Names:
Omolola Okesanjo
Qingquan Liu
Lingxiang Cai

NetIDs:
omolola2
ql21
lcai15

ECE 445 Senior Design Document
An Automated Multi-Cat Feeder System
Spring 2024
February 22th, 2024

ECE 445 Design Document
Automated Multi-Cat Feeder System

1. Introduction

Problem Statement:

Many pet owners, especially those with multiple cats, face significant challenges in managing the dietary needs of their pets, especially when these pets are of different breeds with varying nutritional requirements. Each cat's unique health, age, activity level, and weight contribute to its specific dietary needs, making the task of feeding them a complex and time-consuming process. This challenge is further compounded when owners are away from home, whether for daily work commitments or longer periods of absence. Traditional feeding solutions, such as leaving out large quantities of food, do not address the individual needs of each pet and can lead to issues such as overfeeding, underfeeding, or even health complications arising from inappropriate nutrition. Furthermore, the risk of one cat consuming the food meant for another adds to the difficulty, potentially leading to nutritional imbalances and food aggression among pets. Consequently, there is a pressing need for an automated feeding solution capable of accurately assessing and addressing the unique dietary requirements of each cat. Such a system should not only be able to identify individual pets and dispense food accordingly but also ensure that each cat receives a specific type of food, tailored to its specific health needs, regardless of the owner's physical presence. Implementing a solution that effectively manages these aspects would significantly enhance the well-being of pets and provide peace of mind to pet owners, ensuring that their furry companions are well-fed and healthy, even in their absence

Proposed solution:

To address the outlined challenges pet owners face with multiple cats, our proposed solution is to develop a comprehensive, automated cat feeder system that is both intelligent and highly customizable. This system will feature an advanced identification mechanism for distinguishing between different cats, ensuring that each pet is fed according to its specific dietary requirements and nutritional needs. The core components of this solution include:

1. Automated Feeder System: At the heart of our solution is a sophisticated feeder system capable of dispensing precise portions of food. This system will be programmable to accommodate the unique diet plans of each cat (the specific amount that is chosen by ourselves based on how much each cat needs),. This precision in portion control not only promotes healthier eating habits but also helps in managing food intake for pets with specific dietary restrictions.

2. RFID Identification: To accurately identify each cat and ensure that they receive the correct food portion, our system will incorporate Radio Frequency Identification (RFID) technology. In the U.S., it is common for domestic cats to be implanted with an RFID tag beneath the skin, located between the shoulder blades, just behind the neck. This tag will be scanned by the feeder

before dispensing food. This ensures that the food intended for a particular cat is only accessible to that cat, thereby preventing food theft among pets and supporting individual dietary requirements.

3. Programmable Timer Integration: The system will feature a fully programmable timer that works in tandem with the feeder mechanism. This allows pet owners to set specific feeding times throughout the day, ensuring that the cats maintain a regular eating schedule, even in the absence of the owner. The timer can be adjusted to match the feeding frequency recommended for each cat's health and nutritional needs.

4. Integrated PCB with Direct Control and Notification System: At the core of our automated cat feeder system lies a meticulously designed Printed Circuit Board (PCB) that controls all aspects of the feeding process, from pet identification to precise food dispensation. This PCB allows for direct interaction with the feeder system offering a different approach to customization and monitoring. Owners can program feeding schedules and portion sizes directly on the device through a built-in interface. This interface will be intuitive and designed to accommodate the setting of multiple feeding times and specific portion sizes easily.

To enhance the system's functionality, the PCB will integrate with various sensors (e.g., RFID readers for pet identification, and weight sensors for food dispensation accuracy) and control mechanisms (motors for dispensing food) to ensure precise and reliable operation. This design prioritizes ease of use, reliability, and the ability to meet the individual dietary needs of each cat, all while providing feedback and control mechanisms that keep the owner informed and in charge of their pets' nutrition, even in their absence.

5. Scalability and Customization: Recognizing that households may have varying numbers of pets with different needs, our system will be scalable and customizable. It will support multiple RFID tags and can be expanded or adjusted to cater to the growing needs of pet owners, whether they have one cat or several.

In summary, our solution aims to revolutionize pet care for cat owners by providing an automated, intelligent feeding system that ensures each cat receives personalized nutrition on a consistent basis. This system not only addresses the challenges of feeding multiple cats with different dietary needs but also offers convenience, peace of mind, and enhanced health and well-being for pets.

Visual Aid:

RFID Scanner on Collar

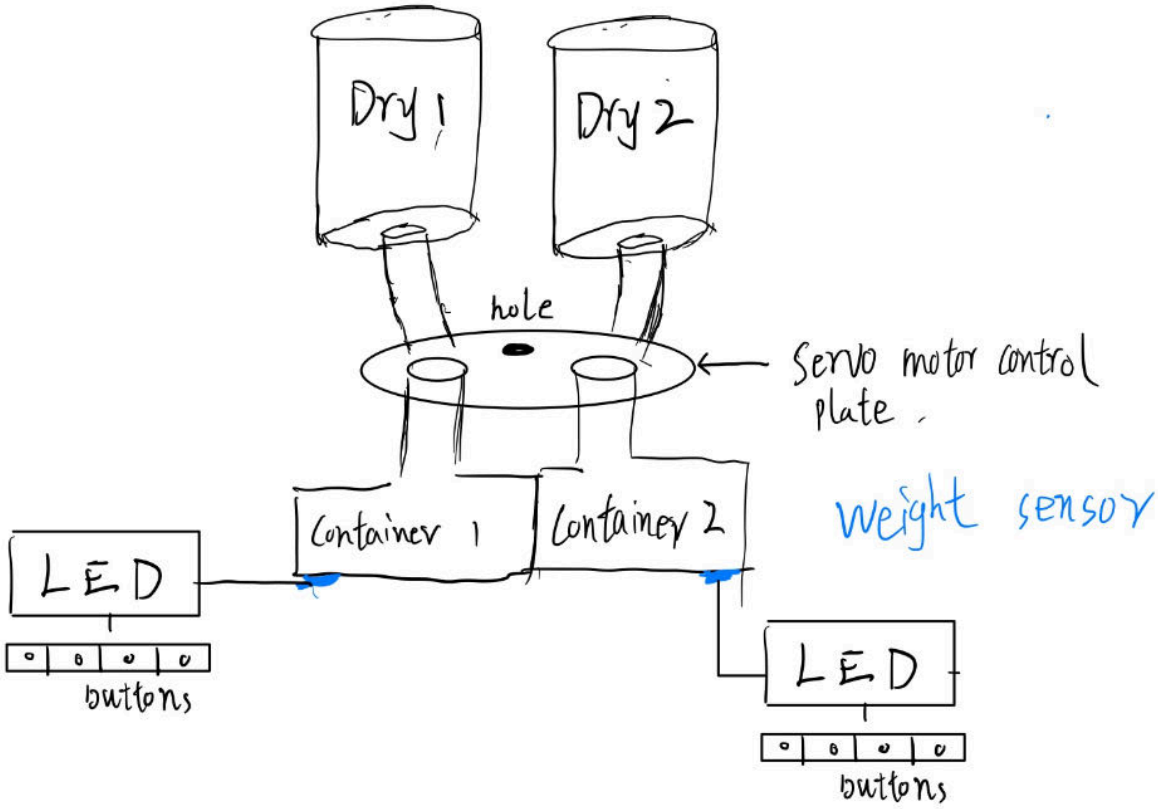
Control System/Interface

Cat food dispenser

High Level Requirements:

- **Reliable Pet Identification and Differentiation**: The system must accurately identify and differentiate between each cat using RFID technology. This involves ensuring that the feeder can read RFID tags with a high degree of accuracy to prevent feeding errors. Accurate pet identification is crucial to ensure that each cat receives food according to its specific dietary requirements. This is particularly important in households with multiple cats, where there may be varying nutritional needs or restrictions. A failure in this system could result in pets receiving the wrong diet, leading to potential health issues.

- **Dispensing Mechanism**: The system's dispensing mechanism must be capable of handling a variety of cat food types, include dry food type 1 and dry food type 2. To achieve that, we simply use two plastic bottles/wood boxes(they can hold up to 3 pounds of food) representing two storages for different food. We will have one plate in between the food storages and containers. This round plate will have a hole that allows food to pass through and it was controlled by a servo motor. The servo motor can be set to some specific rotation degrees(in this case, we have 90 degrees for each state) so that can allow us to make the hole stop at either the dry food type 1 or dry food type 2 or nothing – block food from falling. To make the mechanism capable of delivering food smoothly and consistently, we use the servo motor with larger torque – 25 kg/0.13 S to make sure the food will not stick. In addition, we have two weight sensors to measure how much food is left. If the measured value is below 100 grams, the red LED that connects to the sensor will light up and let users know that they need to add food into that.



Servo High Torque Metal Gear Standard Digital Servo 25KG/0.13S 6.8V for 1/8 1/10 RC Cars(Control Angle 180)

Visit the ZOSKAY Store

4.5 ★★★★½ 868 ratings | Search this page

Amazon's Choice

200+ bought in past month

$17.99

FREE Returns

Thank you for being an Amazon customer. Get $50 off: Pay $0.00 ~~$17.99~~ upon approval for Amazon Visa.

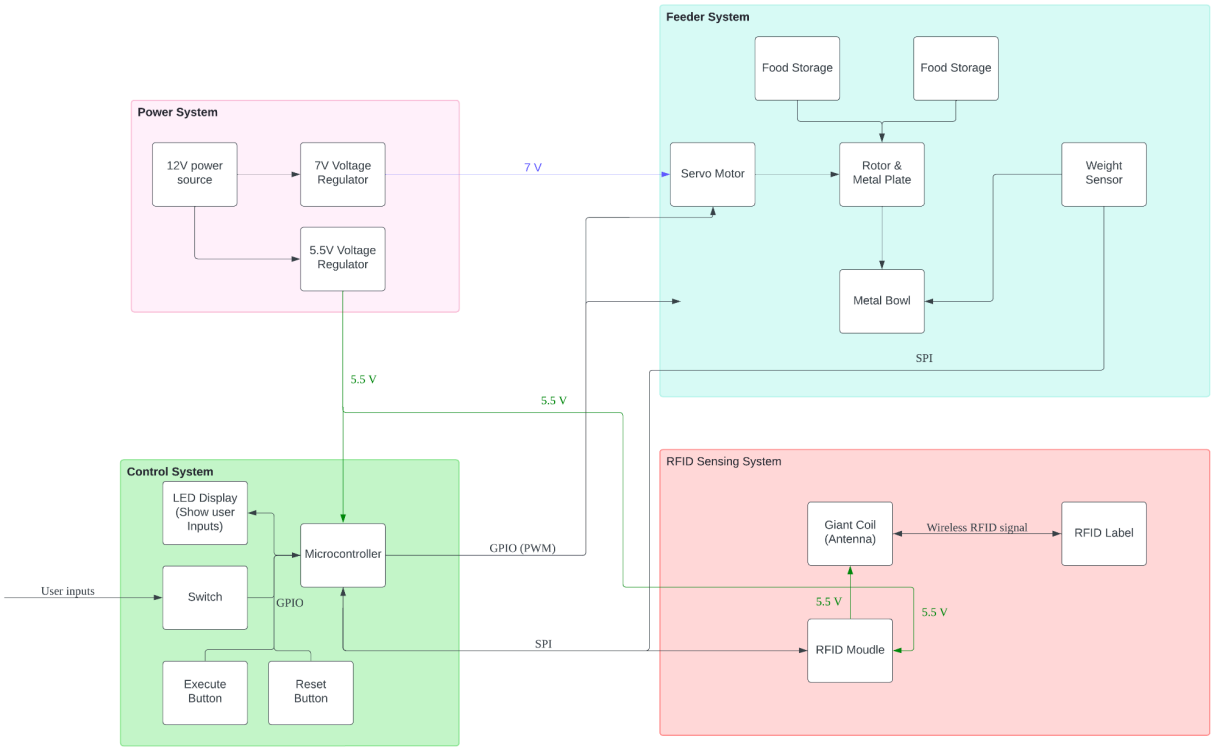
- 25KG servo - maximum torque can up to 25kg.cm (6.8V)
- Digital servo features HV high torque, metal gear, fast heat dissipation, sensitivity and responsiveness. With high quality and performance
- High- metal gear with hard anodizing for better accuracy CNC aluminium middle shell enhances heat dissipation and longer service life
- High Quality - equipped with strong copper & aluminum gears,CNC aluminium middle Shell，made of first-grade material
- Standard servo size:40 x 20 x 40.5 mm (1.58 x 0.79 x 1.60 in) 1/8 1/10 scale car

Report an issue with this product or seller

- **User Controlling Panel**: This design can allow the users to adjust the amount of food they want to dispense at one time. We have a weight sensor on the bottom of the container and connect back to the dispensing system. Our design is to have four LED lights with four buttons, which means that the weight of food can be added one time in the range of ‘0000’ to ‘1111’ in the binary system, which is from 0 to 15 grams in decimal. LED light will be connected to the sensor to show the weight of the food in the container and stop dispensing when it is finished.

2. Design

Block Diagram:



Subsystem Overview:

The automated feeder system is designed with four distinct subsystems, each serving a specialized function to ensure the proper dispensing of food and system control.

1. The Power System in the automated feeder is engineered to cater to the distinct voltage demands of various subsystems by converting a 12V power source down to 7V and 5.5V outputs through two voltage regulators. The 7V output is primarily designated for the servo motor, which requires this specific voltage for optimal operation of the food dispensing mechanism in the Feeder System. Meanwhile, the 5.5V output is essential for the lower voltage needs of the microcontroller, which orchestrates the feeder's operations in the Control System, and the RFID Module, responsible for pet identification in the RFID Sensing System, ensuring both components function efficiently without the risk of voltage-induced damage.

2. The Control System of the automated feeder is centered around the ESP32 s3 microcontroller, a compact yet powerful chip that orchestrates the feeder's functions. Through user input via a switch, the system allows for the precise setting of food portions in grams, which the ATTiny85 then processes to control the servo motor accurately via PWM signals. For identification purposes, the system incorporates a TMS3705EDRQ1 RFID reader module, known for its simplicity and built-in antenna. This module operates at a lower voltage input, enhancing system efficiency, and it's capable of wirelessly

reading 125kHz RFID tags to capture the unique ID of the tags without physical contact. Communication between the ATTiny85 and the RFID reader is established through SPI, enabling a seamless integration of tracking capabilities within the feeding process.

3. The Feeder System is the tangible unit responsible for the actual food dispensing operation. It meticulously holds the food and, under the control of the ATTiny85 microcontroller, it prompts a servo motor into action. The motor manipulates a rotor and metal plate arrangement to allocate food into a metal bowl. The system is refined to dispense food precisely when two conditions are concurrently met: the weight sensor detects that the quantity of food in the bowl is below the user-defined threshold (defaulting to 2 grams) and the TMS3705EDRQ1 RFID reader senses the specific RFID tag of a cat nearby. Only when these criteria are satisfied does the system activate, releasing a user-adjustable serving of food, standardly set to 5 grams, ensuring tailored feeding for each cat.

4. The RFID Sensing System, equipped with the TMS3705EDRQ1 RFID module and a coil antenna, offers identification capabilities by detecting RFID labels on pets or containers. Powered by the ATTiny85 microcontroller, this system sends the unique ID of the detected labels via a serial connection to the control system for appropriate actions, such as dispensing food. The module operates on a lower voltage for efficiency and is paired with an adjustable coil antenna, approximately 10cm in radius, to optimize the detection range. This setup ensures seamless integration with the Feeder System, as outlined in the block diagram, enabling the automated feeder to accurately identify and respond to the presence of tagged pets.

Subsystem Requirements:

Power System Requirements

- Must convert a 12V input to the required 7V and 5.5V outputs with sufficient current to power all components.
- Should provide stable and reliable voltage levels to prevent damage to sensitive electronic parts.

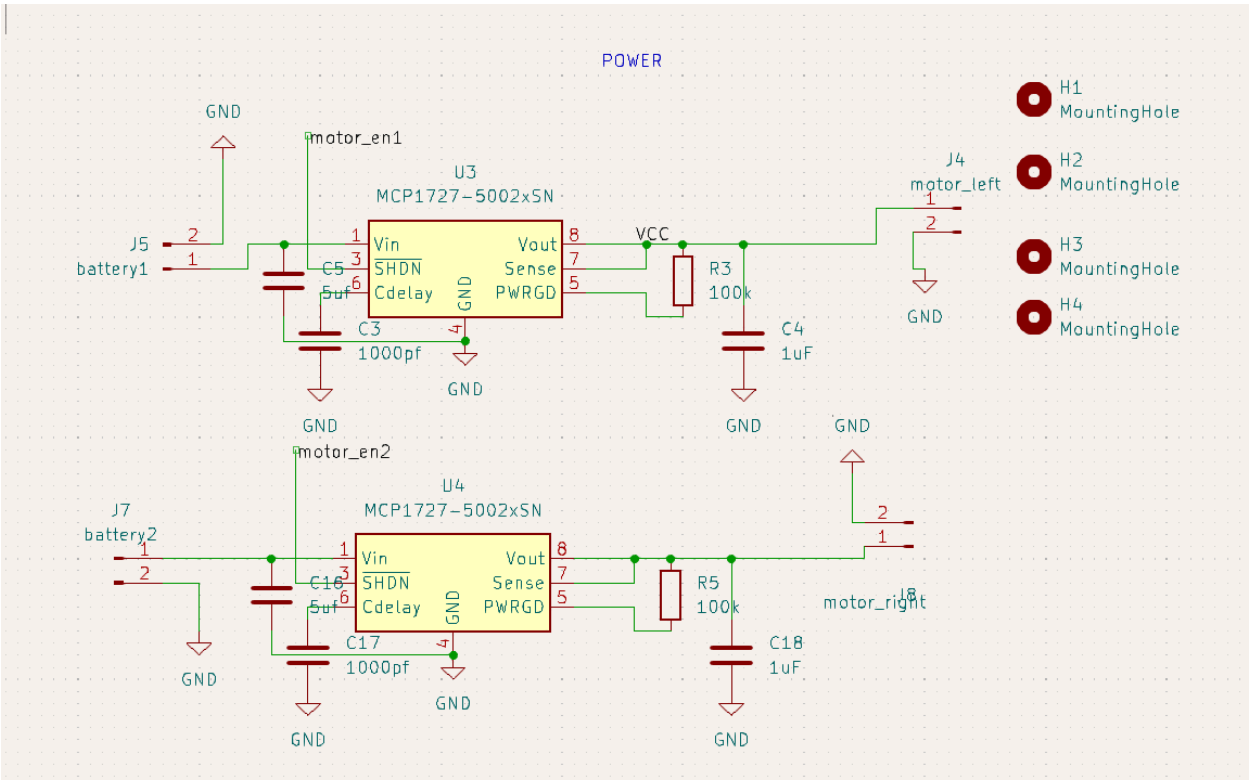


Fig 1: Power system and linear regulators

From the above screenshot in Kicad, we used MAP1727-5002 as our regulator to convert 12V battery power into 5.5 V output power so that it can be used both for the motors and for the chip power supplies. In addition to that, we have two batteries just in case to make sure the enough power. Also, we control that by using the motor_en1 and motor_en2, which will be the outputs from MCU to determine if the motors should work.

Control System Requirements

- The ESP32-S3 microcontroller must generate PWM signals for servo motor control and handle SPI communication with the RFID reader effectively.
- It should have enough processing power and memory to manage the feeder logic, user inputs, and handle inputs from sensors and the RFID system.

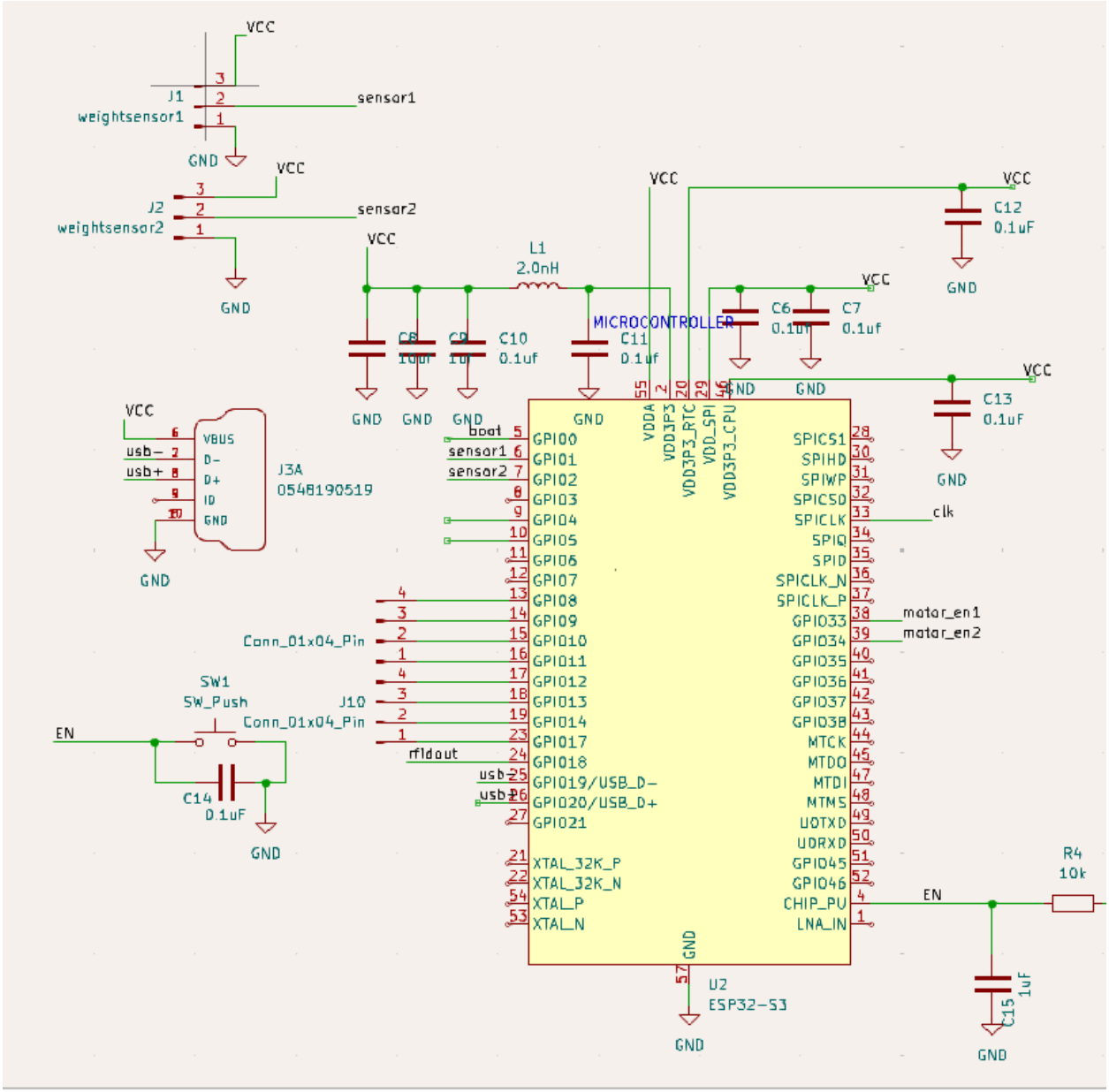


Fig 2: Control System with USB outputs

From the above picture, the MCU we chose here is ESP32-s3. We use EN to turn it on and off with the buttons to control this signal. We also have four inputs to control how much food should be on the plates, so the total will be eight inputs for two plates. In addition, we use a USB port here to code our MCU.

Feeder System Requirements

- Must accurately control the amount of food dispensed using a servo motor, based on user-defined portion sizes.

- Should include a weight sensor capable of detecting the quantity of food in the bowl and triggering food dispensing when it falls below a user-defined threshold (default 2 grams).
- Needs to integrate with the RFID Sensing System to dispense food only when the correct pet is identified.

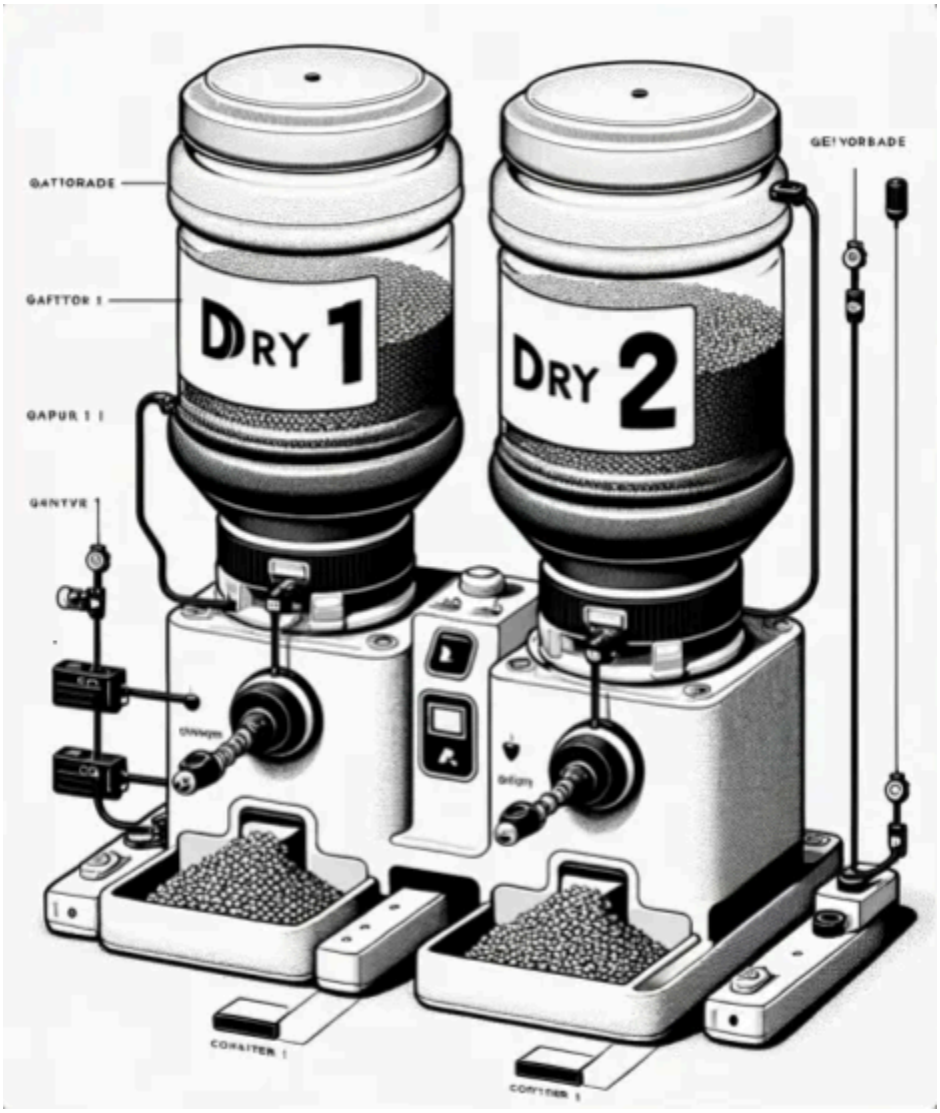


Fig 3: Graph of the overall feeder system

RFID Sensing System Requirements

- The TMS3705EDRQ1 RFID module should reliably read RFID tags at a reasonable range to allow for pet identification without delays.
- The antenna (coil) should be adjustable to optimize the detection range, with an approximate default radius of 10cm.

- The system must be able to communicate the RFID data to the ATTiny85 microcontroller with minimal latency for timely food dispensing.

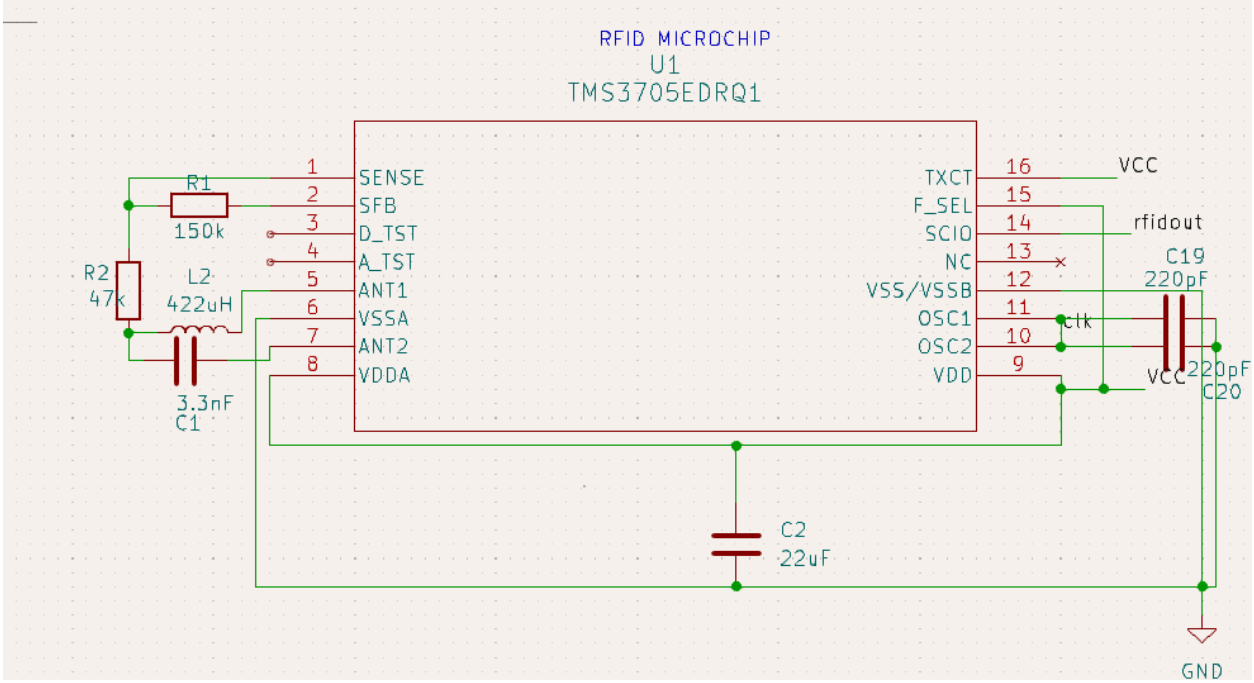


Fig 4: RFID System

We use the TMS3705EDRQ1 RFID chip to detect the frequency of different tags from different cats. The inductor L2 here is the one we need to control to make sure the detecting range of frequency will be around 155Hz.

R&V Table

Power System:

Requirement	Verification
The power system must convert a 12V input to a 7V output for the servo motor.	Use a multimeter to measure the output voltage under no load and a nominal load. The voltage should be within the range of 6.9V to 7.1V.
The power system must convert a 12V input to a 5.5V output for the microcontroller and RFID module.	Use a multimeter to measure the output voltage under no load and a nominal load. The voltage should be within the range of 5.4V to 5.6V.

Control System:

Requirement	Verification
The ATTiny85 microcontroller must process user input to set food portions in grams.	Verify that the microcontroller accepts input from the switch and accurately stores the portion size in memory.
The system must accurately control the servo motor via PWM signals to dispense the set food portion.	Set various portion sizes and observe the servo motor's operation. Measure the dispensed food quantity to ensure it matches the set portion size within a tolerance of ±0.5 grams.
The ATTiny85 must communicate with the RFID reader module via SPI to identify pets.	Test the communication by placing different RFID tags near the reader and verify that the microcontroller correctly identifies each tag.

Feeder System:

Requirement	Verification
The servo motor must rotate the rotor and metal plate to dispense food into the bowl.	Manually activate the servo motor and observe the movement of the rotor and plate to ensure proper operation.
The system must dispense food only when the bowl's weight is below the threshold and a cat's RFID tag is detected.	Place the bowl with varying weights and RFID tags near the system. Verify that food is dispensed only under the correct conditions.
The dispensed food quantity must be adjustable and accurate to within ±0.5 grams of the set portion size.	Set different portion sizes and measure the dispensed food quantity to ensure accuracy within the specified tolerance.

RFID Sensing System:

Requirement	Verification
The RFID module must detect RFID labels and send the unique ID to the control system.	Place RFID labels at various distances within the detection range and verify that the IDs are correctly transmitted to the control system.
The module must operate at a lower voltage	Use a multimeter to measure the operating

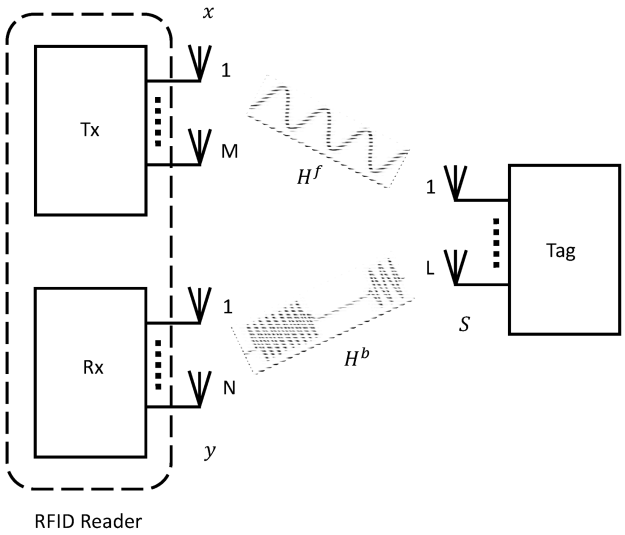
for efficiency.	voltage of the RFID module to ensure it is within the specified range for efficiency.
The coil antenna must be adjustable and optimized for a detection range of approximately 5cm.	Adjust the coil antenna and test the detection range with RFID labels to ensure optimal performance within the specified range.

Tolerance Analysis

Some potential errors may include:

1. Our RFID system may not detect the correct cats as they approach – mismatch the cats
2. Food may not be dispensed into the correct containers for the cats
3. What if two cats enter at the same time
4. The range of the amount of food added each time

For the first potential problem, the basic idea of RFID is to differentiate different frequencies from the tags in the readers, like the picture shown below:



We can make sure that either the frequencies from the tags are different so much that the reader will not mix them or we can make the reader accurate in detecting the different frequencies.
For the second part, so far, we want to use the plate to block the feeder and containers. The motor will be used to control the position of the plate to determine if we should dispense the first food or second food or just block the feeder. We will use the powerful servo motor to avoid the problem with this since that motor can accurately adjust the position to the holes without leaving any food in between the connections.
The third point is that since our container can only allow one cat to have the food, cats probably won't be able to eat food together. In addition to that, our sensor for RFID is in the ring shape –

we have two readers for two different tags, if the wrong cat passes, no food will be dropped until the correct cat passes through the sensor.
Last but not least, we will have the weight sensor to detect the weight of the food in the reasonable error bound. For example, if we want to dispense the 10 grams of food each time, the tolerance will be 10 grams $\pm$ 1 gram. Within that range, our weight sensor can work properly and decide when to stop dispensing the food.

3. Cost and Schedule

Cost Analysis: The overall cost will be the total cost of the components plus the total labor we spend on this project.

$Total\ Labor\ cost\ by\ group\ members = (\$40 * 2.5) * 3\ people * 30\ hours = \$9000$

$Total\ Labor\ cost\ by\ Machine\ Shop(approximately) = (\$40) * 2\ people * 10\ hours = \$800$

$Total\ Labor\ cost\ by\ all\ components = \$150$ (so far)

The total cost will be about $9950

Description	Manufacturer	Quantity	Price
Servo Motor with 25kg/0.13S	ZosKay Store	1	$19
Stainless Steel Cat Bowls	Serentive	2	$8.5
Two plastic bottle containers	Gatorade Drink	2	$2.5
LED display light	uxcell Store	5	$6.49
Buttons(Switches)	Comidox	5	$7.99
1kg 5kg 10kg 20kg Load Cell and HX711 Combo Pack Kit - Load Cell Amplifier ADC Weight Sensor	NOYITO	2	$16
HLK-PM03 DC Power Module AC DC Converter 220V to 5.5V	EC-Buying Store	3	$10.5
Cat Food – two types	Meow Mix Store	2	$17

of dry food(6.15 pounds each)			
Res 1k ohm 1/4W	Yageo	5	$0.5
Res 10k ohm 1/4W	Yageo	5	$0.5
Caps 1000PF 50V	Digikey	5	$11
Caps 100PF 100V	Digikey	5	$11
PCB design	PCBway	1(maybe more)	$10(Not sure)
RFID Reader (TMS3705EDRQ1)	Texas Instruments	1	$10.28

Week	Task	Person
Feb 18 - 24	Re-do proposal, design review, Order Parts	All
Feb 25 - 29	Start assembly of dispenser structure	All
March 3 - 9	Finish & submit PCB design	Lingxiang
March 10 - 16	Communicate with machine shop on dispenser	Omolola
March 17 - 23	Begin integration of RFID, PCB, etc	Omolola
March 24 - 30	Integration of all electrical components, test PCB	Qingyuan
April 1 - 6	Fix and debug PCB if any issue	Lingxiang
April 7 - 13	Integrate microcontroller with PCB to ensure proper functioning and communication between motors, supply etc	All
April 14 - 20	Assemble the whole design	All
April 21 - 27	Continue test and fix issues till demo	All
April 28 -	Done!	

4. Ethics & Safety

When developing an automated multi-cat feeder system, it is crucial to consider both ethical and safety issues that could arise during the project's development and from its potential misuse. Addressing these concerns involves adhering to professional codes of ethics, such as those outlined by the IEEE (Institute of Electrical and Electronics Engineers) and ACM (Association for Computing Machinery), as well as complying with relevant safety and regulatory standards.

Ethical Issues

Privacy and Data Protection: Given that the system may collect data about pets and potentially their owners, it's essential to ensure the privacy and security of this information in line with *IEEE's commitment to respecting user privacy* (IEEE Code of Ethics). To avoid breaches, data collected by the system will be encrypted, and personal data will be anonymized where possible. Access controls will be implemented to prevent unauthorized data access.

Nonmaleficence: According to the ACM Code of Ethics, designers should "*avoid harm.*" In the context of this project, it's vital to ensure that the system does not inadvertently harm pets, for example, by dispensing incorrect food portions or malfunctioning. This involves rigorous testing of the feeding mechanism and sensors to ensure reliability and accuracy.

Honesty: According to the ACM Code of Ethics, designers should "*be honest and trustworthy.*" This involves being transparent about the limitations of the feeder system, such as the conditions under which it might fail to correctly identify a pet or dispense the wrong portion size, and providing clear instructions for mitigating such risks.

Safety Issues

Mechanical and Electrical Safety: The system involves moving parts and electrical components, posing potential risks. Compliance with safety standards, such as those set by the Consumer Product Safety Commission (CPSC) and Underwriters Laboratories (UL), is crucial to minimize risks of injury or electrical hazards.

Material Safety: All materials in contact with food must be non-toxic and safe for pets, adhering to FDA regulations for food safety. This ensures that pets are not exposed to harmful substances.

Potential Safety Concerns:
-Choking Hazard: Small parts or improperly dispensed food sizes could pose a choking hazard to pets. Designs will ensure that food is dispensed in safe, manageable portions.
-Electrical Safety: Protecting against electrical shock is paramount. This includes designing enclosures that prevent pets or their owners from accessing electrical components.

-System Failure: A failure in the system could lead to pets being underfed or overfed. Implementing redundant systems for monitoring food levels and dispensing mechanisms can mitigate this risk.

To address these concerns, the project will undergo a thorough risk assessment process, incorporating feedback from multiple testing phases to identify and rectify potential hazards. Regular reviews of the project's adherence to the IEEE and ACM codes of ethics, as well as compliance with relevant safety and regulatory standards, will be conducted to ensure ethical and safety considerations are met throughout the project lifecycle.

Designed with the well-being of pets in mind, our feeder will be built using safe, non-toxic materials that are easy to clean and maintain. The system will include safety features to prevent accidental injury to the pets during feeding and to ensure that the food remains fresh and free from contamination.

5. References

[1] Institute of Electrical and Electronics Engineers. "**IEEE Code of Ethics.**" IEEE, 2020, www.ieee.org/about/corporate/governance/p7-8.html.

[2] Association for Computing Machinery. "**ACM Code of Ethics and Professional Conduct.**" ACM, 2018, www.acm.org/code-of-ethics.

[3] US Consumer Product Safety Commission. "**Regulations, Laws & Standards."** USCPSC, 2018, https://www.cpsc.gov/Regulations-Laws--Standards.