AUTO CAT SNACK DISPENSER
ECE 445 DESIGN DOCUMENT - SPRING 2022

Team #39
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Contents

1 Introduction

1.1 Problem

When people are not at home, pet cats may get bored and hungry. Although there are various independent feeders and toys on the market, there isn't a device that can cheer cats up, feed them remotely, and ensure enough exercise for cats all at the same time.

Most of the feeders on the market are designed to dispense food-based either on the remote command of the owners or the request of cats themselves. Feeders, based solely on cats' demands, may cause cats to overeat and gain unhealthy diet habits. Other feeders, which require owners to manually feed their cats on remote control, can be inconvenient when owners are not able to stay active.

Therefore, an auto feeder, which can keep track of the amount of cats' exercise and play with cats, is needed.

1.2 Solution

To solve the problem, we plan to design an auto cat snack dispenser and exercise machine. This cat feeder toy project involves three crucial parts: a special collar placed on cats, a dispenser put on the ground, and laser pointer attached to a mechanical arm connected to the base of the dispenser. Our snack dispenser can attract cats' attention and lead them to do exercise, and it can also detect cats' movements and record how much exercise cats have done.

We will connect an infrared sensor (IR) right under the dispenser. Once cats are hungry and approach their bowl, the IR sensor will detect it and send the data to the microcontroller unit (MCU).

The laser pointer attached on the mechanical arm will then start to work, and at the same time, the inertial measurement unit (IMU) in the special collar will also begin to record cats' movements. Once enough exercise is done, the IMU will send the data back to the microcontroller unit and tell the dispenser to drop some amount of snacks.

The whole device will halt for a period of time until the next activation.

1.3 High-Level Requirements List

- We are using a battery to power the collar. The IMU needs to stay at low power consumption mode (0W power consumption) before the entertainment unit activates. It should not start to record data until the infrared sensor detects cats' movement.
- The MCU in the motion detection unit should at least provide an output that achieves 80% accuracy. The accuracy is calculated by: $Accuracy = |recorded\ \#\ of\ times - actual\ \#\ of\ times| / actual\ \#\ of\ times$.

The ‘time’ in the equation stands for the times that the IMU records an acceleration which is above the set threshold.

- The infrared sensor is placed near the bowl and below the dispenser. When cats are eating snacks, they may accidentally activate the whole system again. To avoid this situation, once the dispenser drops snacks, the whole system needs to halt for at least three minutes to start the next activation.

1.4 Visual Aid

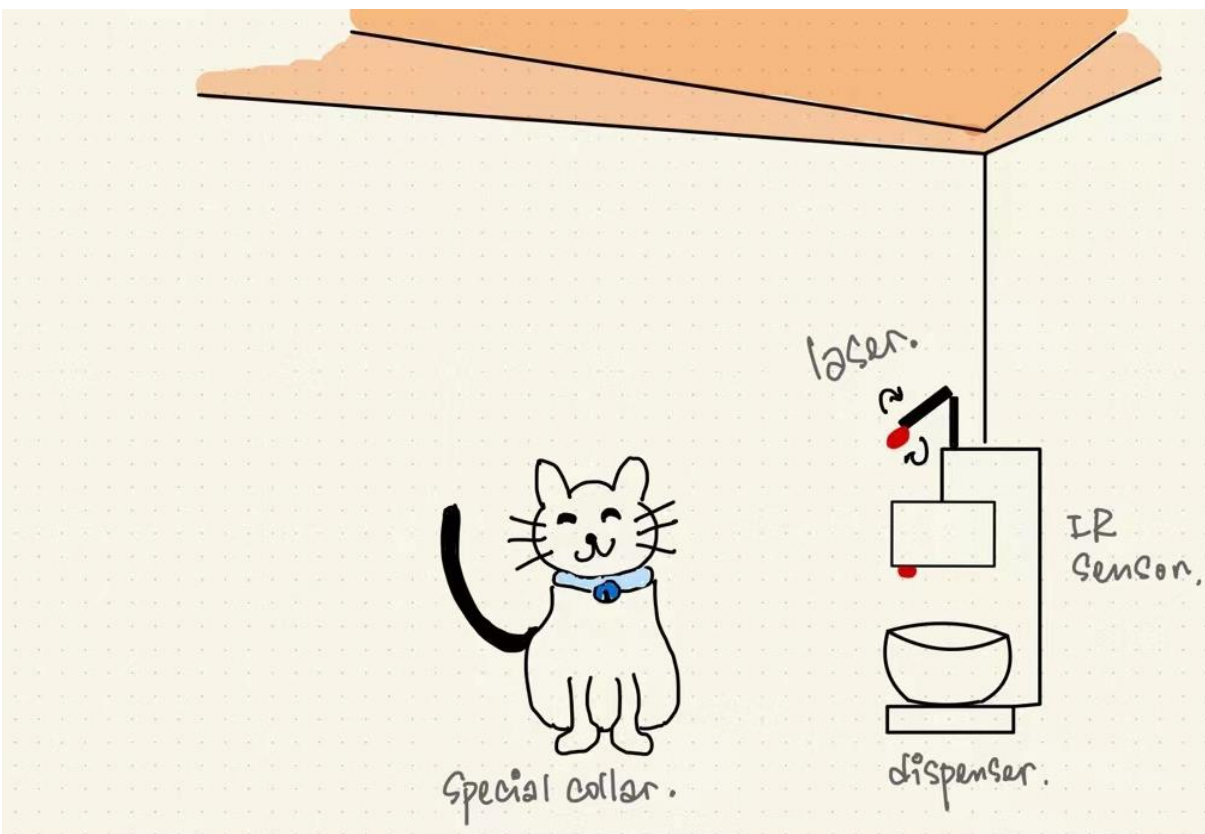

Figure 1. Physical Design of Auto Cat Snack Dispenser

2 Design

2.1 Block Diagram

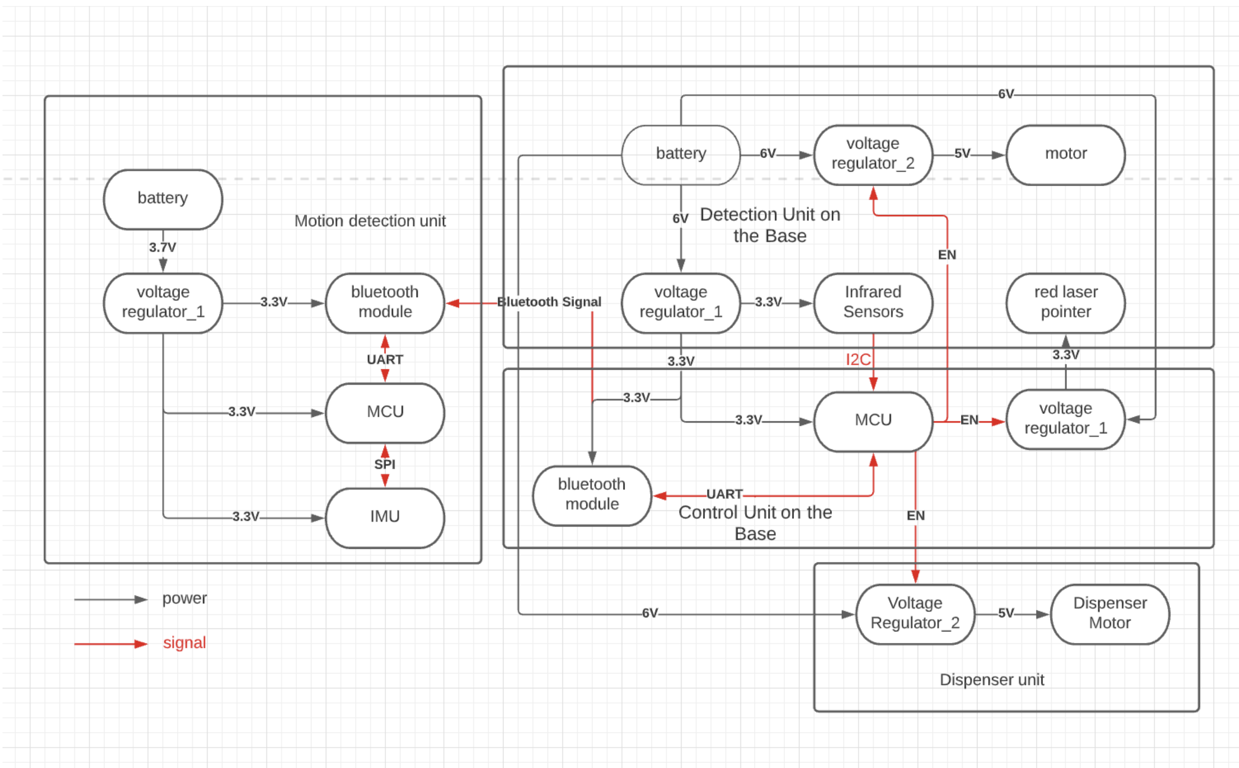

Figure 2. Block Diagram of Auto Cat Snack Dispenser

2.2 Block Diagram Description

To successfully operate our device, our auto cat snack dispenser is composed of four units. The four units are the motion detection unit (the special collar on cats), the entertainment unit (the laser pointer attached to the mechanical arm), the dispenser unit (the dispenser on the ground), and the control unit. The control unit is composed of an MCU and Bluetooth chip.

2.3 Subsystem Requirements

2.3.1 Subsystem 1: Detection Unit on the Base

Description:

The detection unit includes an infrared sensor and a red laser pointer to attract and detect cats' attention. The red laser pointer is attached to the mechanical arm on the dispenser. Once the IR sensor detects cats approaching, it will send the signal to the MCU on base, which then sends signals to turn on the red laser pointer and start the motion detection unit on the collar.

Subsystem requirement:

Requirements	Verification
1. The infrared sensor, motor, and laser pointer should be all provided 3.3V +/- 5% from a 6V battery. 2. The whole subsystem should operate at a clock speed greater than 8MHz for effective data processing. (The infrared sensor to the MCU, and the MCU to the voltage regulator).	1. Use the oscilloscope to measure the output voltage across the three components and ensure their errors are between 5% of 3.3V. 2. The MCU should output a system clock signal onto the generic microcontroller clock output pin. Then use an oscilloscope to measure if the frequency meets the desired number.

	Requirements	Verifications
1	The whole system should be able to at least operate 8 hours under an average current drain of 833 mA.	Verification steps: 1). Use the stopwatch to record the time it can operate Alternative method: 1). Use an oscilloscope to find the current when the system is in sleep mode. 2). Do calculations based on the current measured to check if it meets the requirements.
2	The battery needs to be capable of providing a voltage between 2.3V to 6.0V. (2.3V is the minimum input voltage required for the voltage regulator).	Verification steps: 1). Fully charge the battery 2). Use an oscilloscope to check if the voltage across the battery reaches about 3.7V. 3). Wait until the battery fully discharged and check if the voltage provided by the battery gets below 2.3V.

Table 2.3.1.1. Battery Requirements and Verifications

	Requirements	Verifications
1	With a 0.4V of the voltage dropout, the voltage regulator is still able to provide a fixed voltage of 3.3V +/- 5% to the IR sensor and the MCU.	Verification steps: 1). Connect a resistor in parallel with the voltage regulator 2). Gradually adjust the voltage across the resistor from 6.0V to 5.6V 3). Use an oscilloscope to measure the voltage across the resistor.
2	With a 0.4V of the voltage dropout, the voltage regulator is still able to provide a fixed voltage of 5.0V +/- 5% to the two gear motors.	Verification steps: 1). Connect a resistor in parallel with the voltage regulator 2). Gradually adjust the voltage across the resistor from 6.0V to 5.6V 3). Use an oscilloscope to measure the voltage across the resistor.

Table 2.3.1.2. Voltage Regulators Requirements and Verifications

	Requirements	Verifications
1	MCU needs to operate at 8MHz for effective data processing.	Verification steps: 1). Use a generic microcontroller clock output pin to check if the output clock of the MCU meets the requirements.
2	MCU needs to stay at a low power mode before an enable signal is detected from the IR sensor.	Verification steps: 1). Use two separate LEDs connected to both the IR sensor and the MCU. 2). Connect a current meter to both components and check if the current changes when the IR sensor detects something.
3	MCU is able to give an enable to the voltage regulator connected to the gear motor and the laser pointer attached to it.	Verification steps: 1). Connect a resistor in parallel with the voltage regulator. 2). Use an oscilloscope to check the voltage across the resistor and see if the voltage regulator is operating correctly.

Table 2.3.1.3. MCU Requirements and Verifications

	Requirements	Verifications
1	The Bluetooth module of the collar needs to be paired with the other Bluetooth module of the base unit.	Verification steps: 1). Connect a button to the Bluetooth module of the collar 2). Connect a LED to the Bluetooth of the base unit 3). Check when the button is pressed, if the LED of the other one turns on. 4). Connect a button and a LED inversely and follow step 1-3 again.

Table 2.3.1.4. Bluetooth Module Requirements and Verifications

	Requirements	Verifications

1	It is capable of sending a signal to and turning on the MCU.	Verification steps: 1). Let the IR sensor detect hot sources from creatures. 2). Use an oscilloscope and connect it across the MCU to check if it is turned on.

Table 2.3.1.5. IR Sensor Requirements and Verifications

Components in this subsystem:

Infrared sensor: This sensor is used to detect if cats approach the machine. It turns on the machine when the cat is seeking snacks under it.

Laser pointer: The laser pointer is to attract cats' attention. It is turned on once the IR sensor detects cats approaching.

Schematics:

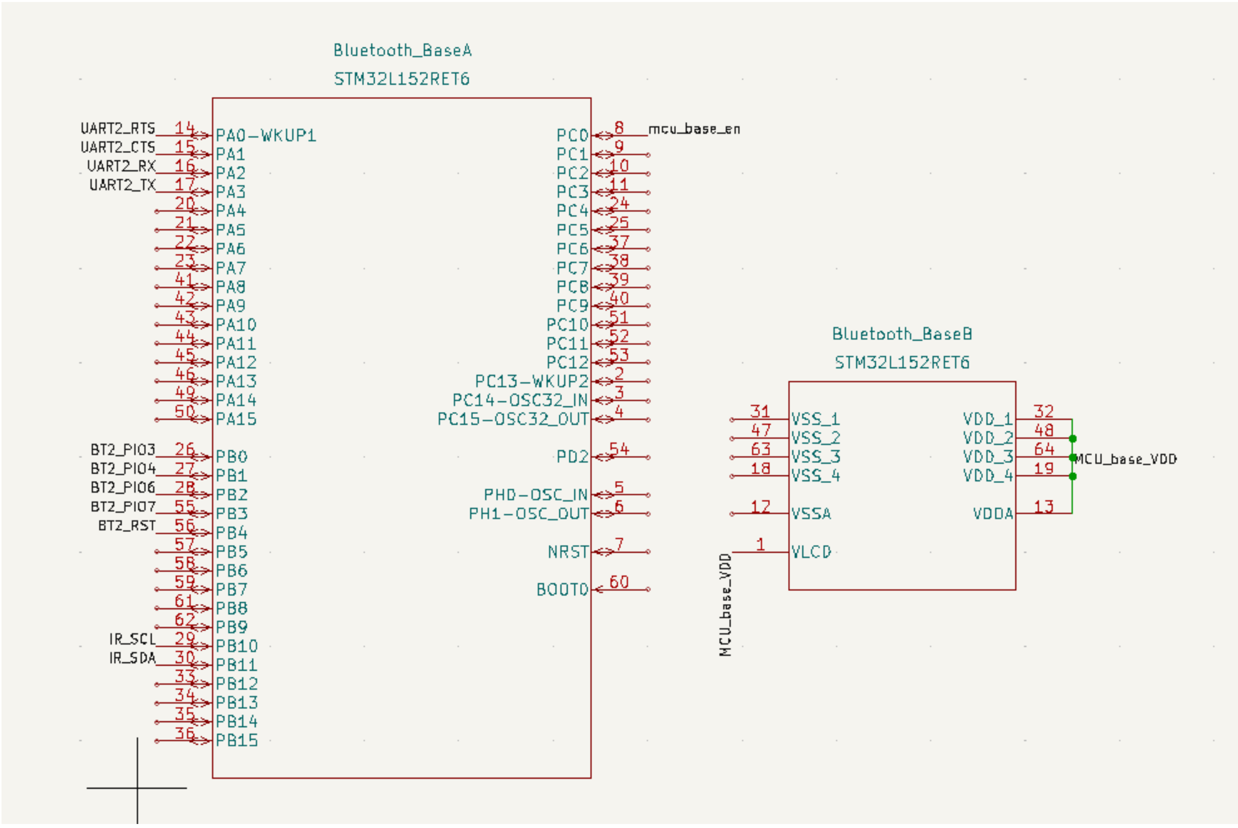

Figure 2.3.1.1 Bluetooth Module

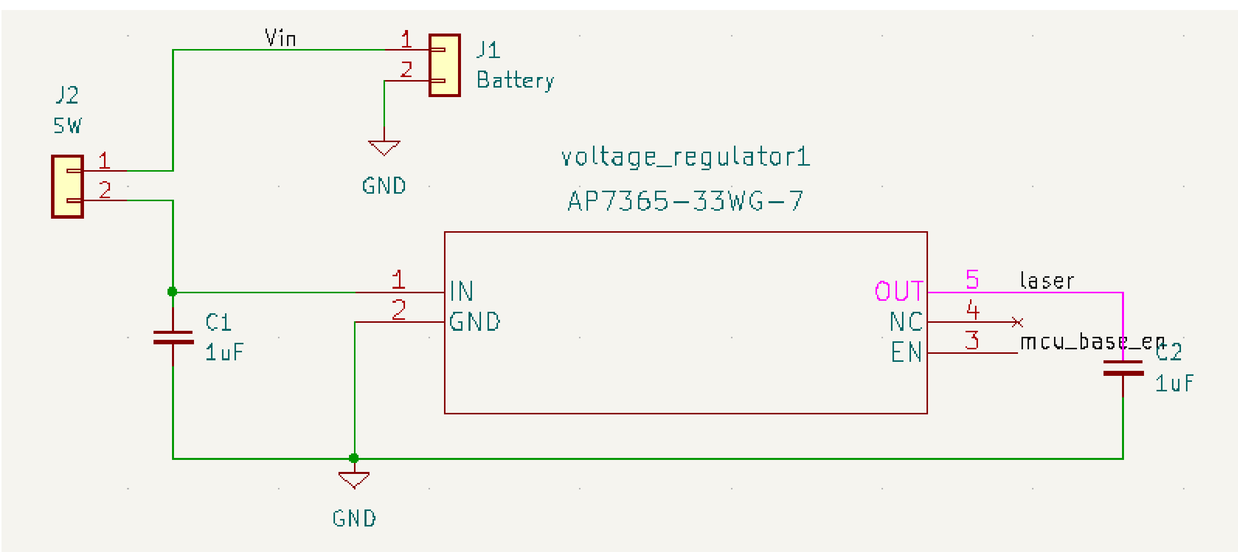

Figure 2.3.1.2 Voltage Regulator 1

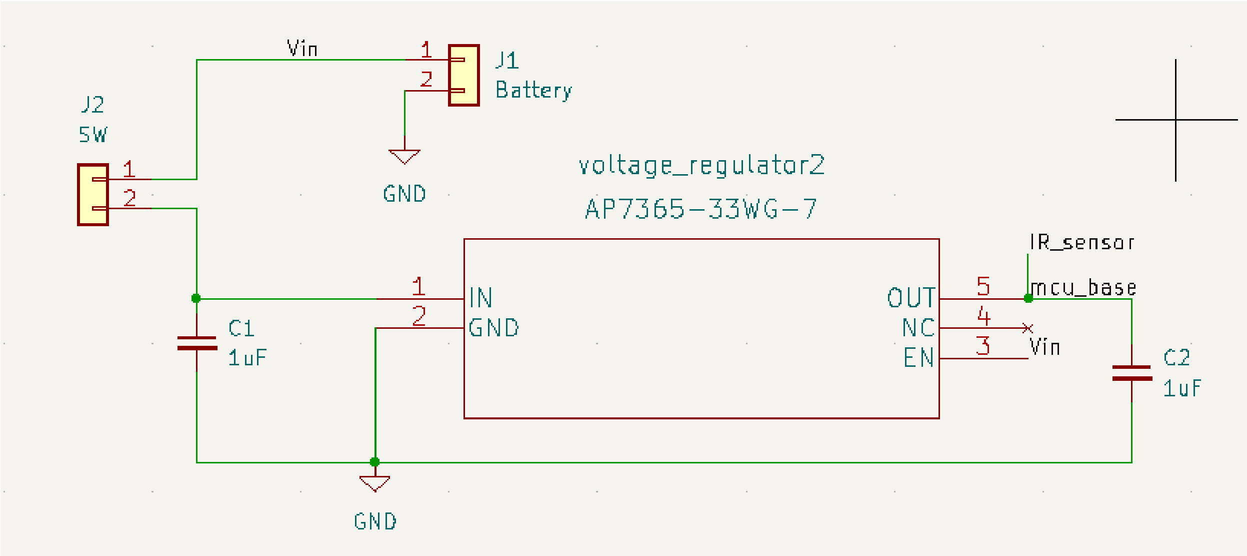

Figure 2.3.1.3 Voltage Regulator 2

2.3.2 Subsystem 2: Movement Detection Unit

Description:

The movement detection unit contains an IMU and a Bluetooth microchip. This system is powered by a battery through a voltage regulator. Once the Bluetooth microchip receives signals from the other Bluetooth microchip in the control unit, IMU starts to detect cats' motion. After enough exercise is recorded, IMU sends data back to the Bluetooth microchip.

Components in the subsystem:

IMU**:** It includes all the sensors for detecting cats' movements. It also sends the wireless signal to the control unit. IMU stands for inertial measurement unit, and it contains a gyroscope and an accelerometer, which are both used to detect cats' motion.

Bluetooth microchip: It is used to send and receive wireless signals.

<u>Subsystem Requirement:</u>

	Requirements	Verifications
1	The whole system should be able to at least operate 10 hours under an average current drain of 600mA.	Verification steps: 1). Use the stopwatch to record the time it can operate Alternative method: 1). Use an oscilloscope to find the current when the system is in sleep mode. 2). Do calculations based on the current measured to check if it meets the requirements.
2	The battery needs to be capable of providing a voltage between 2.0V to 3.7V. (2.0V is the minimum input voltage required for the voltage regulator).	Verification steps: 1). Fully charge the battery 2). Use an oscilloscope to check if the voltage across the battery reaches about 3.7V. 3). Wait until the battery fully discharged and check if the voltage provided by the battery gets below 2.0V.

Table 2.3.2.1. Battery Requirements and Verifications

	Requirements	Verifications
1	With a 0.4V of the voltage dropout, the voltage regulator is still able to provide a fixed voltage of 3.3V +/- 5% to MCU, IMU, and the Bluetooth	Verification steps: 1). Connect a resistor in parallel with the voltage regulator 2). Gradually adjust the voltage across the resistor from 3.7V to 3.3V

	module.	3). Use an oscilloscope to measure the voltage across the resistor.

Table 2.3.2.2. Voltage Regulators Requirements and Verifications

	Requirements	Verifications
1	MCU needs to operate at 8MHz for effective data processing.	Verification steps: 1). Use a generic microcontroller clock output pin to check if the output clock of the MCU meets the requirements.
2	MCU needs to stay at a low power mode before an enable signal is detected from the Bluetooth module.	Verification steps: 1). Check if the sleep mode of the MCU is turned on. 2). Use an oscilloscope to check if the typical current is about 340mA and no more than 700mA.

Table 2.3.2.3. MCU Requirements and Verifications

	Requirements	Verifications
1	The Bluetooth module of the collar needs to be paired with the other Bluetooth module of the base unit.	Verification steps: 1). Connect a button to the Bluetooth module of the collar 2). Connect a LED to the Bluetooth of the base unit 3). Check when the button is pressed, if the LED of the other one turns on. 4). Connect a button and a LED inversely and follow step 1-3 again.

Table 2.3.2.4. Bluetooth Module Requirements and Verifications

	Requirements	Verifications
1	The time cats' acceleration reaches the threshold needs to be at least 80% accuracy.	Verification steps: 1). Let cats do exercise five times, and check if snacks are dispensed at the base unit. 2). Do this experiment five times to find the average and see if it meets the requirement.
2	When cats are shaking their hair, check if the count number increases accordingly.	Verification steps: 1). Shake the IMU rapidly 2). Check if the snacks are dispensed at the base unit.

Table 2.3.2.5. IMU Requirements and Verifications

Schematics:

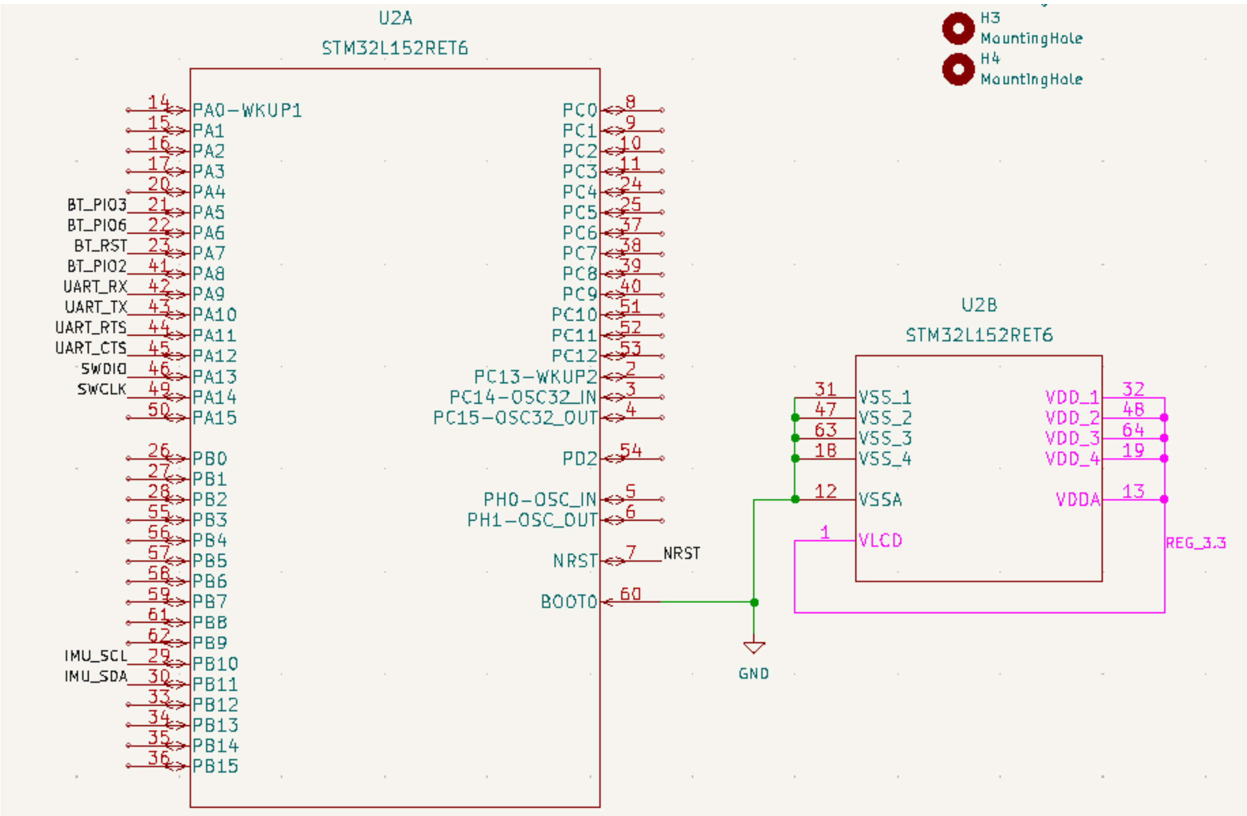

Figure 2.3.2.1 MCU_collar

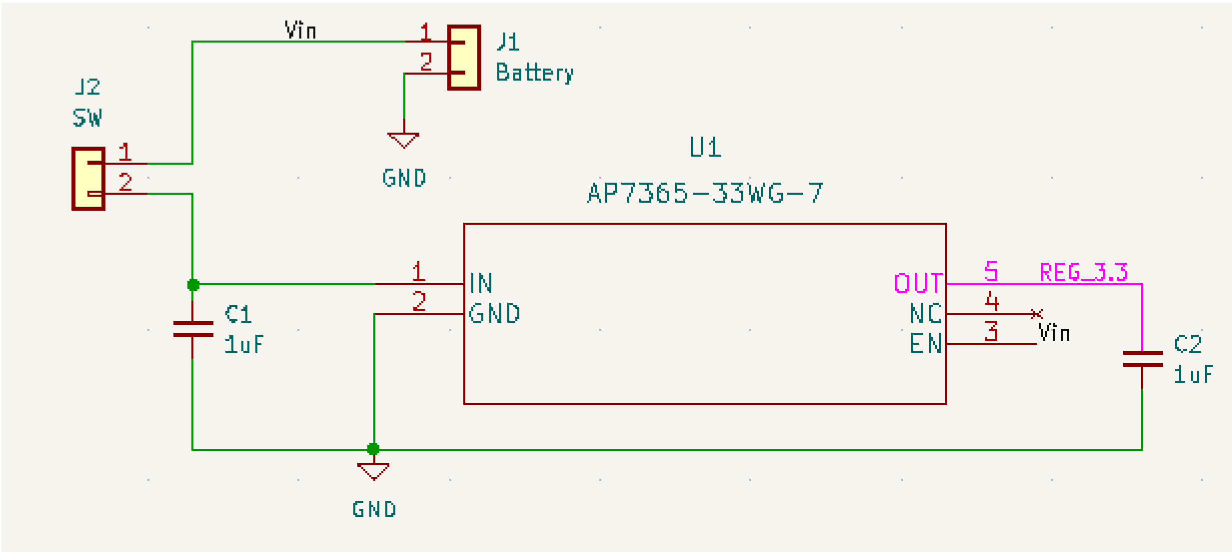

Figure 2.3.2.2 Voltage_Regulator_collar

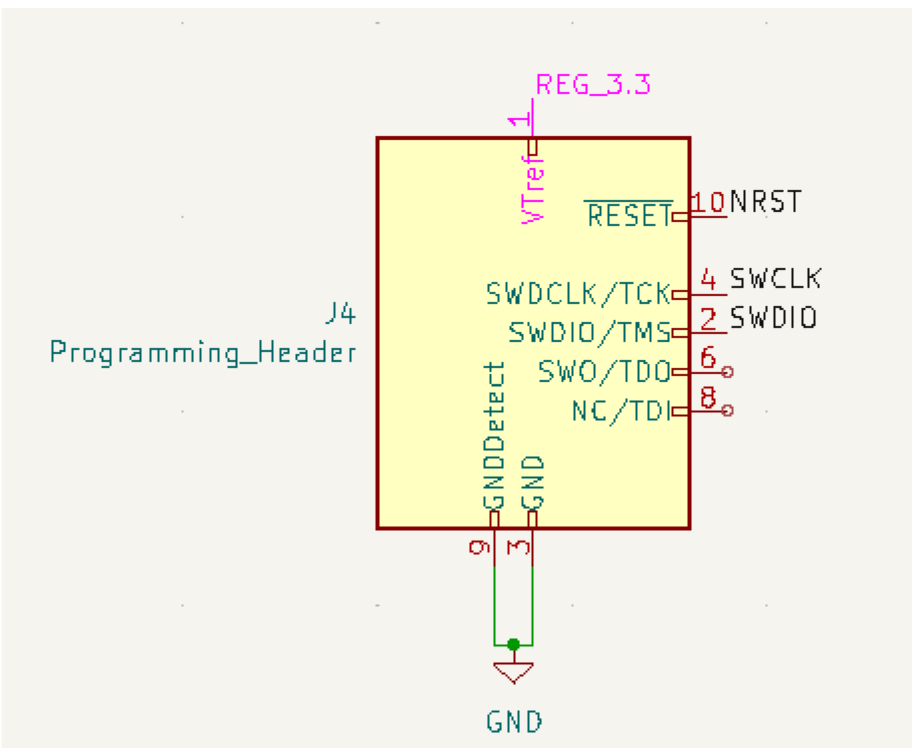

Figure 2.3.2.3 Programming Header

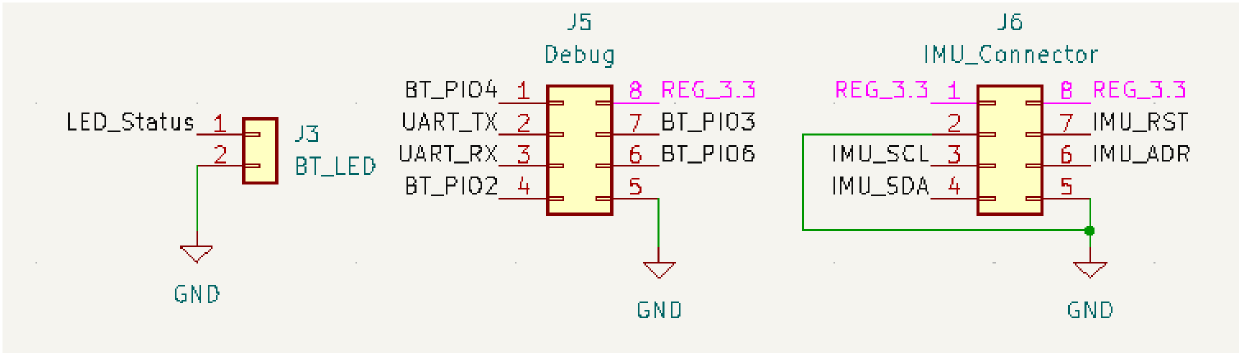

Figure 2.3.2.4 Debug System

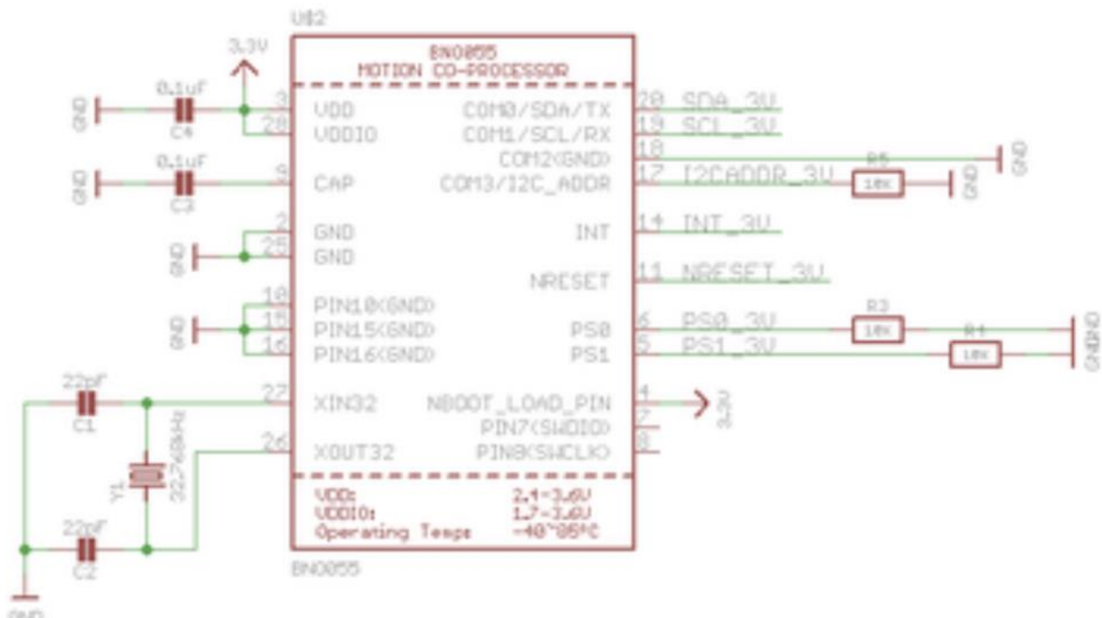

Figure 2.3.2.5 IMU [6]

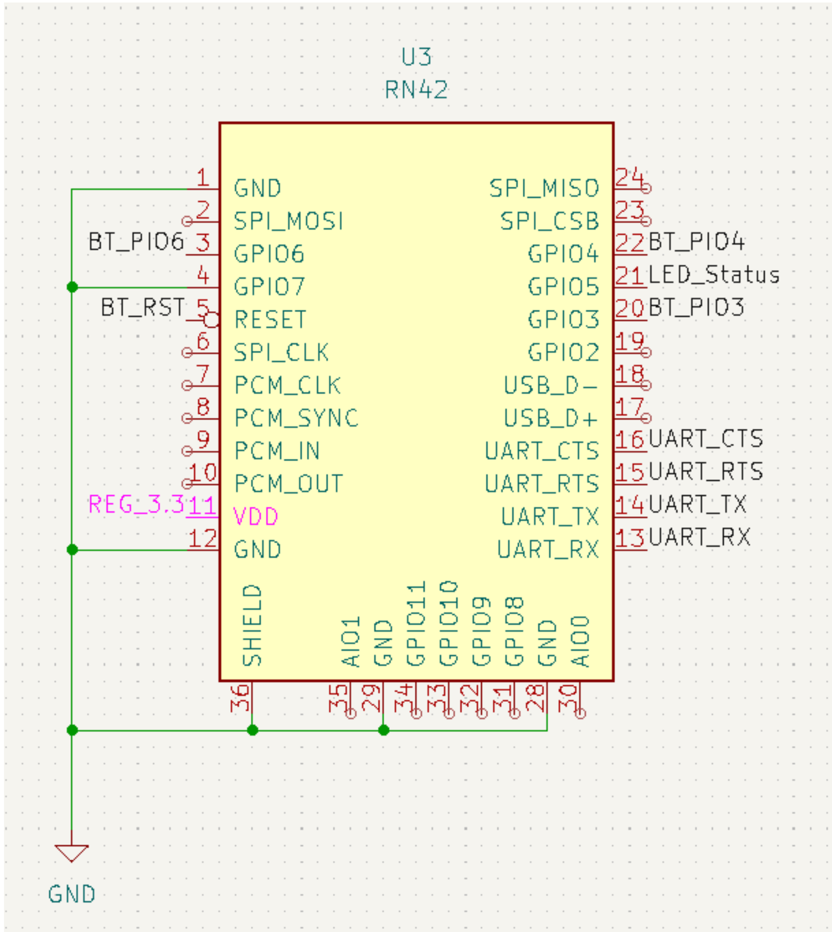

Figure 2.3.2.6 Bluetooth

2.3.3 Subsystem 3: Snacks Dispenser

Description:

After enough exercises are recorded, snacks will be dispensed. This subsystem ensures a fixed amount of snacks is dispensed each time. The system then halts for a period of time until the next activation becomes available.

Components in the subsystem:

Dispenser motor: It is used to control the number of snacks dropped by turning a fixed angle at every activation.

Subsystem requirement:

Requirements	Verification
1. This subsystem is powered by the same 6V battery with the entertainment unit. The motor will not start turning until the MCU gives a signal to the voltage regulator. The voltage regulator needs to be provided with a 3.3V +/- 5%. 2. The dispenser will halt for three minutes and not start the next activation. 3. Once the motor receives the signal from the MCU, the dispenser only drops 10g +/- 20% snacks every time.	1. Use an oscilloscope to measure the voltage and ensure the error for the regulator is between 3.3V +/- 5%. 2. Use the stopwatch to check if the time meets the requirements. 3. Measure the weight of all snacks dispensed with a scale. Ensure the weight dropped is between 8g and 12g.

Schematics:

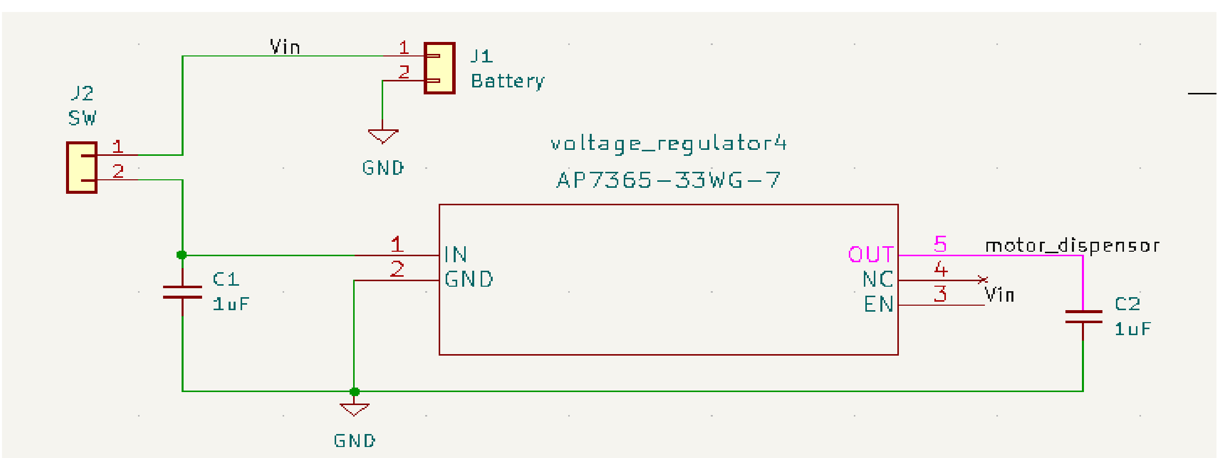

Figure 2.3.3.1 Voltage_Regulator

2.3.4 Subsystem 4: Control Unit on the Base

Description:

This subsystem contains an MCU and a Bluetooth microchip. It receives signals from the other three subsystems, and it sends corresponding signals back to the three subsystems.

The MCU receives signals from the infrared sensors first, and then it sends data to start the red laser pointer and start the movement detector. Once enough exercise is recorded, the Bluetooth microchip from the motion detection subsystem will transmit data to the Bluetooth microchip in this subsystem. After the MCU processes the signals, it tells the dispenser to drop snacks.

Components in this subsystem:

MCU: It stands for the microcontroller unit. It should process the data from IMU and calculate whether the cat has consumed enough energy.

Bluetooth subsystem: It is used to send and receive wireless signals between MCU and IMU.

Subsystem requirement:

Requirements	Verification
1. The Bluetooth module and the MCU are both provided with a 3.3V +/- 5%.	1. Use an oscilloscope to measure the voltage and ensure the error for the

2. The MCU should be able to give a signal that is within 20% accuracy to the dispenser.	regulator is between 3.3V +/- 5%. 2. Use the weight scale to check if the dispenser drops between 8g and 12g.

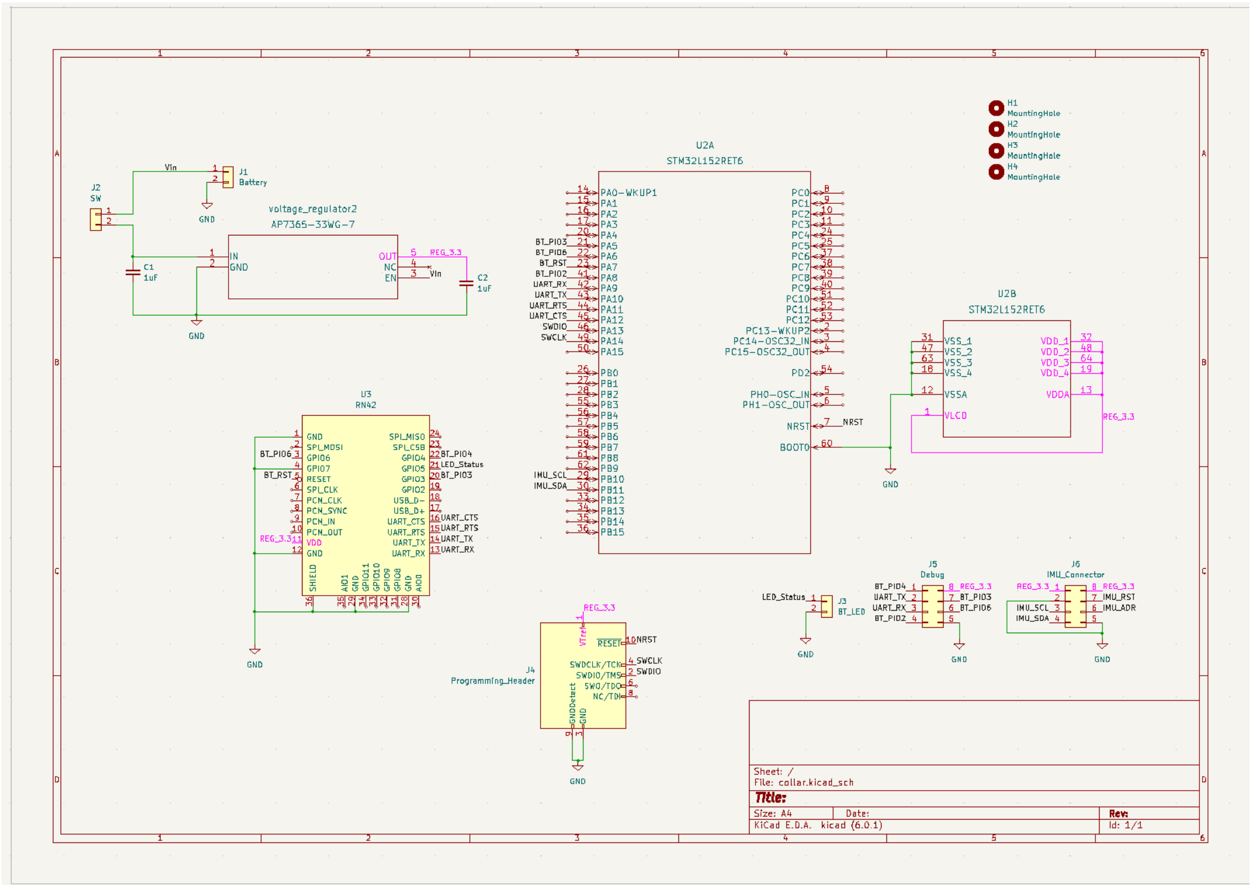

Figure 2.3.5 General Schematic

2.4 Mechanical Design

2.4.1 Physical Design of the Dispenser

The laser pointer will be attached to the top of this machine, and the IR sensor will be attached near the bowl. This is where the base unit is placed.

2.4.2 Physical Design of the Collar


[7]

The motion detection unit will be put into a small box attached to a collar. This is where the collar unit will be placed.

2.5 Tolerance Analysis

When detecting if cats are doing exercise, we use the accelerometer and gyroscope to find the acceleration of cats. After the IMU detects the motion of cats, to find the magnitude of the acceleration on three directions, we use the equation: $a = \sqrt{ax^2 + ay^2 + az^2}$.

However, when we were trying to find the set acceleration, we figured out that cats do not walk around with the laser pointer, they pounce on the bright dot created by the laser pointer. We will use the magnitude of acceleration to determine if cats are actually doing exercises. When cats pounce on the dot and then stop, their acceleration will increase to a peak value, and then decrease to a negative peak value passing an acceleration of zero. When we are determining the cats' motion, we will not consider the direction of their acceleration, and we will be only looking at the magnitude of their acceleration from three axes. Every time when the IMU detects cats pouncing, the count number increases by 2.

When the IMU is at rest, it will experience a downward acceleration of $g = 9.81m/s^2$. Before calculating the acceleration of cats, we need to calibrate the accelerometer to compensate the gravity acceleration $9.81m/s^2$.

The most challenging part of our project is how to classify between when cats are actually doing exercises or when cats are just shaking dirt off.

One method we could use is to take the rotational acceleration into account at the same time. If our cats are simply doing exercises, the linear acceleration will be a big number, however the rotational acceleration will be very small. However, if our cats are shaking off the dirt, both the linear acceleration and the rotational accelerations will output a significant amount. To check if the rotational acceleration is higher than the expected value could help to clarify the case.

The other method we think of is to input a clock signal when coding. If cats are shaking their bodies, the IMU will output a signal showing that cats reach the desired acceleration very rapidly. On the other hand, if cats are exercising, the IMU will likely output a signal showing that cats reach the desired acceleration only twice in the same amount of time.

Both of these two methods above rely only on the magnitude of the detected acceleration, which could avoid the complexity of dealing with a vectored acceleration. In our project, the dispenser should dispense snacks every time when the count number reaches 10. Our system should reach an accuracy of 80%, and the equation for calculating the accuracy is: $Accuracy = |recorded\ \#\, of\ times - actual\ \#\, of\ times| / actual\ \#\, of\ times$. It means that the dispenser will be dropping snacks if the count number is between 8 and 12.

3 Costs and Schedule

3.1 Cost Analysis

3.1.1 Labor Force Cost

Based on the 2019-2020 Annual Illini Success Report, the average salary for an electrical engineer graduated from our college is about 36 dollars per hour [1]. Since we all major in electrical engineering, and we plan to work about 8 hours a week, it would result in a total of 2592 dollars for the rest of nine weeks.

	Yuhan Bi	Zutai Chen	Natalie Xu
Major	Electrical Engineering	Electrical Engineering	Electrical Engineering
Total hours worked	72	72	72
Multiplier	2.5	2.5	2.5
Labor force cost ($)	6480	6480	6480

3.1.2 Parts Cost

Parts	Parts Name	Price per unit ($)	Quantity	Actual Cost ($)
Line Laser Diode	1528-1402-ND(3~5V)	8.95	1	8.95
USB Power Adapter	N/A	0	1	0
Bluetooth	RH42HID-	19.95	2	39.9

Module	I/RM (3.3V)			
IMU	1888-1001-ND (3.3V)	77.22	1	77.22
Gear Motor	1568-1645-ND (4.5V)	4.95	2	9.9
Rechargeable Battery 1	PRT-13851 (3.7V)	4.95	1	4.95
Rechargeable Battery 2	HR9-6-T2-ND (6V)	32.02	1	32.02
MCU	STM32L152RET6(3.3V)	9.92	2	19.84
IR Sensor	516-3963-2-ND - Tape & Reel (TR) (3.3V)	1.51	1	1.51
Voltage Regulator	AP7365-33WG-7DITR-ND - Tape & Reel (TR) (3.3V)	0.46	3	1.38
Voltage Regulator	MIC5156YM (5V) MCP1826ST-5002E/DB	3.43	2	6.86
Total Cost ($)				217.67

3.2 Schedule

Week	Yuhan	Zutai	Natalie

1	Complete PCB design. Complete design document.	Complete PCB design. Complete design document.	Complete PCB design. Complete design document.
2	Refine PCB design. Acquire parts needed for the project.	Refine PCB design. Get PCB design approved.	Refine PCB design. Prepare for first round PCB order.
3	Complete PCB board assembly. Work on software code.	Complete PCB board assembly. Bluetooth interface.	Complete PCB board assembly. Power supply and other parts.
4	Complete software code.	Work on driver/BT connection.	Complete PCB board assembly with soldering and mounting.
5	Test software code. Perform full system testing with software.	Test hardware system.	Test hardware system.
6	Complete individual progress report.	Complete individual progress report.	Complete individual progress report.
7	Debug and complete hardware system testing.	Debug and complete hardware system testing.	Debug and complete hardware system testing.
8	Perform entire system testing with software.	Perform entire system testing with software.	Perform entire system testing with software.
9	Final presentation and final paper.	Final presentation and final paper.	Final presentation and final paper.

4 Ethics and Safety

Our project is to build a safe and convenient snack dispenser for cats. We will "uphold the highest standards of integrity and responsible behaviors" while we are working on this project, and we will make sure our final project is ethical [2]. Any resources we will be using for this project will be correctly cited, and any time we need to seek for help, we will always talk to our TA first.

One potential ethical problem of our product is that if there is any component so small in our final product that cats may eat them accidentlly. Based on our design, cats are only able to reach the dispenser (the bowl) and the special collar, and both these two parts should be big enough so that cats cannot swallow them. One other concern may be that the laser pointer is harmful for cats. However, since the laser pointer is constantly moving, cats are not supposed to have direct eye contact with it. If the owner chooses to directly use the laser to hurt his cat, it is really beyond the control, but we will include a safety instruction clearly stating the potential danger of misusing the laser pointer.

We will regulate our behaviors to avoid safety issues in the lab. We will not work alone in the lab, will not bring any food or drink to the lab room, will use both hands when connecting circuits, will notify our TA if anything is broken, and will clean up our workstation after we finish our work.

5. References

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