Tape & Reel (TR)	2	$2.03	$4.06

Infrared Sensor	MOTION SENSOR	Murata Electronics	490-11915-ND	1	$3.07	$3.07
Crystal	CRYSTAL 32.768KHZ 9PF SMT	Fox Electronics	631-FK135EIWM0.032768-T3TR-ND - Tape & Reel (TR)	1	$1.49	$1.49
Subotal						**$108.48**
Quoted Machine Shop Labor Hours	3 days	8 hours per day	56 $/hr			$1344.00
Quoted Team Labor Hours						$19,313.28
Total						$20,765.76

Schedule

Week	Saurav Kumar	Christina Hejny	Avram Fouad
2/21	Complete Design Document, Meet with Machine Shop to discuss Feeder Implementation, Start PCB Design, Create Flowchart of overall system, Prepare for Design Review, Order Parts	Complete Design Document, Meet with Machine Shop to discuss Feeder Implementation, Start PCB Design, Select New Microcontroller, Prepare for Design Review, Order Parts	Complete Design Document,Meet with Machine Shop to discuss Feeder Implementation, Start PCB Design, Order 1st round of parts, Prepare for Design Review, Order Parts
2/28	Finalize PCB Design and submit for Review, Take a look at code for generating speaker sound and Test on Breadboard	Finalize PCB Design, Simulate Pressure Sensor Resistance with her Rat, Hand over the Cage to Machine Shop	Finalize PCB Design, Test Power System on Breadboard,

3/7	Work on necessary changes to PCB if needed, Write code for Microcontroller to correctly gather input time from Keypad	Solder Parts onto PCB, Unit Test Servo Motor for the door and take measurements ono rotation angle	Write Code for Microcontroller to display user input time on 7-segment Display, Debug Power Sub-System if necessary
3/14	Spring Break	Spring Break	Spring Break
3/21	Write Code to read Analog Voltage at Ouput of FSR voltage divider, Debug any troublesome Sub-Systems	Finalize code for correctly opening and closing Cage Door, Debug any troublesome sub-systems	Begin writing code for Feeder to dispense food Order any remaining parts needed and fix any mistakes in PCB Design
3/28	Begin Wiring any required sub-systems together and enclose wires with Conduit Protective covering,	Make any necessary changes to cage design if needed, Begin training the rat on how to properly use our solution if necessary	Unit test Feeder Sub-System and ensure that it dispenses food at the correct time
4/4	Start testing overall design with everything together, take videos of results as well as any quantitative measurements, conduct any troubleshooting if required	Start testing overall design with everything together, take videos of results as well as any quantitative measurements, conduct any troubleshooting if required	Start testing overall design with everything together, take videos of results as well as any quantitative measurements, conduct any troubleshooting if required
4/11	Prepare for mock demo, conduct last-minute changes if needed	Prepare for mock demo, do conduct last-minute changes if needed	Prepare for mock demo, conduct last-minute changes if needed
4/18	Prepare for presentation	Prepare for presentation	Prepare for presentation
4/25	Work on final paper	Work on final paper	Work on final paper
5/2	Finalize lab notebook and teamwork evaluation.	Finalize lab notebook and teamwork evaluation.	Finalize lab notebook and teamwork evaluation.

4. Ethics and Safety:

We predict that three ethics and safety issues will arise during the development of our project. The first one would be the pet chewing on any of our wires. To resolve this problem, we will make sure all wires used are placed in a manner inaccessible to the pet. We will also use steel conduit coverings to protect any vulnerable wires. These are highly protective against rodents and will ensure that our wires won't be damaged or exposed [5]. The second issue would be the pet under eating due to the owner's failure to train the pet on how to use the feeder or the food getting stuck in the feeder. To resolve first issue, we will closely monitor the pet's behavior to make sure it is correctly using the new cage and we will also make sure to inform anyone who uses our project in the future that training the pet is their responsibility. To resolve the second issue, we picked a high torque servo motor for our feeder system which will drive a wheel beneath the dispenser to crush any treats that cause a blockage in the dispenser. On the other hand, we want to make sure the food in the dispenser's storage isn't accessible to the pet to avoid the scenario where the rodent finds it and overeats. We aim to tackle this problem by placing the dispenser in a high corner to prevent the rodent from eating its way through it and finding all the treats. The third issue is if the pet came in the way of the door while it is closing, which could cause injury to the pet. To prevent this, we will use an PIR sensor mounted on the side of the door, so that it senses if the pet is in the way and sends a signal to the control subsystem that the door must be reopened. IEEE code I1 states how we must "hold paramount the safety, health, and welfare of the public" [6]. The safety of the pet rodent is essential for our project. We believe that by addressing these concerns, our device will be able to operate in a safe and ethical manner.

5. Citations:

[1] Ades, Emily. “Species Specific Information: Rat.” *Johns Hopkins University*, Mar. 11 2009. [Online]. Available: https://web.jhu.edu/animalcare/procedures/rat.html. [Accessed Feb. 18, 2022]

[2]DFRobot, “RP-C18.3-ST Thin Film Pressure Sensor,” SEN0294 datasheet. [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/SEN0294_Web.pdf. [Accessed Feb. 10, 2022]

[3]Electrical and Computer Engineering Department, “Salary Averages,” ece.illinois.edu, table 1, 2022. [Online]. Available: https://ece.illinois.edu/admissions/why-ece/salary-averages. [Accessed Feb. 18, 2022].

[4]E. Adams, “A List of Safe and Dangerous Foods for Your Pet Rat,” pethelpful.com, Mar. 31, 2021. [Online]. Available: https://pethelpful.com/rodents/Rat-Nutritional-Information-Can-my-Pet-Rat-Eat-This#:~:text=Dry%20cereal.,krispies%20and%20other%20sugary%20choices. [Accessed Feb. 18, 2022].

[5]White Electric, “How To Protect Electrical Wiring From Rodents,” white-electric.com, Mar. 7, 2021. [Online]. Available: https://white-electric.com/2021/electrical-safety/how-to-protect-electrical-wiring-from-rodents/. [Accessed Feb. 18, 2022].

[6]IEEE, “7.8 IEEE Code of Ethics,” *Institute of Electrical and Electronics Engineers,* ieee.org, 2022. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed Feb. 3, 2022]