An Automated Multi-Cat Feeder System

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Abstract

The main objective of this report is to design multi-cat feeders that can detect different cats and dispense food in the correct amount and type. A few high-level requirements are necessary to achieve this. Firstly, the RFID system should be able to detect the tags on the cat to trigger the dispensing system, and the weight sensor should measure the weight correctly. Second, the dispenser should drop food as soon as it receives the signal from RFID and stop dropping when the food reaches a certain amount. Finally, the user can use a website and WiFi to control how much food should be dropped and what cats correspond to what food. Since we need to include WiFi, ESP32-S3-WROOM-1 will be the best microcontroller for this project.

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1. Introduction

1.1 Problem

Many pet owners, particularly those with multiple cats of different breeds, face challenges in managing their pets' dietary needs due to varying health, age, activity levels, and weight requirements. This complexity is exacerbated when owners are away, leading to reliance on traditional feeding methods that may result in overfeeding, underfeeding, or food aggression among pets. To address these issues, there is a demand for automated feeding systems capable of individual pet recognition and precise food dispensing based on each cat's specific dietary needs, regardless of the owner's presence. Such solutions would enhance pet well-being and provide peace of mind to owners.

1.2 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.

1.3 Visual Aid

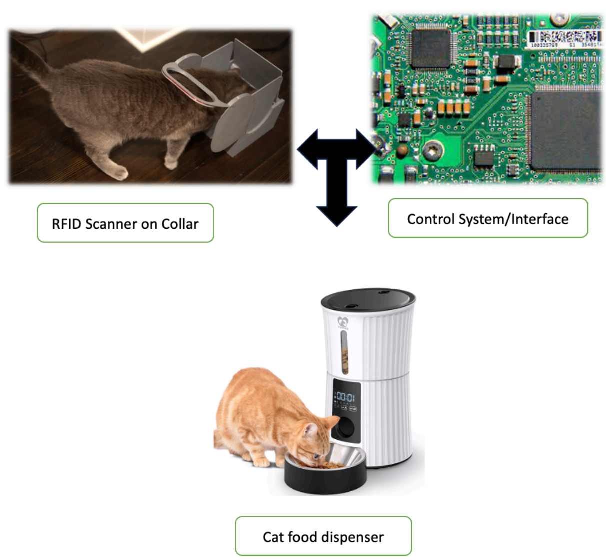

Figure 1: Visual Aid of the design

1.4 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.
- **Dispensing Mechanism**: The system's dispensing mechanism must be capable of dropping a variety of cat food types, including 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 storage and containers. This round plate will have a hole that allows food to pass through and it is controlled by a step motor. When a tag is detected and the weight is not higher than the user's set value, the food will be dropped until it reaches the set value.
- **User Controlling Panel**: This design allows 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 that connects back to the dispensing system. Our design used to have buttons for control, but now we use Wi-Fi and websites to control the system. The user can define how much food should be dropped/left on the bowl and also define the RFID tag they want to be detected.

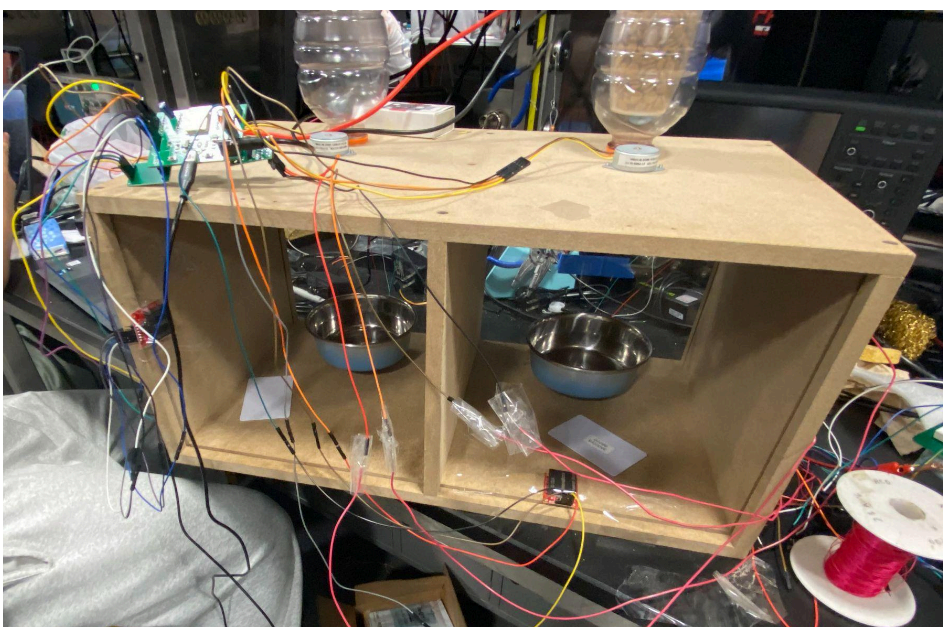

Figure 2: Project Overview

2 Design

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.

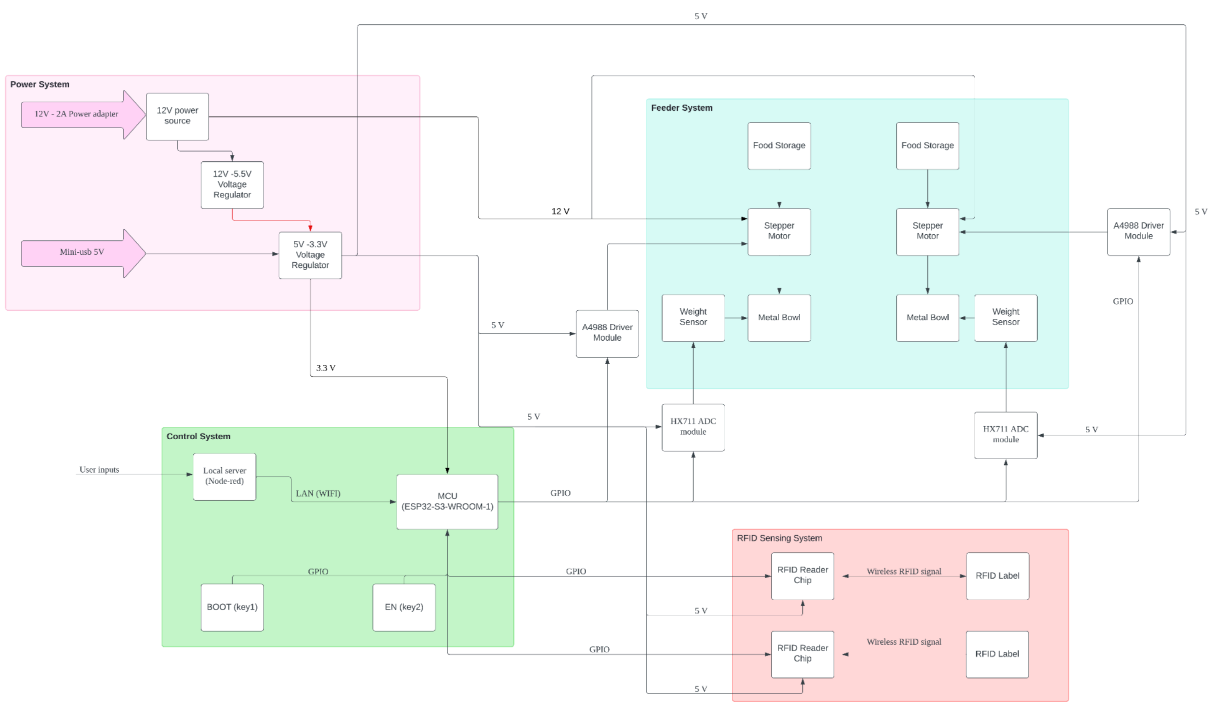

Figure 3: Block Diagram overview

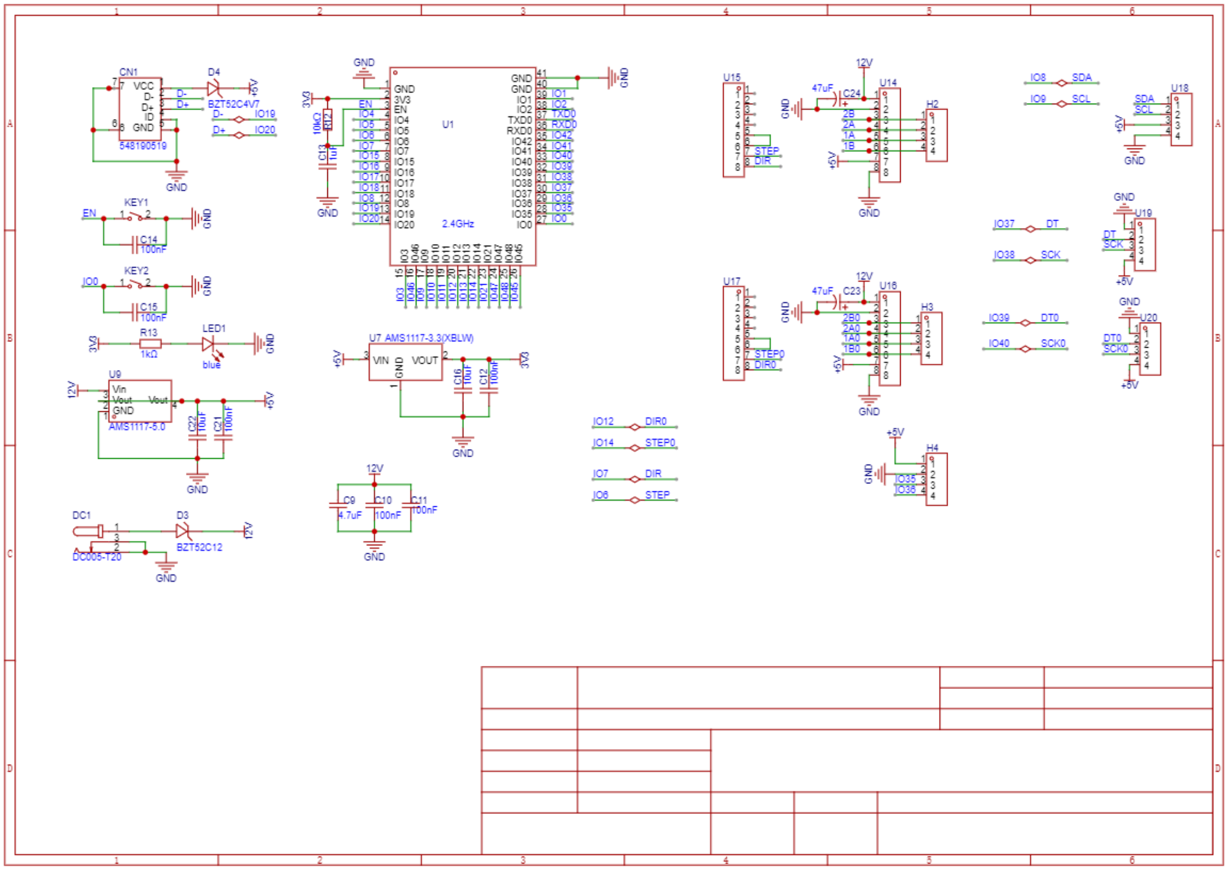

Figure 4: Schematic Diagram overview

2.1 Power System

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 5.5V outputs through the voltage regulator. The 12V from the plug is primarily designated for the stepper 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, stepper motor driver, and weight sensor amplifier. In addition to that, we also need the isolation from 12V to 5.5V to ensure there will be no risks of voltage-induced damage.

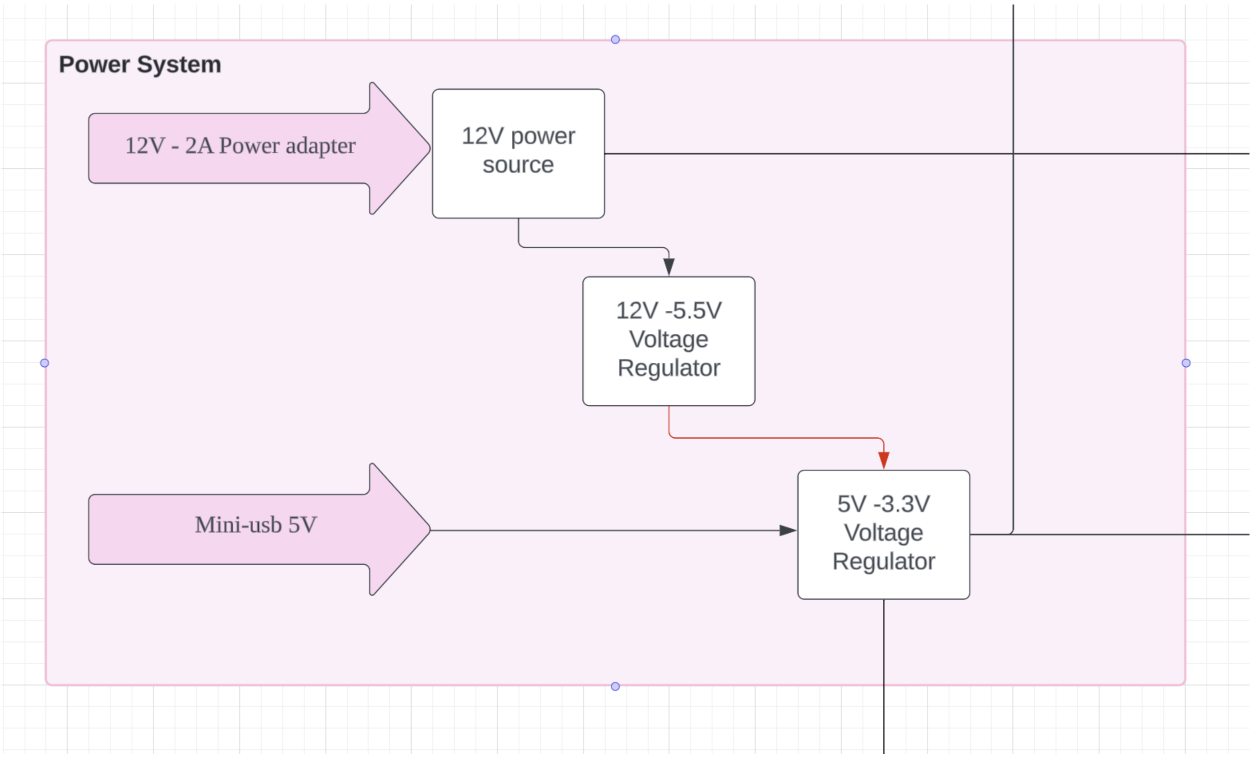

Figure 5: Power System (Close-up)

2.2 Feeder System

The feeder system consists of two identical dispensing systems. Each dispensing system includes a food storage unit made from a Gatorade bottle, connected to a chute leading to a metal bowl. This chute is controlled by a stepper motor that rotates an acrylic plate, dispensing food. The stepper motor communicates with the MCU via an A4988 driver. Beneath the metal bowl, a weight sensor measures the weight of the food and exchanges signals with the MCU through an HX711 ADC module.

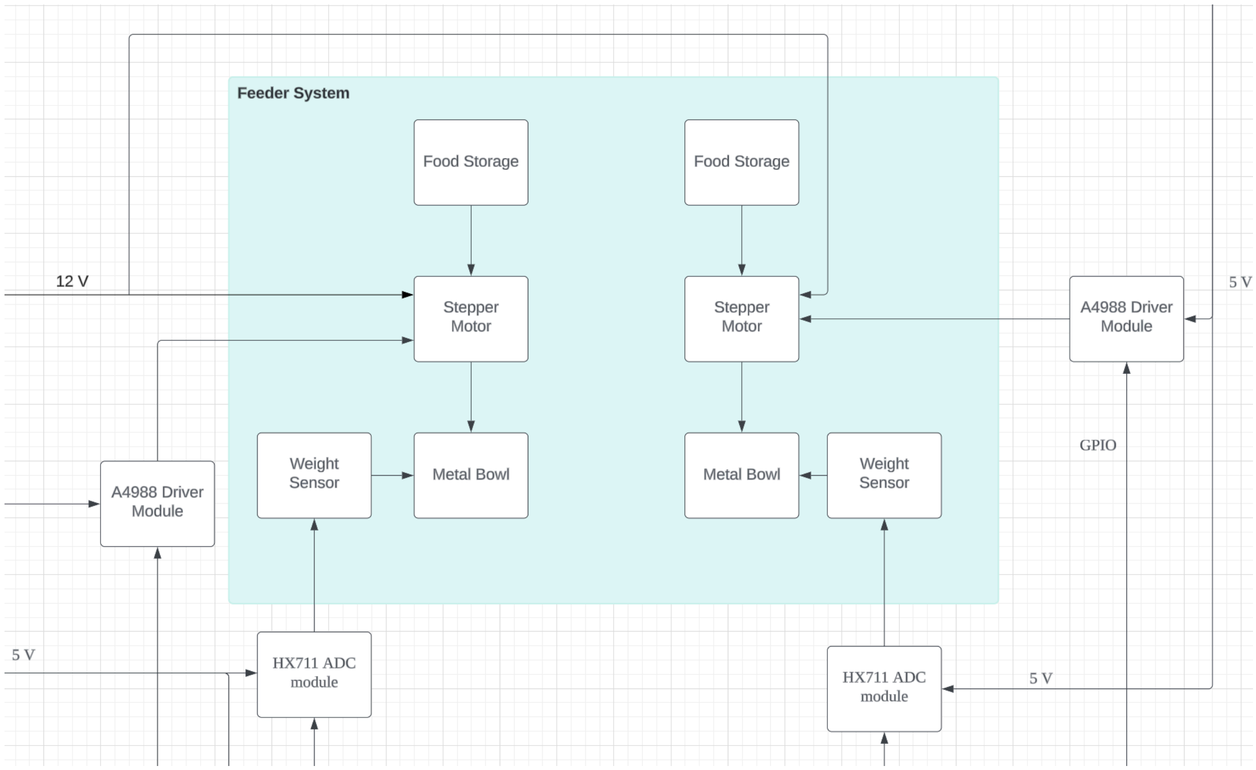

Figure 6: Feeder System (Close-up)

2.3 Control 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. We choose ESP32-S3-WROOM-1 as our microcontroller since it has WiFi implemented already and can have about 30 GPIO pins for us to use. Specifically, this microcontroller will be used to connect weight sensor, stepper motor, power and RFID system.

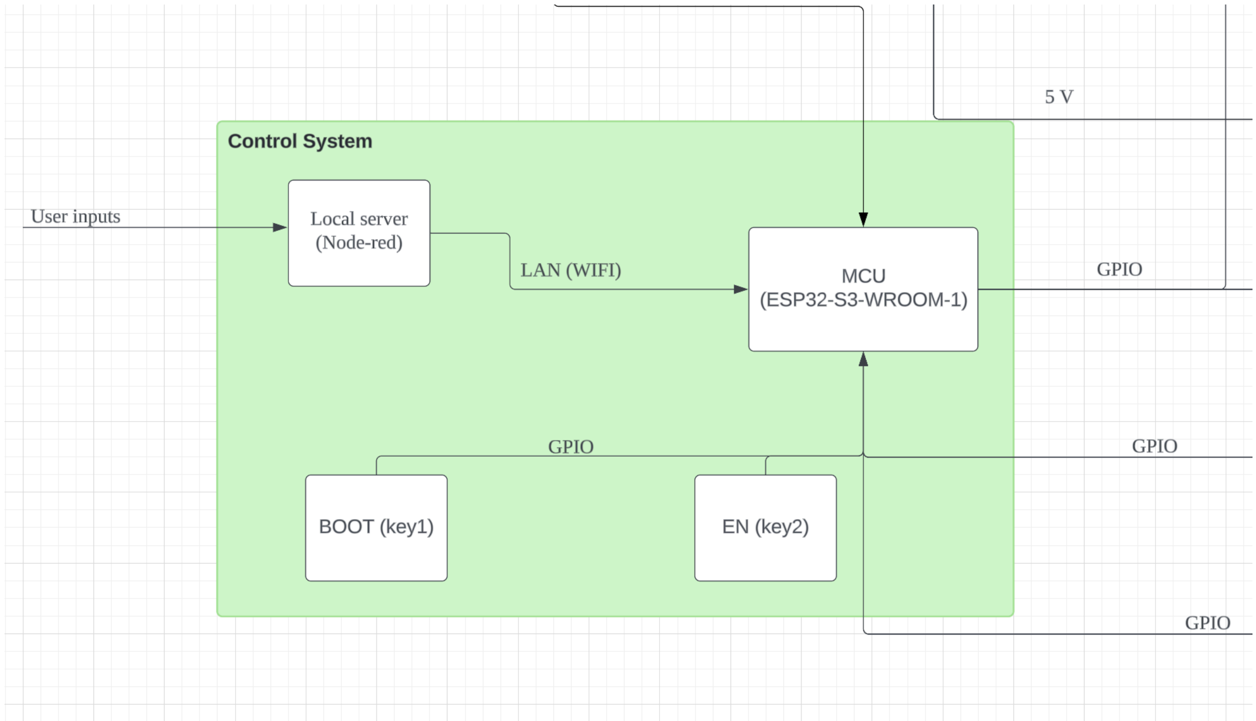

Figure 7: Control System (Close-up)

2.4 RFID Sensing System

The RFID system consists of two RFID reader chips, each with a built-in antenna capable of detecting tags within a 12cm range. To prevent interference, these two chips must be placed at least 12 inches (30.48 cm) apart from each other.

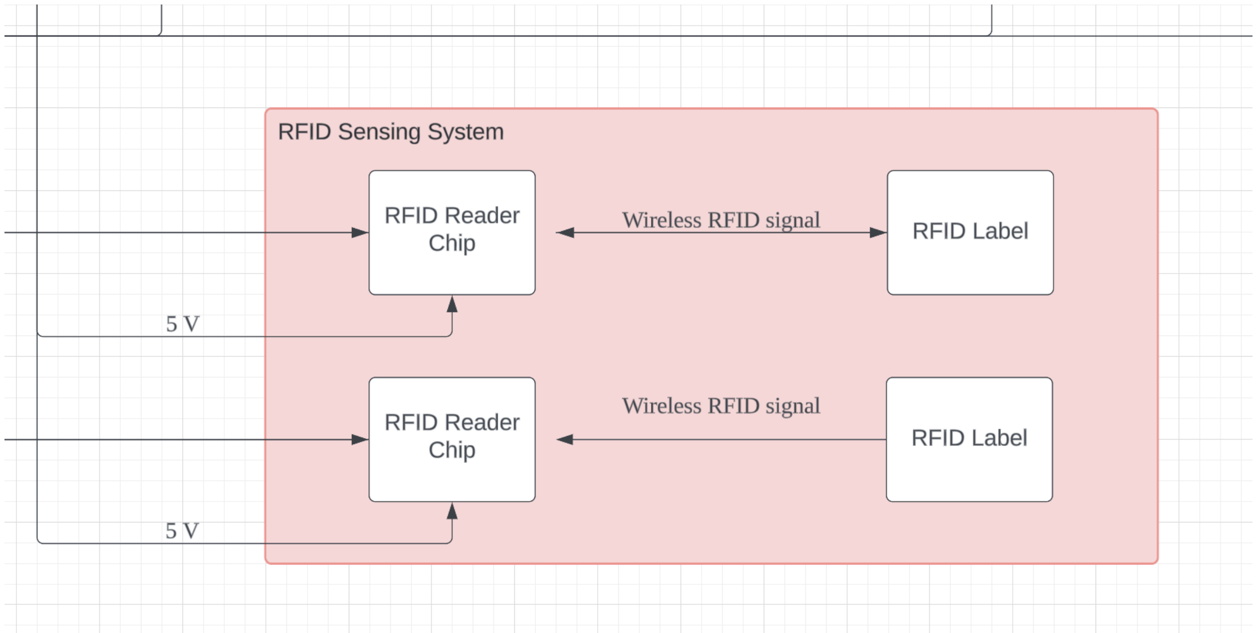

Figure 8: RFID Sensing System (Close-up)

3. Design Verification

3.1 Power System

For the power system, we must measure the voltage on the supply part and the voltage on the converter's output. The supply voltage should be closed to the 12V with the 5% error and the voltage out of the converter should also be around 5V with the 5% error. The result is shown in the figures below.

Figure 9: 12V Voltage Input

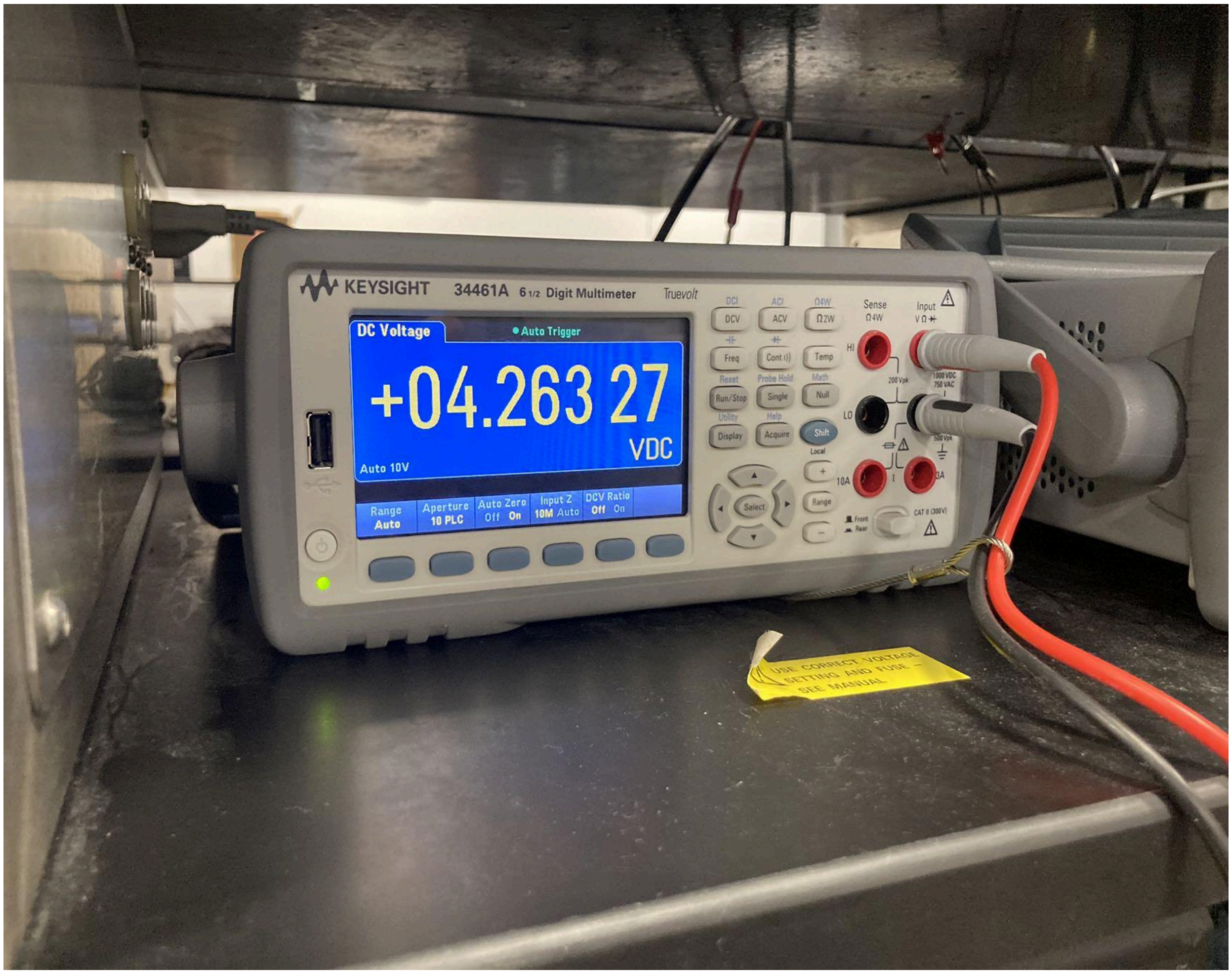

Figure 10: 5V Voltage Output

The results are slightly different from what we expected, but within the error bounds. The slight fluctuations in the output voltage may be due to the miss of capacitance that can maintain the voltage to certain levels and also the measuring errors.

3.2 Control System

To test our control system, we simply set a weight value for the system in Arduino ide and perform the test. We also connect ESP32-S3-WROOM-1 to WiFi and use the website to both monitor the values of the weight sensors and make changes to the system, such as changing the tags and adjusting the maximum weight.

```
void loop() {
  MQTT_connect();
  if (!mqtt.ping()) {
    mqtt.disconnect();
  }
  mqtt.processPackets(5000); // Adjust the timeout as needed

  digitalWrite(DIR, HIGH);
  a = scale.get_units();
  digitalWrite(DIR2, HIGH);
  b = scale2.get_units();

//first one
  if (rfid1.readTag(tag, sizeof(tag)))
  {
    Serial.print("Tag: ");
    Serial.print(tag);
    if (SerialRFID::isEqualTag(tag, matchTag))
    {
      //count++

      Serial.println("    ");
      if (a < limit_wR && count == 0){
        for (int i = 0; i<steps_per_rev; i++) {
          digitalWrite(DIR, HIGH);
          digitalWrite(STEP, HIGH);
          delayMicroseconds(4500);
          digitalWrite(STEP, LOW);
          delayMicroseconds(4500);
          count++;
        }
      }

      Serial.println(" / Match: OK");
```

Figure 11: Code Snippet for Control System

```
Output    Serial Monitor ×
Message (Enter to send message to 'ESP32S3 Dev Module' on 'COM5')

Connecting to 1901-108
..................Connecting to ttcc
WiFi connected
IP address:
172.20.10.2
Connecting to MQTT... MQTT Connected!

Sending Right_weight = 0.00 OK
Weight_R:
0.00
count:
0
Weight_L:
-0.05
count2:
0
Dropped a packet

Sending Right_weight = -0.04 OK
Weight_R:
-0.04
count:
0
Weight_L:
-0.07
count2:
0
Dropped a packet
```

Figure 12: Arduino Panal for Control System Testing

The code in Arduino ide includes the function of making connections between local WiFi and microcontroller, the function of RFID to read tags and determine whether correct or not, detecting weight from weightsensor and make the decision of whether move the stepper motor clockwise or counterclockwise by 90 degrees depending on several factors – RFID tags detection and the weight on the bowl.

The result on the screen shows us that all the functions are activated and performed well. “MQTT connected!” means our ESP32 has correctly connect to our website through WiFi with the IP address showing on the top of that. In addition to that, several lines after that show us how much weight has been detected on both the right bowl and left bowl, and the internal logic will determine if the food should be dropped. Moreover, to make sure our control system minimizes the delay, we set our delay time in the code to be 100, which is around 0.1 second.

3.3 Feeder System

To test feeder system, we will only focus on the stepper motor part since it is the core of the dispensing system. In this case, we will test if the motor can rotate our cover with correct degrees and we will only test on one side. The table below shows the angle that the slide rotates corresponding the the STEP value we give to the driver and the potentiometer value we adjust.

	STEP	Potentiometer	Degree
Trial 1	10	100 mA	Only shaking
Trial 2	10	200 mA	Around 15 degrees
Trial 3	10	400 mA	Around 45 degrees
Trial 4	15	400 mA	Around 60 degrees
Trail 5	20	400 mA	Approximately 90 degrees(Go with this)

Table 1 : Results of Stepper Motor Behaviors

The real value for the STEP is around 20, which is different from what we expect – 12. This maybe due to the fact that the fricional force between the cover and the wood box will force the rotation angle to decrease, so we need the larger STEP value to achieve the approximately 90 degrees rotation.

3.4 RFID System

To test RFID system, we will activate the function "rfid.readTag()" in Arduino ide and perform the comparison between correct tag ID and the one that is detected. Whenever the tag is detected, the reader will beep for once to let us know that the tag has been detected. If the correct one is detected, the function returns "True" and print out "Match:OK".

```
#include <SoftwareSerial.h>
#include <SerialRFID.h>


const byte RX_PIN = 16;
const byte TX_PIN = 17;

SoftwareSerial sSerial(RX_PIN, TX_PIN);
SerialRFID rfid(sSerial);

char tag[SIZE_TAG_ID];
char matchTag[SIZE_TAG_ID] = "6B001CF90A84";

void setup()
{
  Serial.begin(115200);//115200
  sSerial.begin(9600);//9600

  Serial.println(">> Starting SerialRFID example program");
}

void loop()
{
  //Serial.println(tag);
  if (rfid.readTag(tag, sizeof(tag)))
  {
    Serial.print("Tag: ");
    Serial.print(tag);

    if (SerialRFID::isEqualTag(tag, matchTag))
    {
      Serial.println(" / Match: OK");
    }
    else
    {
      Serial.println(" / Match: No");
    }
  }
}
```

Figure 13: Code Snippet for RFID System

4. Costs

4.1 Parts

Part	Manufacturer	Retail Cost ($)	Bulk Purchase Cost ($)	Actual Cost ($)
SmoTecQ 12V 2A Power Supply AC Adapter, AC 100-240V to DC 12 Volt Transformers, 2.1mm X 5.5mm Wall Plug	SmoTecQ Store	$9.99		$9.99
Stepper Motor Mercury Motor (ST-PM35-15-11C)	ECEshop	$8		$16
HiLetgo 5pcs A4988 Stepstick Stepper Motor Driver Module with Heat Sink for 3D Printer Reprap Suitable for Mendel Huxley Arduino	HiLetgo Store	$10.19		$10.19
1kg 5kg 10kg 20kg Load Cell and HX711 Combo Pack Kit - Load Cell Amplifier ADC Weight Sensor	NOYITO	$16		$32
HiLetgo 3pcs HX711 Weighing Sensor Dual-Channel 24 Bit Precision A/D Module Pressure Sensor	HiLetgo Store	$6.79		$6.79
RFID Reader ID-12LA (125 kHz)	Sparkfun	$32.50		$65
Two plastic bottle containers	Gatorade	$2.5		$5
Cat Food	Purina	$16.88		$16.88
Whisker City®	Whisker City	$8.5		$8.5

Blue Ombre Glitter Non-Skid Stainless Steel Cat Bowl, 2-cup				
CAP 4.7UF-C1206	Digikey	$0.18		$0.18
CAP 100nF-C0805	Digikey	$0.10	$0.65	$0.65
CAP 10UF-C0805	Digikey	$0.10	$0.70	$0.70
CAP 1UF-C0805	Digikey	$0.10	$0.62	$0.62
CAP 47UF (Through Hole)	ECE lab	$0		$0
CONN RCPT USB2.0 MINI B 5P R/A	Digikey	$2.10		$2.10
12V Zenor Diode-SOD123	Digikey	$0.21	$1.44	$1.44
5V Zenor Diode-SOD123	Digikey	$0.21	$1.44	$1.44
CONN PWR JACK 2X5.5MM SOLDER	Digikey	$0.61		$1.83
SWITCH TACTILE SPST-NO 0.05A 12V	C&K	$0.24		$0.24
LED BLUE CLEAR 0805 SMD	Würth Elektronik	$0.19		$0.19
ESP32-S3-WROOM-1-N32R8V	Digikey	$6.68		$6.68
RES 10K OHM 1% 1/8W 0805	Digikey	$0.10	$0.27	$0.27
RES 1K OHM 1% 1/8W 0805	Digikey	$0.10	$0.25	$0.25
AMS1117-3.3-SOT223	Digikey	$0.43		$0.43
AMS1117-5.0-SOT223	Digikey	$0.38		$0.38
PCB design	PCBway	$0		$0
Total				**$187.51**

Table 2 : Costs of all parts

4.2 Labor

Based on the records, the salary for the electrical engineer graduating students is about $102,676, which is same as $48.77/hr. If we assume that every week, our group met for about 12 hours, the total hours per person over 12 weeks will be 12*12 = 144 hours. Since we have three group members, the total hours will be 144 * 3 = 432 hours. Hence, the total labor cost will be 432 * 48.77 = $21068.64.

4.3 Total Cost

The total cost for ECE 445 project will be $21068.64 + $187.51 = $21256.15. I think this cost can be reduced by reduce the quality of some components but also make sure the product can work. Some sunk cost comes from the waste of the unused PCB and components, and the time we spent on the meaningless discussion during the project time. If we are more efficient and more experienced with PCB, we can cut down more cost.

5. Conclusion

5.1 Accomplishments

We're grateful because we were able to achieve all of our high-level requirements and complete our requirement and verification table. Our system works as expected; The Printed Circuit Board (PCB) and microcontroller works as expected; We didn't use a development board or breadboard in our final demo.

5.2 Ethical considerations

Privacy and Data Protection: Given that the system collects data about pets and potentially their owners and their wireless networks, 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 is encrypted, and personal data in the wifi system is anonymized where possible. Access controls over the wifi network implemented to prevent unauthorized data access.

Nonmaleficence: According to the ACM Code of Ethics, designers should "*avoid harm.*" In the context of this project, we have made sure 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.

To address safety concerns such as choking hazards, electrical shocks, system failure and the like, our project underwent a thorough risk assessment process, incorporating feedback from multiple testing phases as well as our TA 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.

5.3 Future work

On this project, our future work involves several key enhancements. First, we plan to work on the antenna to amplify the RFID detection range, improving the system's ability to identify individual cats. Second, we aim to conceal all wires inside the wood box, ensuring a neat and safe design. Third, we intend to implement a buffer system that controls the food drop rate, allowing for more precise portion control and reducing food wastage. Finally, we plan to include a shield to prevent other cats from accessing the wrong food, ensuring that each cat receives the intended meal.

References

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[2] "ESP32 with load cell and HX711 amplifier (Digital Scale)," Random Nerd Tutorials, https://randomnerdtutorials.com/esp32-load-cell-hx711/ (accessed Apr. 25, 2024).

[3] "Esp32 MQTT publish subscribe with Arduino Ide," Random Nerd Tutorials, https://randomnerdtutorials.com/esp32-mqtt-publish-subscribe-arduino-ide/ (accessed Apr. 25, 2024).

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[6] Babiuch, Marek, et al. "Using the ESP32 Microcontroller for Data Processing." *2019 20th International Carpathian Control Conference (ICCC)*, May 2019, https://doi.org/10.1109/carpathiancc.2019.8765944.

[7] Vrishanka, P. N, et al. "Automated Pet Feeder Using IoT." *IEEE Xplore*, 1 Dec. 2021, ieeexplore.ieee.org/abstract/document/9688391.

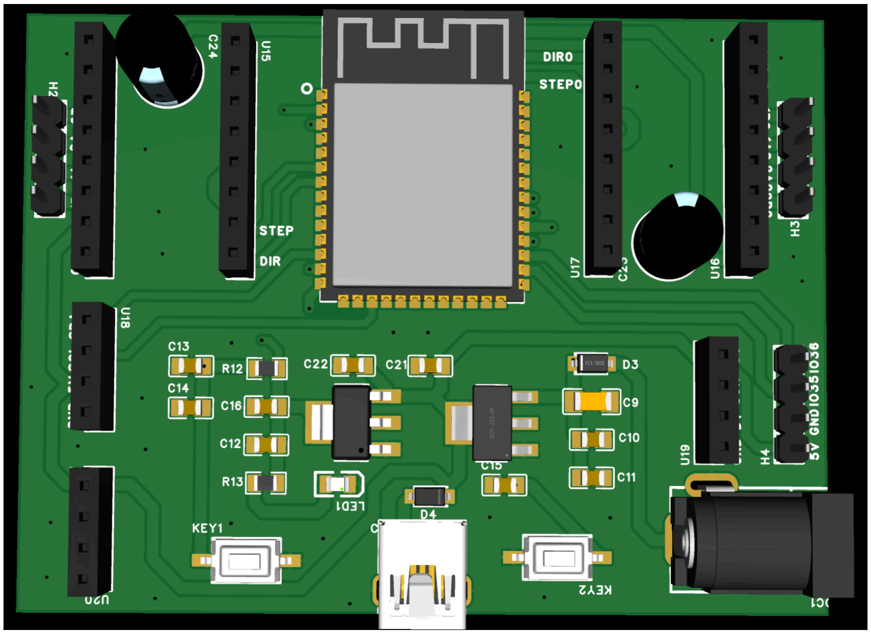
Appendix A: Requirement and Verification Table

Table X System Requirements and Verifications

Requirement	Verification	Verification status (Y or N)
1. Requirement a. The power system must convert a 12V input to a 7V output for the servo motor. b. The power system must convert a 12V input to a 5.5V output for the microcontroller and RFID module.	1. Verification a. 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. b. 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.	Y Y
2. Requirement a. The ATTiny85 microcontroller must process user input to set food portions in grams. b. The system must accurately control the servo motor via PWM signals to dispense the set food portion. c. The ATTiny85 must communicate with the RFID reader module via SPI to identify pets.	2. Verification a. Verify that the microcontroller accepts input from the switch and accurately stores the portion size in memory. b. 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. c. Test the communication by placing different RFID tags near the reader and verify that the microcontroller correctly identifies each tag.	Y Y Y
3. Requirement a. The servo motor must rotate the rotor and metal plate to dispense food into the bowl. b. The system must	3. Verification a. Manually activate the servo motor and observe the movement of the rotor and plate to ensure proper	Y

dispense food only when the bowl's weight is below the threshold and a cat's RFID tag is detected. c. The dispensed food quantity must be adjustable and accurate to within ±0.5 grams of the set portion size.	operation. b. Place the bowl with varying weights and RFID tags near the system. Verify that food is dispensed only under the correct conditions. c. Set different portion sizes and measure the dispensed food quantity to ensure accuracy within the specified tolerance.	Y Y
4. Requirement a. The RFID module must detect RFID labels and send the unique ID to the control system. b. The module must operate at a lower voltage for efficiency. c. The user can enter setup mode to set the RFID tag corresponding to the cat's name.	4. Verification a. Place RFID labels at various distances within the detection range and verify that the IDs are correctly transmitted to the control system. b. Use a multimeter to measure the operating voltage of the RFID module to ensure it is within the specified range for efficiency. c. The system displays a setup interface where the user can assign an RFID tag to a specific cat's name, and the information is saved and retrieved accurately upon subsequent scans.	Y Y Y

Appendix B: PCB Layouts



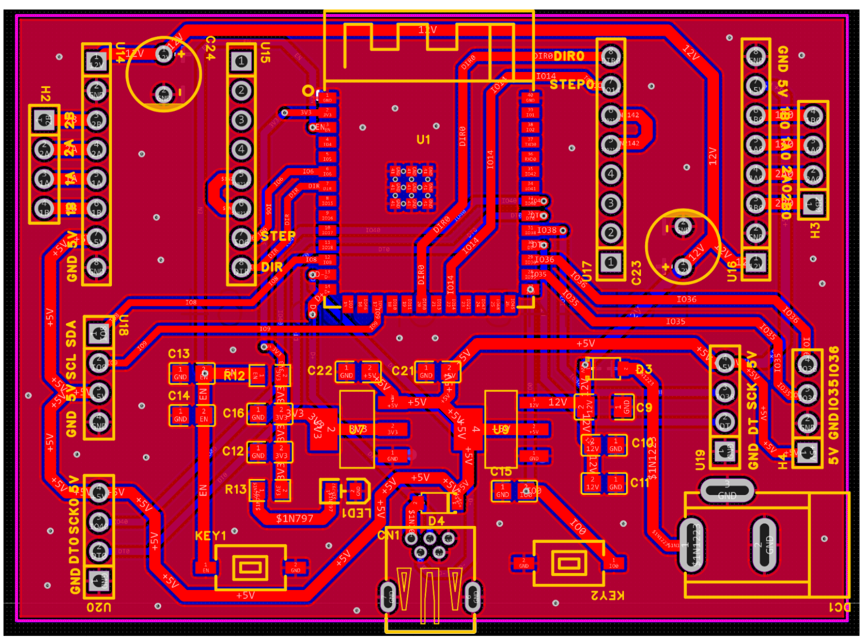


Figure #? PCB (Plug and play)

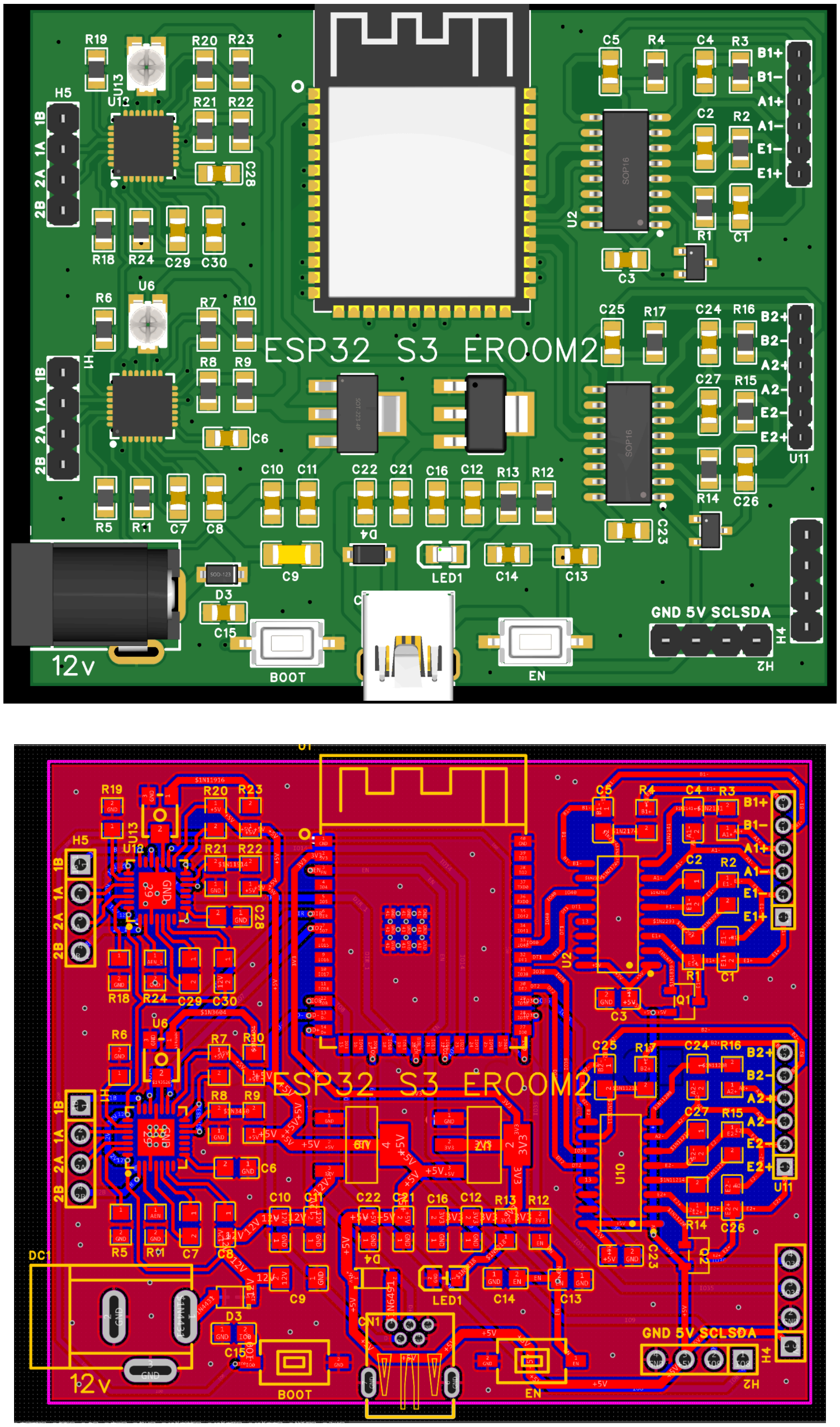
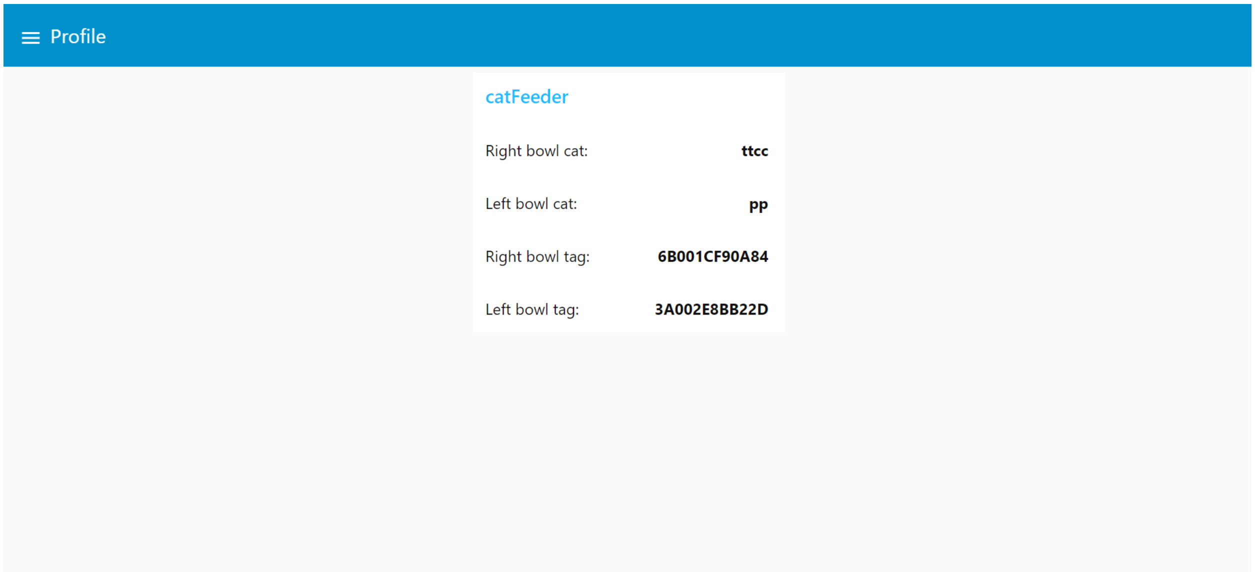
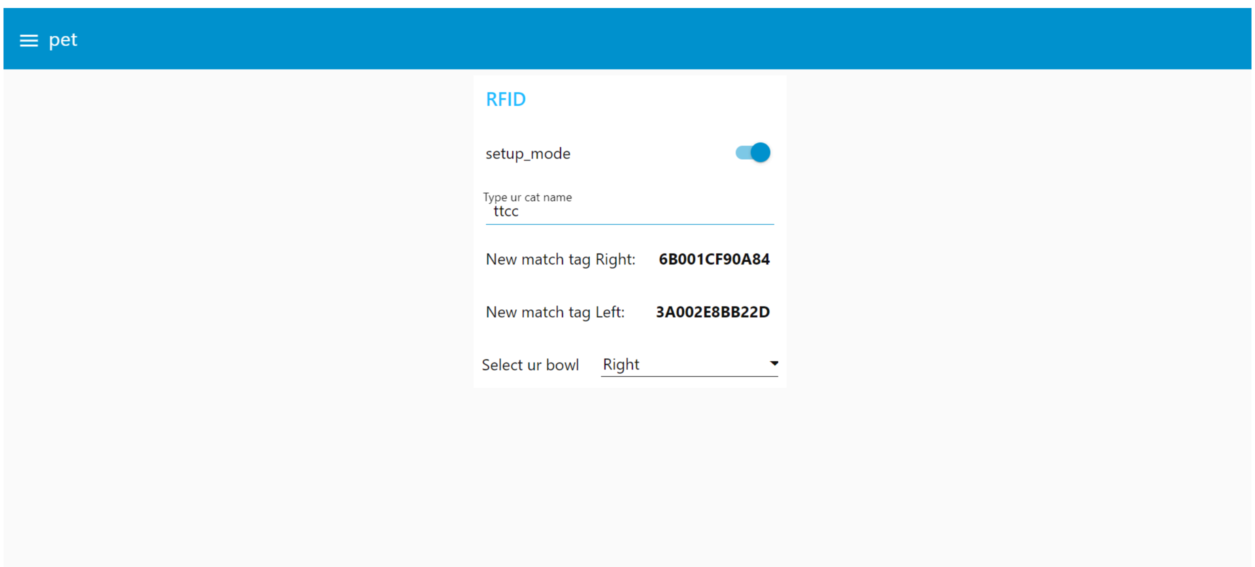
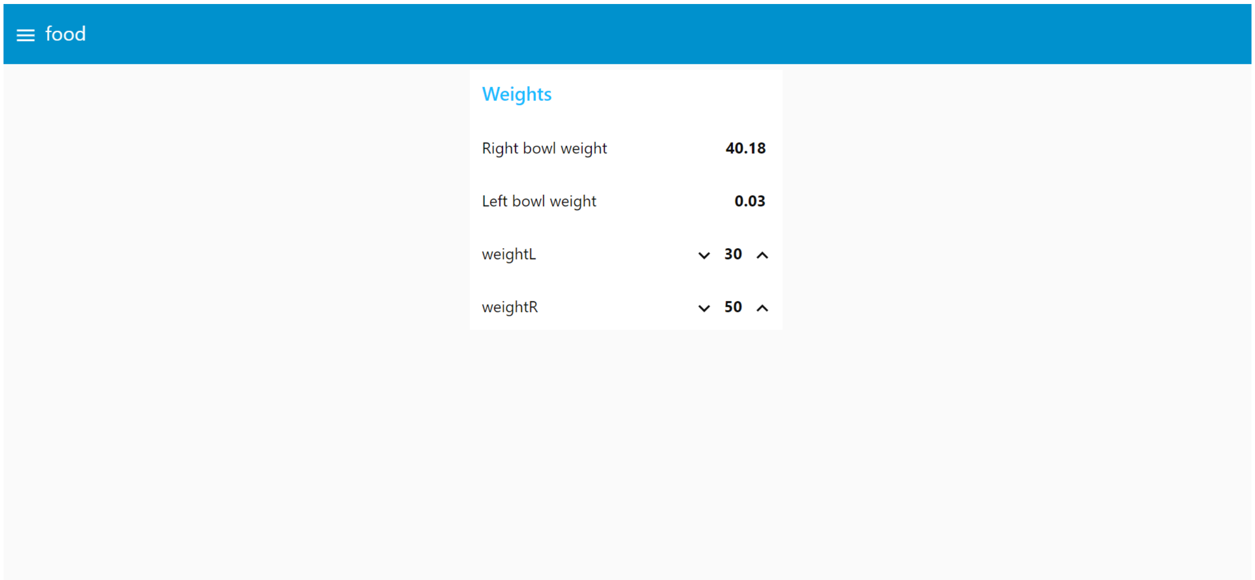


Figure #? PCB (All-In-One)

Appendix C: Wifi Portal






food
Weights
Right bowl weight
40.18
Left bowl weight
0.03
weightL
30
weightR
50