Automated pet cage

ECE 445 Design Document

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1. Introduction

1.1 Problem:

I have a pet rat and as every good rat owner knows, rats and many other pet rodents need plenty of daily enrichment time outside the cage. During days when I have a lot of schoolwork, I am often too busy to walk back to my apartment, let him out, then walk back to where I was working. The crux of the problem is that I have to manually open the cage door. Having an automatic door would mean that the rat could get let out of his cage every day and enjoy his necessary enrichment even when I'm stuck in ECEB all day working. Many busy rat and rodent owners have this same issue. A device that solves this problem would make taking care of your pet rodent much easier and more flexible. It would allow for people with inconsistent and busy schedules to enjoy the benefits of having a pet rodent without sacrificing the rodent's well-being.

1.2 Solution:

For this problem we propose an automated rodent cage. The device will hook onto the outside of a cage door and will include a feeder and pressure sensor inside the cage. The user will first enter a desired time to open the cage using a keypad on the device. Once this specified time is reached, the cage door will open letting the pet out. The solution utilizes a compact servo motor to rotate the door along its hinge to fully open or close it. The servo motor is governed by a control unit that uses a real time clock IC to determine when to open the door. The desired time that was entered by the user will also be displayed using a HEX display. In addition, there are "open" and "close" buttons that immediately open and close the door in case of any emergency.

Once the time entered by the user is reached, the cage will open for at least 2 hours and then begin the closing process. Once the cage has been open for exactly 2 hours, the device will "beep", letting the rodent know it's time to re-enter the cage. Once the rodent has re-entered the cage, it will step on a thin-film pressure sensor pad. Upon activating the pressure sensor, the cage door will begin to close. Once the door has fully closed, the feeder will dispense a treat to the pet. The idea behind the "beep" and feeder system is to train and reinforce the rodent to enter the cage every day (similar to a skinner box). The pet can be easily trained to understand the "beep" means to re-enter the cage and get a treat.

The device will be powered using a lithium-ion battery. A microcontroller will interface with the keypad and communicate with the real time clock IC using I2C communication. Once the microcontroller determines when the desired time entered by the user is reached, it will send a pulse to the servo motor which will open the cage door. A programmable timer IC will then be initiated for two hours. Once the timer reaches two hours, the microcontroller will send a pulse to a speaker to play the "beep". Once the rodent returns to the cage it will first step on the pressure sensor. The microcontroller will then receive the signal from the pressure sensor and send a pulse to the servo motor to close the cage. If the pressure sensor is activated before the 2-hour timer, it will simply be ignored and not close the cage. Once the cage is closed, the microcontroller will send a signal to the feeder to drop the treat.

1.3 Visual Aid:

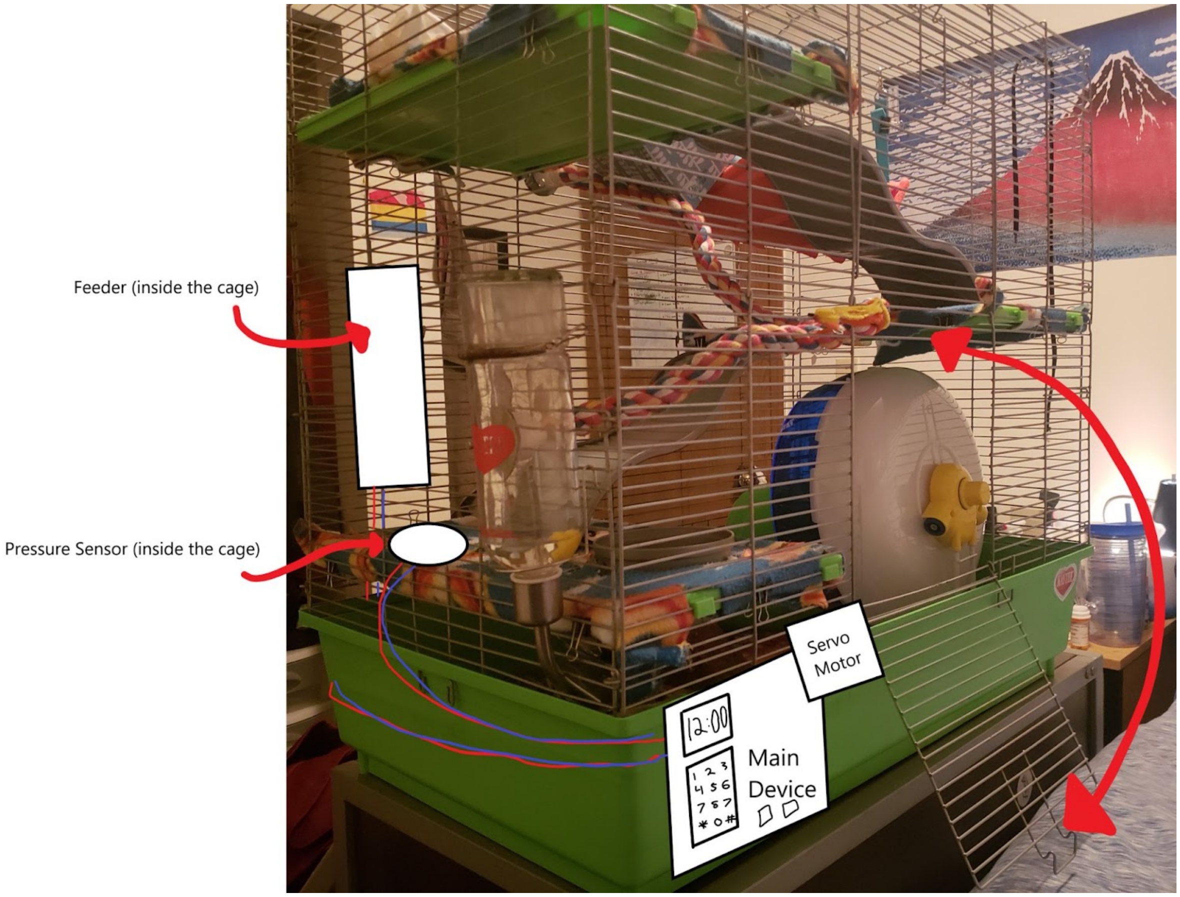

Figure 1

1.4 High-level Requirements

- If the cage has been open for at least 2 hours, 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 at least 65 dB in amplitude. Furthermore, the frequency of the noise generated should be at least 200 Hz. Both these requirements will allow the rat to hear the "beep" generated by the speaker when it is time to return to the cage.
- The cage should not close before being open for under 2 hours under any circumstance unless the emergency "close" button is pressed. In addition, the feeder should not dispense a treat if the door has been open for less than 2 hours, even if the emergency "close" button is pressed.

2. Design

2.1 Block Diagram

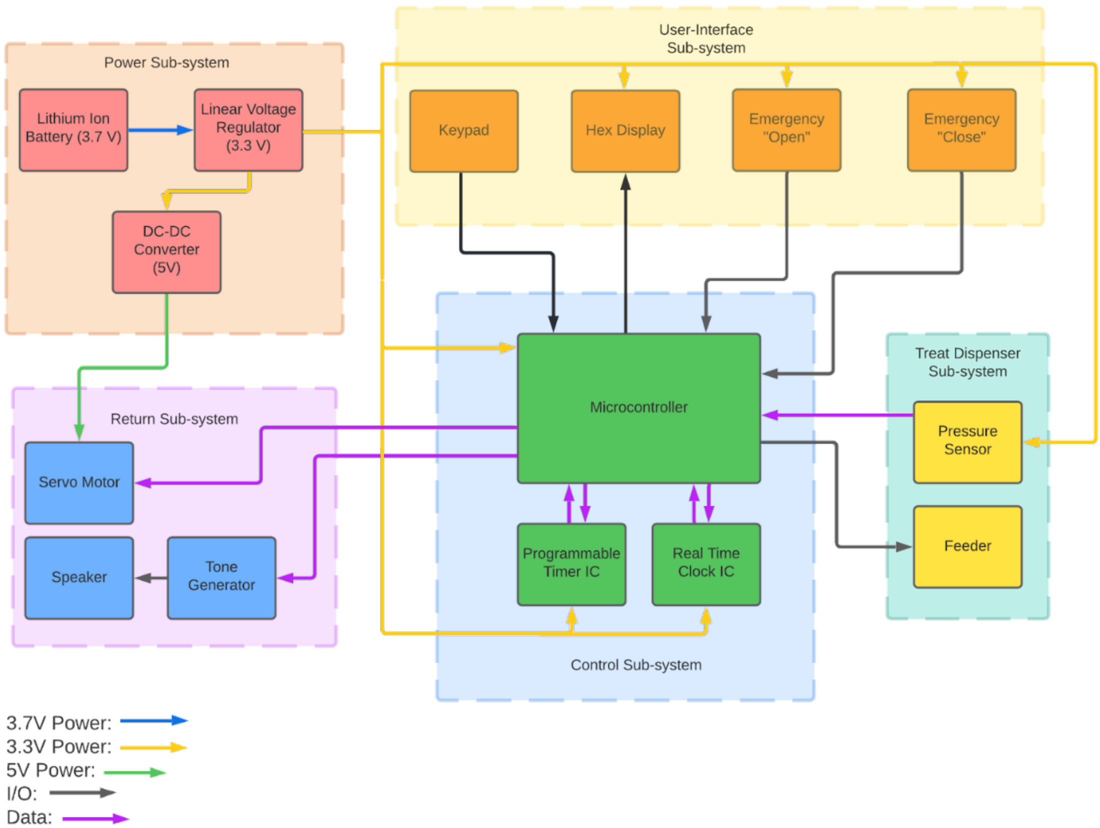

Figure 2

2.2 Subsystem Requirements

2.2.1 Power Subsystem:

The power sub-system is necessary for powering the 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 the Hex Display, the Emergency "Open" and "Close" buttons, the microcontroller, the pressure sensor, and the clock and timer IC's. Finally, 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 the servo motor.

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.

Requirements	Verification
1. Provide 3.3V +/- 6% from a 3.7V source. 2. Provide 5V +/- 8% from a 3.7V source to the servo motor. 3. Can supply the microprocessor with up to 200 mA current.	1A. Measure the output voltage that powers the other modules using an oscilloscope. Monitor the output to confirm that the output voltage stays within 6% of 3.3V. 2A. Measure the output voltage that powers the other modules using an oscilloscope. Monitor the output to confirm that the output voltage stays within 8% of 3.5V. 3A. Connect the 3.3V output to a 100 Ω potentiometer and ground its other side. 3B. Measure the current through the resistor using a multimeter. Adjust the resistance of the potentiometer until it is current reads 200 mA. 3C. Measure the output voltage using an oscilloscope and confirm the voltage stays within 6% of 3.3V.

2.2.2 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 desired time using the following format: “HHMM” where “HH" represents the hour and “MM” represents the exact minute. The user will then press the “#” key to confirm the selected time. The input time will then be sent to the microcontroller which will send the appropriate data to the 7 segment Display in order to present the time selected to open the cage. The time will be displayed in the same format as mentioned above. There will also be emergency “Open” and “Close” push buttons which can immediately open or close the cage. These buttons act as input signals to the microcontroller and send a pulse to open/close the cage door depending on which button was pressed.

System -Level Requirements:

- If the user has not yet confirmed the time they have entered, they should be able to reset/clear the input time by pressing the “*” button. The HEX Display must show the correct time entered by the user.

Requirements	**Verification**
1. Verify the keypad outputs the correct data signals for each key press.	1A. Connect each output pin of the keypad to an LED so that if the signal outputs the high voltage the LED will light up. Connect a 3.3V source and ground to the keypad 1B. Push each button on the keypad and verify that the correct signals are high indicated by the LED turning on.

2.2.3 Control Subsystem

The control sub-system consists of a microcontroller, a timer, and a real time clock. The microcontroller will exchange data with the clock IC chip via I2C communication in order to set the current time on the chip. Next, it will read the time from the chip to check whether the desired time to open the cage has occurred. The microcontroller will use the I/O data from the keypad to display the desired time on the HEX display. To open and close the cage, the microcontroller sends the correct position data to the servo motor. The microcontroller also exchanges data with the timer to keep track of how long the cage has been open for. When the timer reaches two hours, the microcontroller will send an output signal to the speaker using the tone function. The microcontroller also reads the pressure sensor output voltage to determine when to start closing and then sends a signal to the feeder to dispense food.

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 signal to the tone generator 2 hours ± 1 minute after the programmed time.
- The microprocessor should only check for 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 will happen. s

Requirements	Verification
1. The microprocessor should only check if the pressure sensor is triggered after the two hours timer has finished. 2. The control subsystem must send a signal to the tone generator 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. 4. The control subsystem must control the motor to dispense food.	1A. Place a weight on the pressure sensor, before the two hours are done and make sure the door doesn't move. 2A. Set a desired time for the cage to open, and make sure the speaker beeps two hours after the door opens. 3A. Make sure time displayed on hex display is coherent with real time. 4A. Test the signal between the motor and subsystem on the board using an oscilloscope attached to both sides.

2.2.4 Treat Dispenser Subsystem

Treat Dispenser Sub-System: 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. 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 will then determine if more than 2 hours have passed since the cage was first opened and if the FSR threshold voltage has been reached. If both these conditions are met, the microcontroller will send a pulse to the feeder which will then dispense a treat for the rodent.

System Requirements:

- The feeder should be able to dispense at least 20 grams of food. This corresponds to the average amount of food a rat eats in a day.
- The pressure sensor must be sensitive enough to detect a 250-500g rodent.

Requirements	Verification
1. The feeder should be able to dispense at least 20 grams of food. This corresponds to the average amount of food a rat eats in a day. 2. Dispenser is able to function without being jammed with food. 3. The pressure sensor must be sensitive enough to detect a 250-500g rodent.	1A. Run the feeder for 5 trails, and make sure the average amount of food dispensed is not less than 20 grams. 2A. Make sure the treat dispenser is strong enough to crush its way through any jams. 2B. The size of the treat used should be small relative to the opening in the treat dispenser. 3A. The pressure sensor acts as a Force Sensitive Resistor (FSR). Place a 250-gram object and use an ohm meter to monitor a decrease in resistance.

2.2.5 Return Subsystem

The Return Sub-System has two main components: a servo motor and a piezoelectric speaker. The servo motor will be mounted on top of the cage to open and close the door. Once the control system determines whether the selected time input has been reached, the microcontroller will send a pulse to the servo motor which will open the door. A pulse can also be sent to the servo motor to open/close the door if the emergency "Open"/"Close" button is pressed. Once the control system recognizes that the cage has been open for 2 hours, the microcontroller will send an audio output for the speaker to play using a tone generator function. The audio will play a "beep" noise so that the rodent knows to return. Once the rodent returns and activates the pressure sensor, a pulse will be sent to the servo motor to close the door.

System -Level Requirements:

- The servo motor must be able to rotate the door such that it completely opens or closes. If the door should 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.
- Once the cage has been open for 2 hours, the speaker must "beep" in 15-minute intervals until the pet comes back to the cage.

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. 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

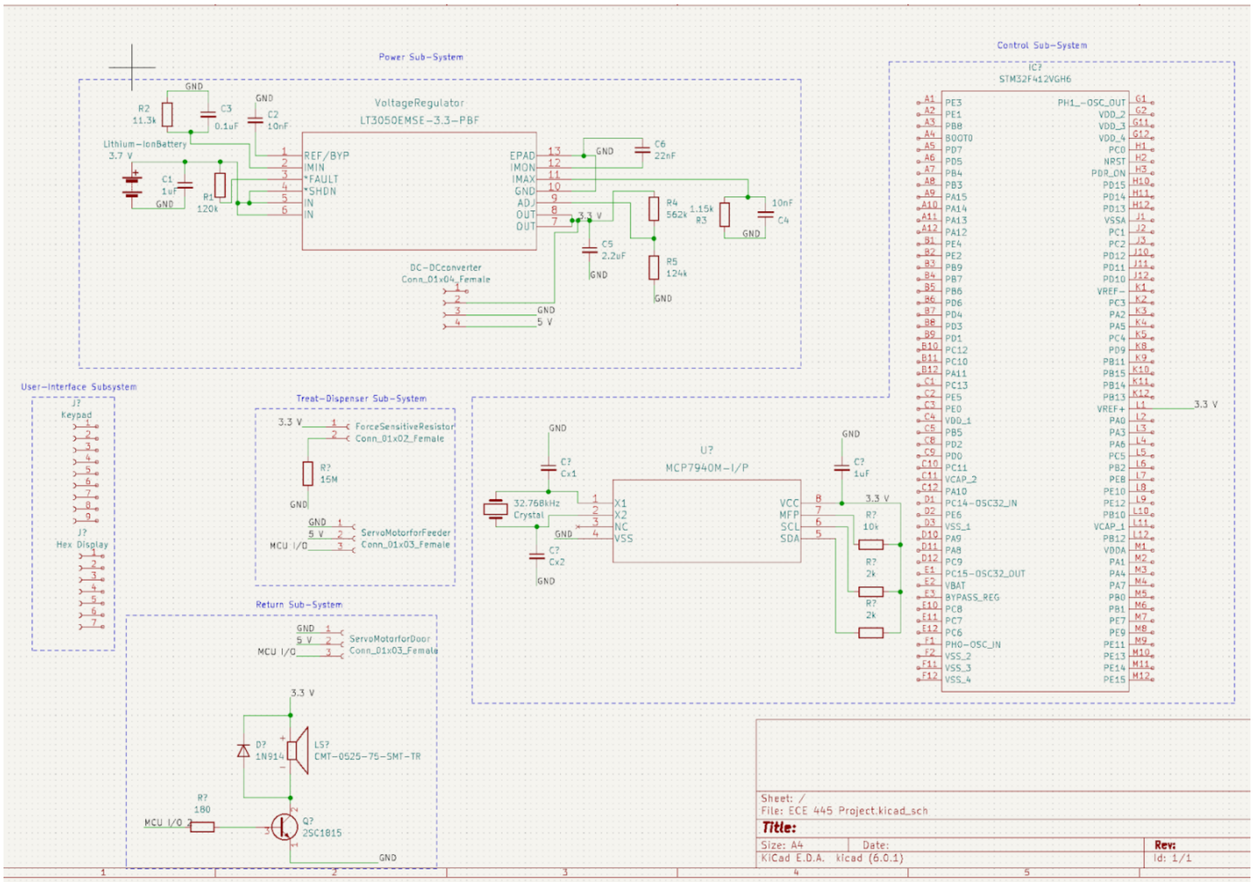

Fig 3: Overall Schematic

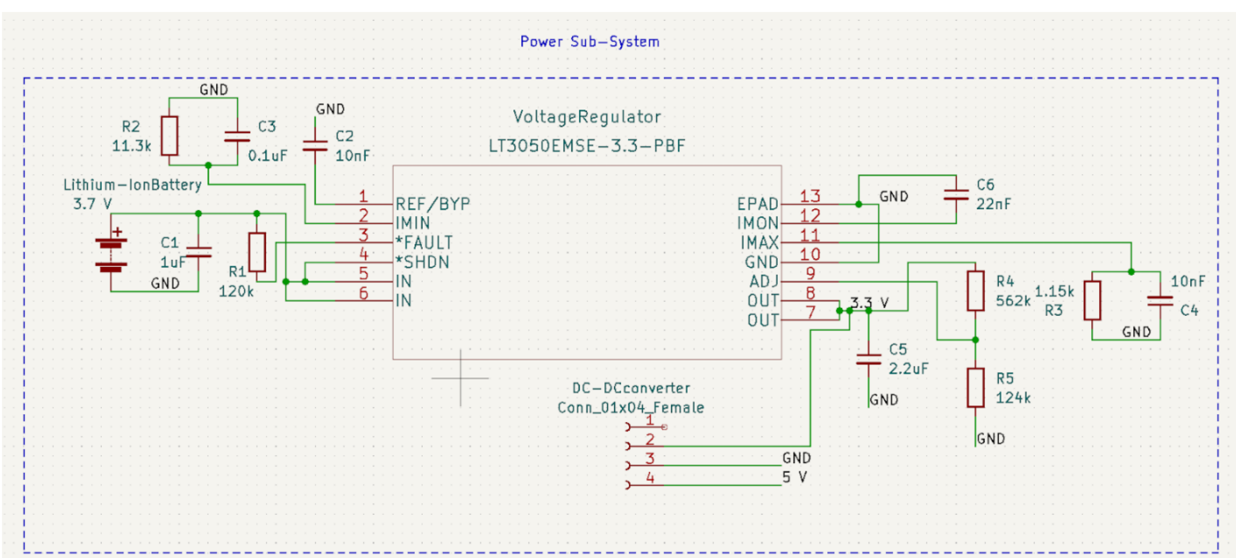

Figure 4: Power Sub-System Schematic

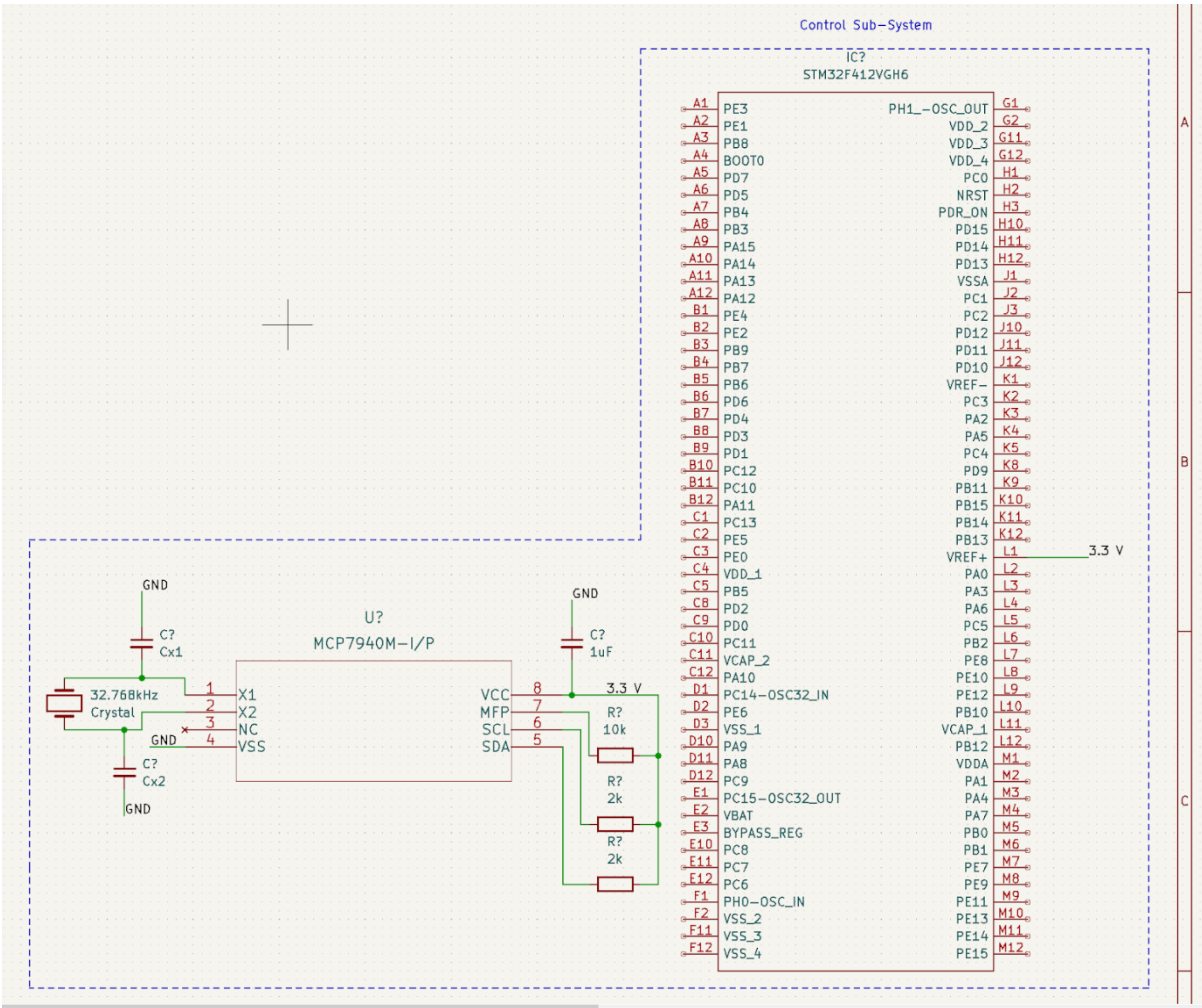

Figure 5: Control Sub-System Schematic

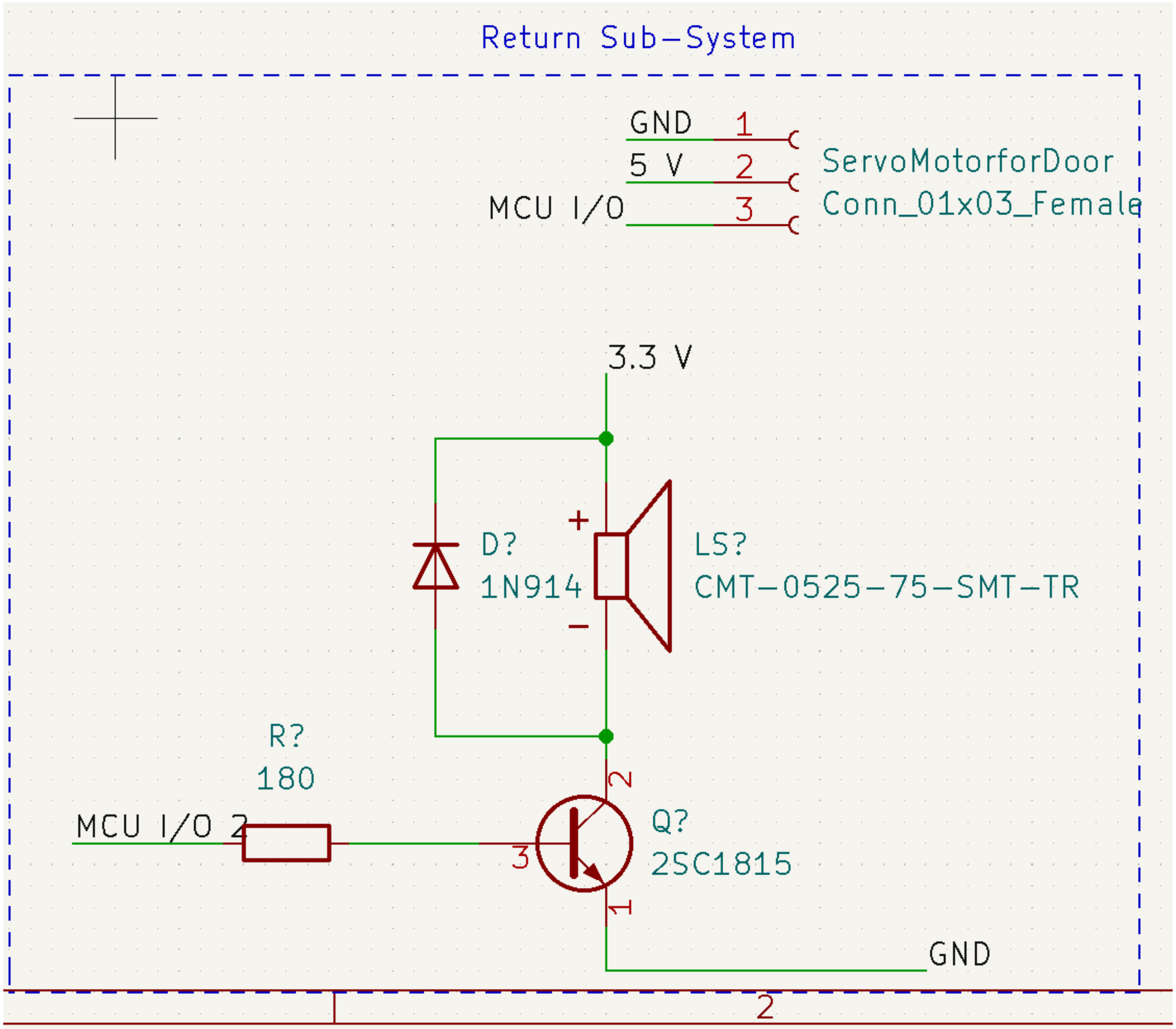

Figure 6: Return Sub-System Schematic

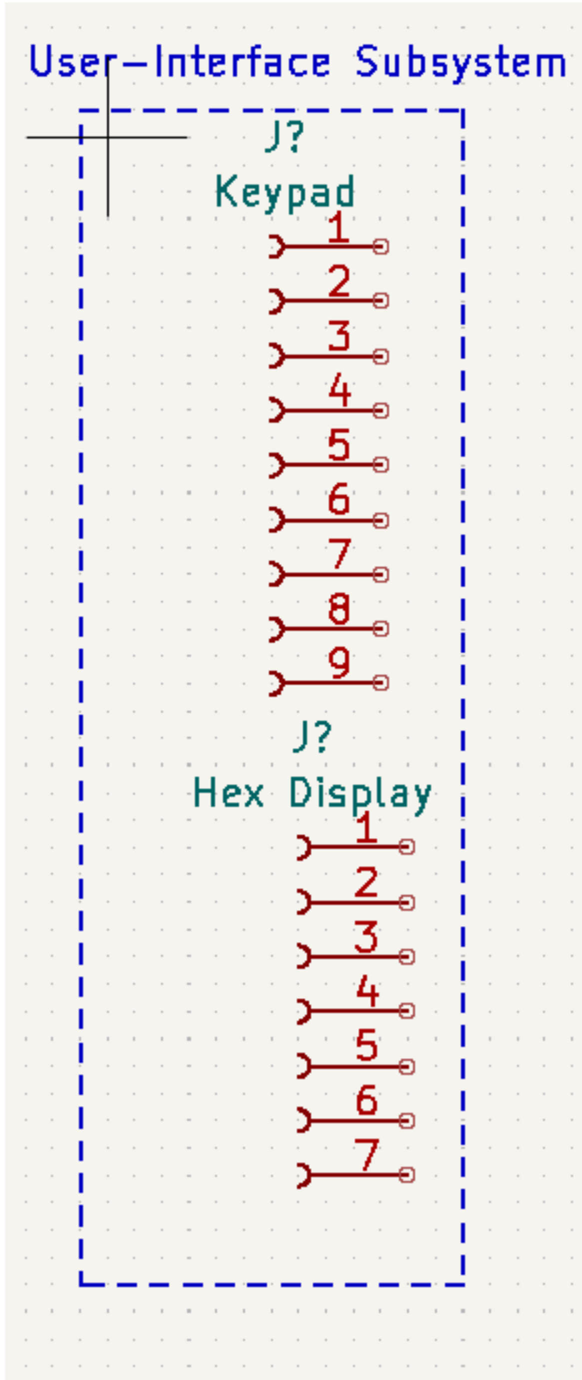

Figure 7: User-Interface Subsystem

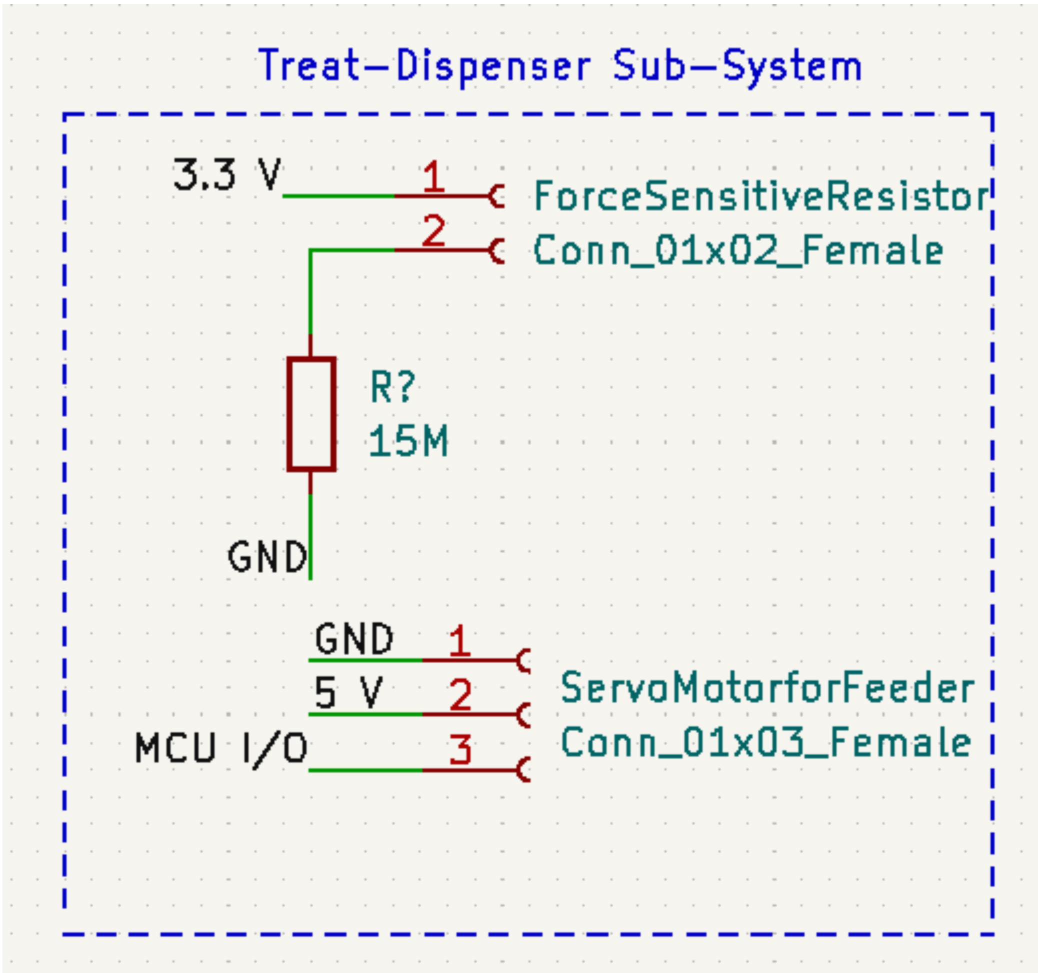

Figure 8: Treat Dispenser Sub-System

2.4 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 #1 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:

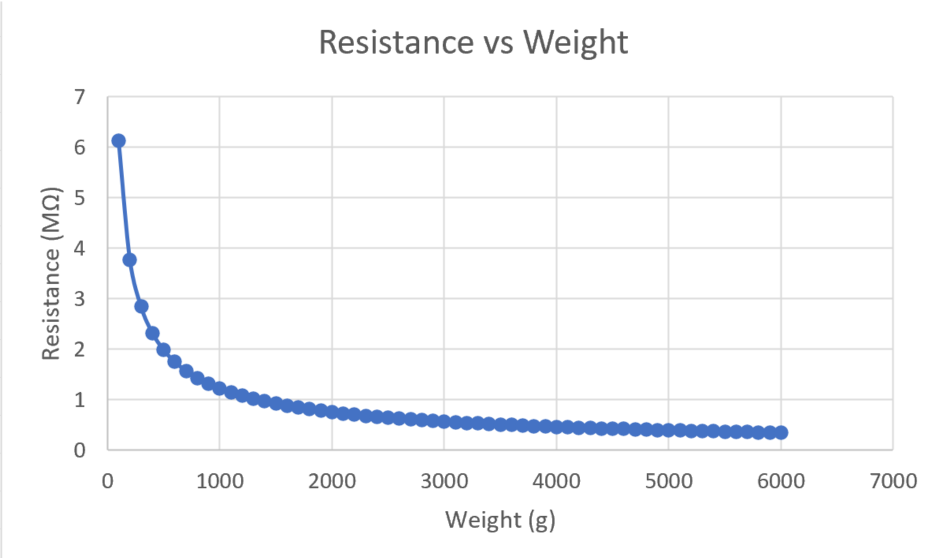

Figure 9

Output Resistance = 153.18(Weight)-0.699

The average weight of an adult rat is between 250-500 grams. 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 below. 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.

0.66 V = 3.3 V*(3.23 MΩ)3.23 MΩ + R

4. Ethics and Safety

We predict that two 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 that problem we will make sure all wires used are placed in a manner inaccessible to the pet. The second issue would be the owner's failure to train the pet on how to use the feeder which could result in the pet undereating, to resolve that 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 of that issue. IEEE code I1 states how we must "hold paramount the safety, health, and welfare of the public" (IEEEp.1.1). 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.

5. References

i) “IEEE Code of Ethics.” IEEE - Advancing Technology for Humanity, IEEE, www.ieee.org/about/corporate/governance/p7-8.html.

ii)Ades, Emily. “Species Specific Information: Rat.” *Johns Hopkins University*, 11 Mar. 2009, https://web.jhu.edu/animalcare/procedures/rat.html .

iii)“SEN0294.” *DigiKey*, https://www.digikey.com/en/products/detail/dfrobot/SEN0294/10136556.