OUTDOOR SMART DOG FEEDER

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Abstract

This report presents the development and implementation of an Outdoor Smart Dog Feeder, a system designed to automate the feeding process for dogs, especially suited for outdoor environments. This device leverages solar power, RFID technology, and a user-friendly interface to ensure reliable operation even during extended periods of owner absence. The feeder operates on a programmable schedule, dispensing pre-set food amounts, and only activates when the authorized pet, identified via an RFID tag, approaches. Key findings include successful integration of the RFID system, which allows feeder access within a 2-foot range, and effective power management supported by solar panels. Despite some challenges with the stepper motor and IR sensors affecting the lid mechanics and food dispensing verification, the system generally meets its design expectations. The report concludes with suggestions for future enhancements to improve reliability and user experience.

Contents

1. Introduction

1.1 Problem

An automatic dog feeder can relieve a dog parent of the habitual task of refilling their pets' bowls. Due to work, travel, and other essential tasks that result in lengthy absences, it can be difficult to keep track of and complete on a regular schedule. Most dogs cannot be self-governed when it comes to how much food they eat and it results in gorging sickness, canine obesity, and sometimes death. An automatic dog feeder prevents these situations and ensures that the dog only gets the amount of nutrition they need throughout the day. The market for indoor automatic dog feeders is saturated with hundreds of brands and models; However, there are limited automatic dog feeders robust and adaptable enough for larger outdoor/part-time outdoor dogs.

1.2 Solution

An improved automatic dog feeder will be effective for outdoor pets in which it operates from a battery, powered by solar energy as a backup to maintain its functionality throughout long periods of time. Our dog feeder will distribute an accurate amount of food depending on the owner's input of the desired food amount per cycle, the dispensing time, and the current time to keep track. RFID tags will also be implemented to determine when the reciprocal of the feeder opens, which assures that only the specified pet is approaching the feeder and prevents stealing. In all, this solution should eliminate concerns from pet owners as they can continue their responsibilities and travel while taking care of their pets at home.

1.3 Visual Aids

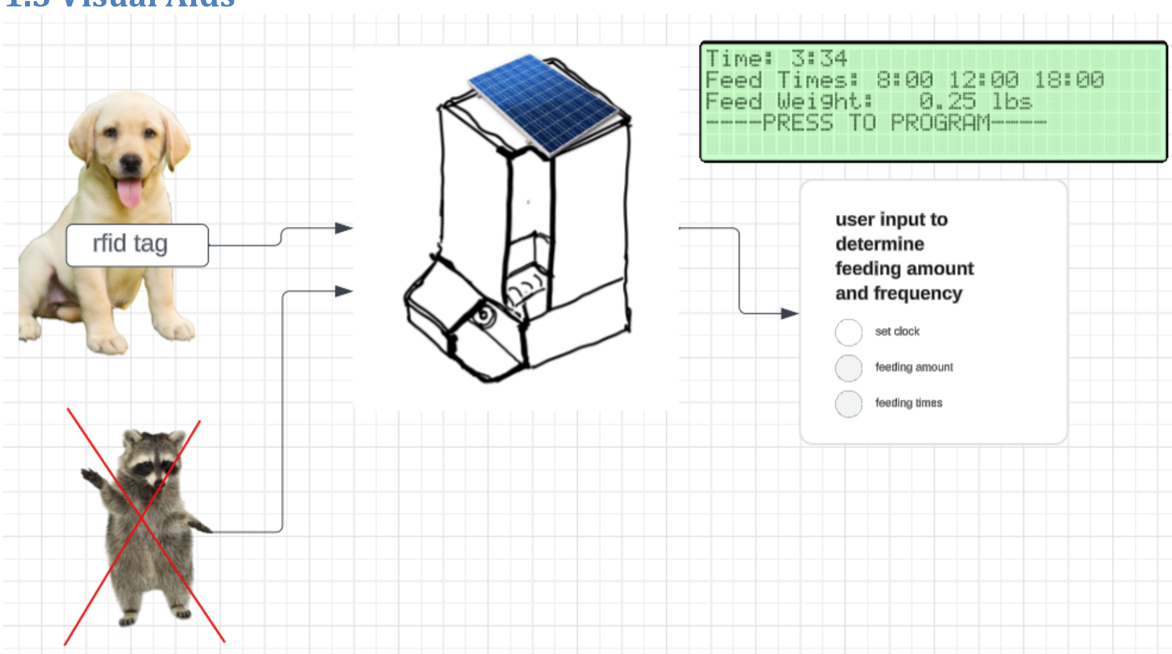

Figure 1 Initial Concept


Figure 2 Initial Design

1.4 High-Level Requirements

- Active RFID Communication- This requirement will be verified when the unit successfully transmits and receives a signal by the transponder on the collar. The MCU on the feeder will communicate a ‘request’ and receive a unique ID from the MCU on the collar. (Approximately 2 ft of range.)

- Network Control- This requirement will be verified when the microcontroller receives and stores input from the user interface subsystem and functions accordingly. The CPU will take input from the rotary encoder and button and provide a menu to the OLED from memory. Implementing a timer and registering set feeding intervals the CPU will activate motor controllers, RFID communications, and utilize the IR sensor and emitter for closed-loop control.

- Power Management- The solar panel can provide enough energy under close-to-ideal (6-8 hours of direct sunlight) conditions to recharge the battery after a reasonable amount of operation (4-5 uses in a day). The battery will be able to reliably supply power to the voltage regulators and the motors drivers.

2 Design

2.1 Block Diagram

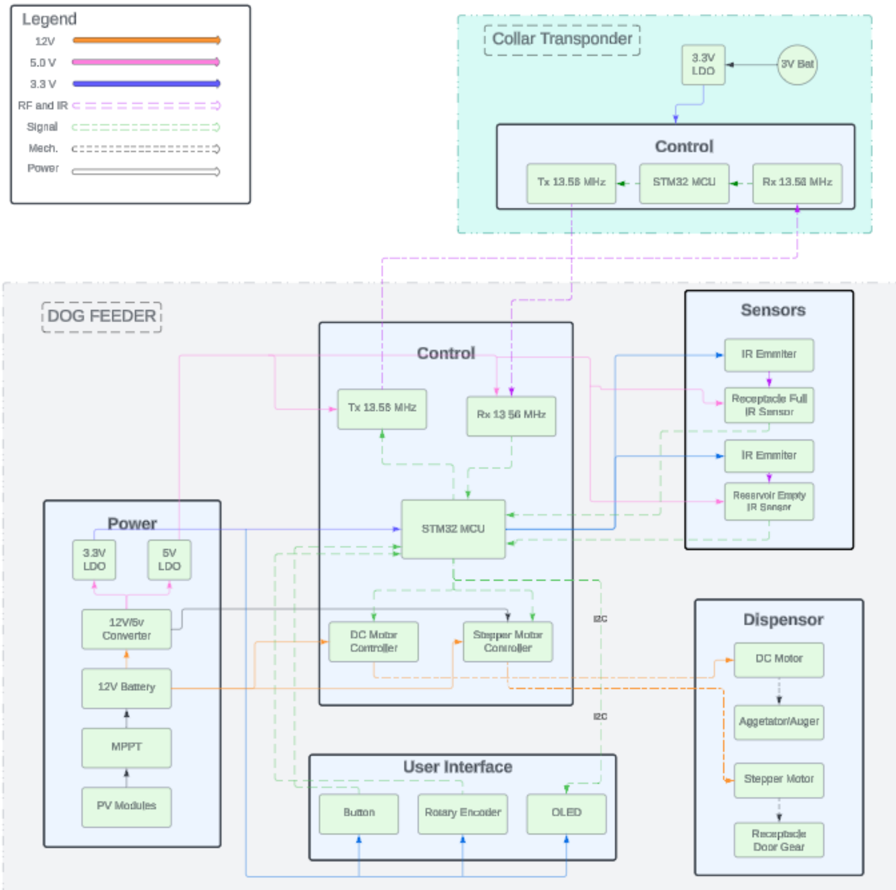

Figure 3 Block Diagram

2.2 Circuit

2.2.1 Schematic

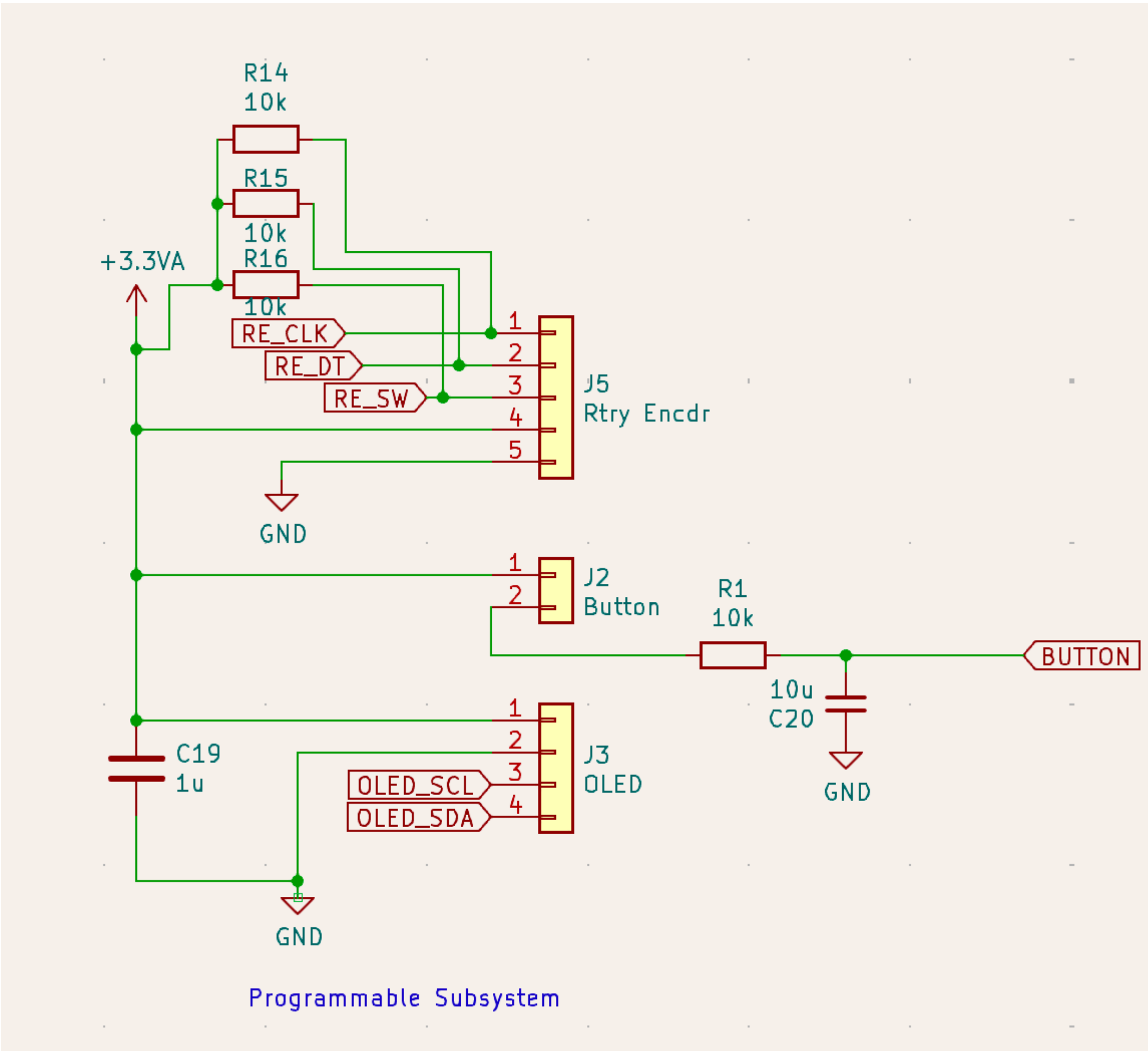

Figure 4 Programmable Subsystem

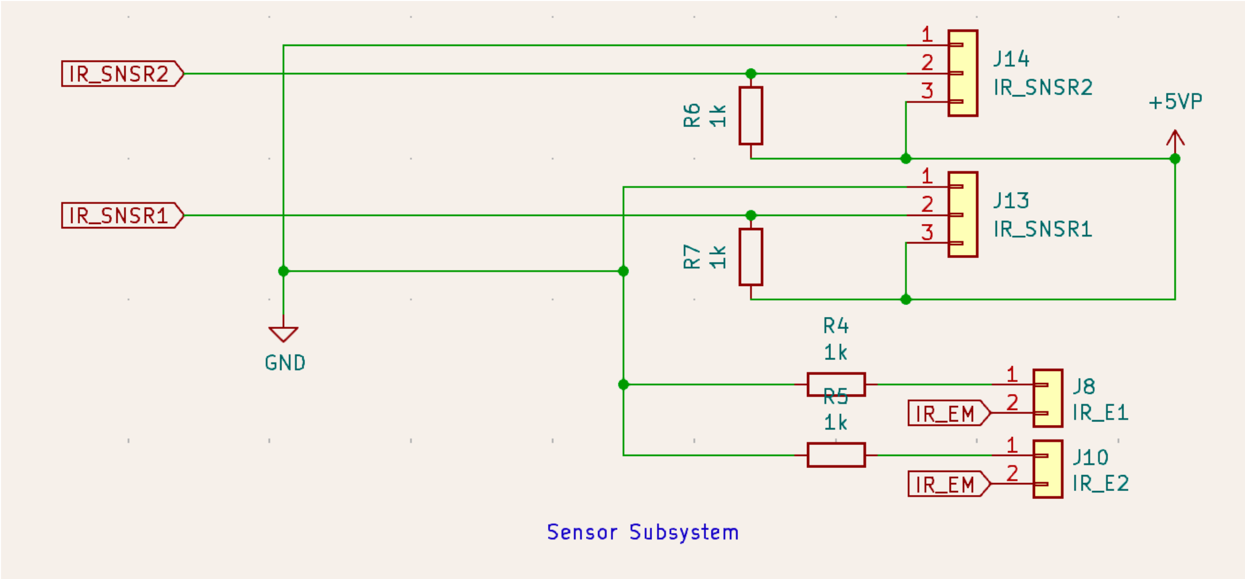

Figure 5 Sensor Subsystem

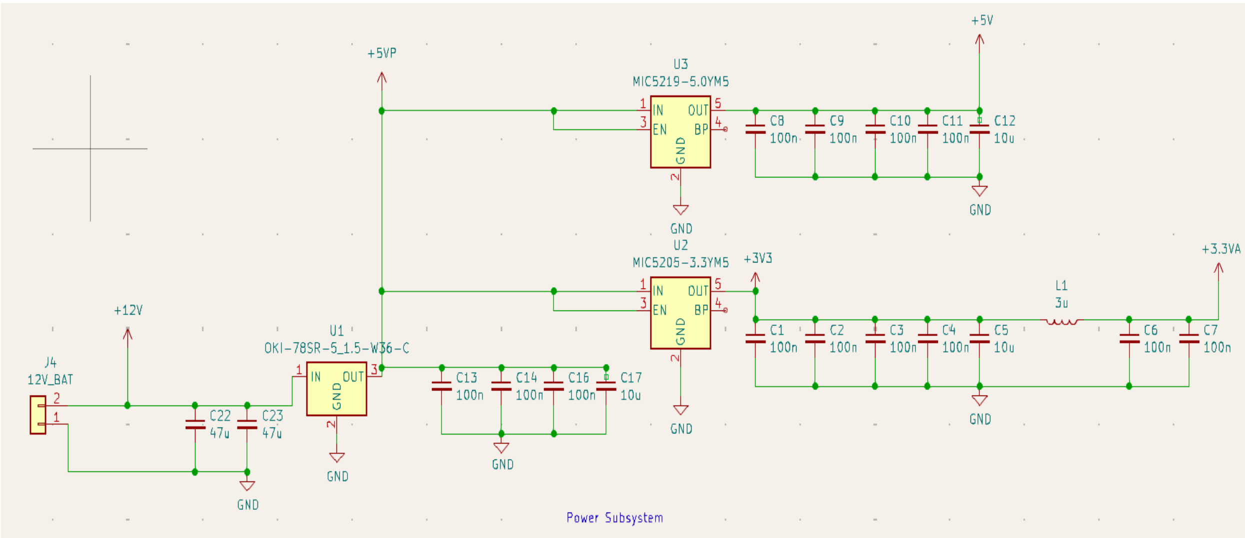

Figure 6 Power Subsystem

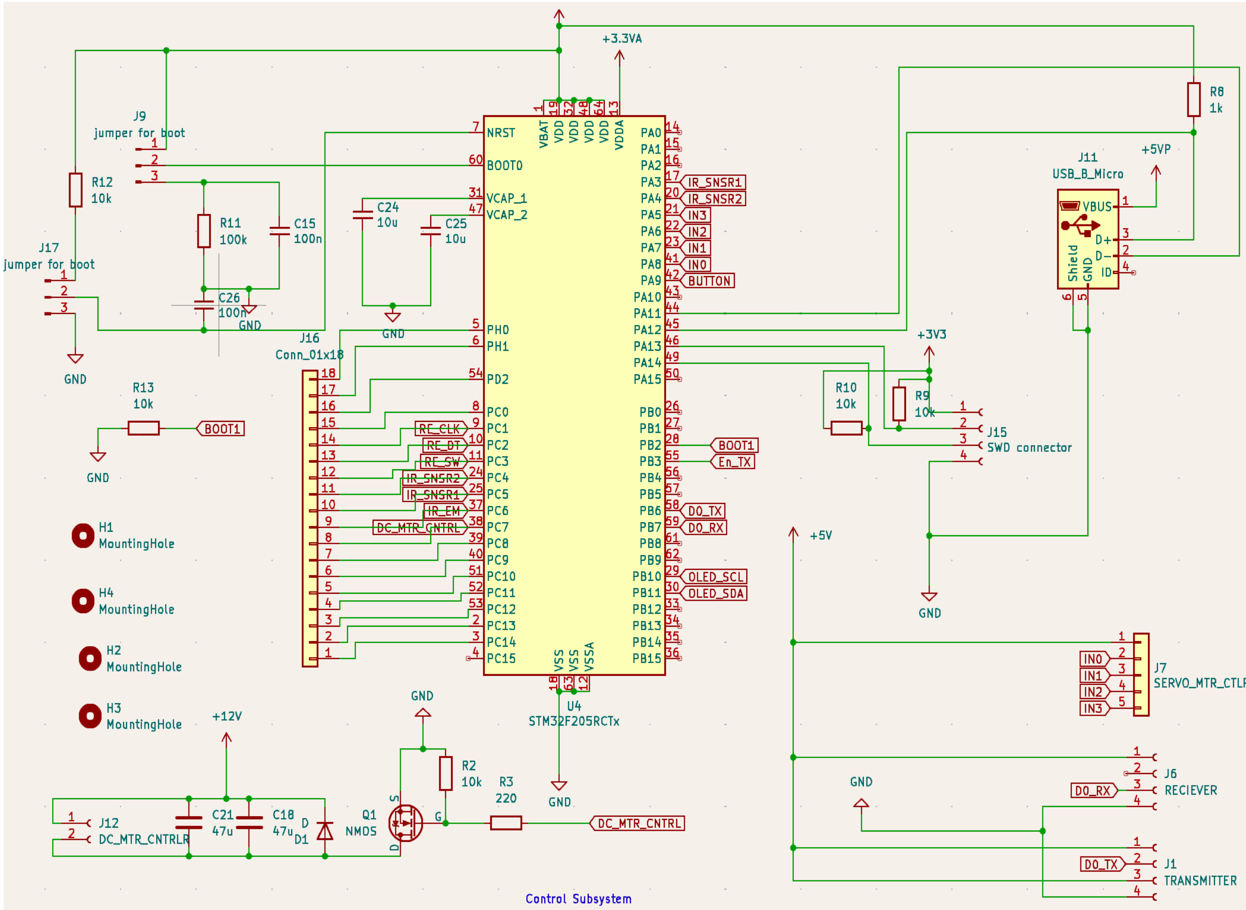

Figure 7 Control Subsystem

2.2.2 Layout

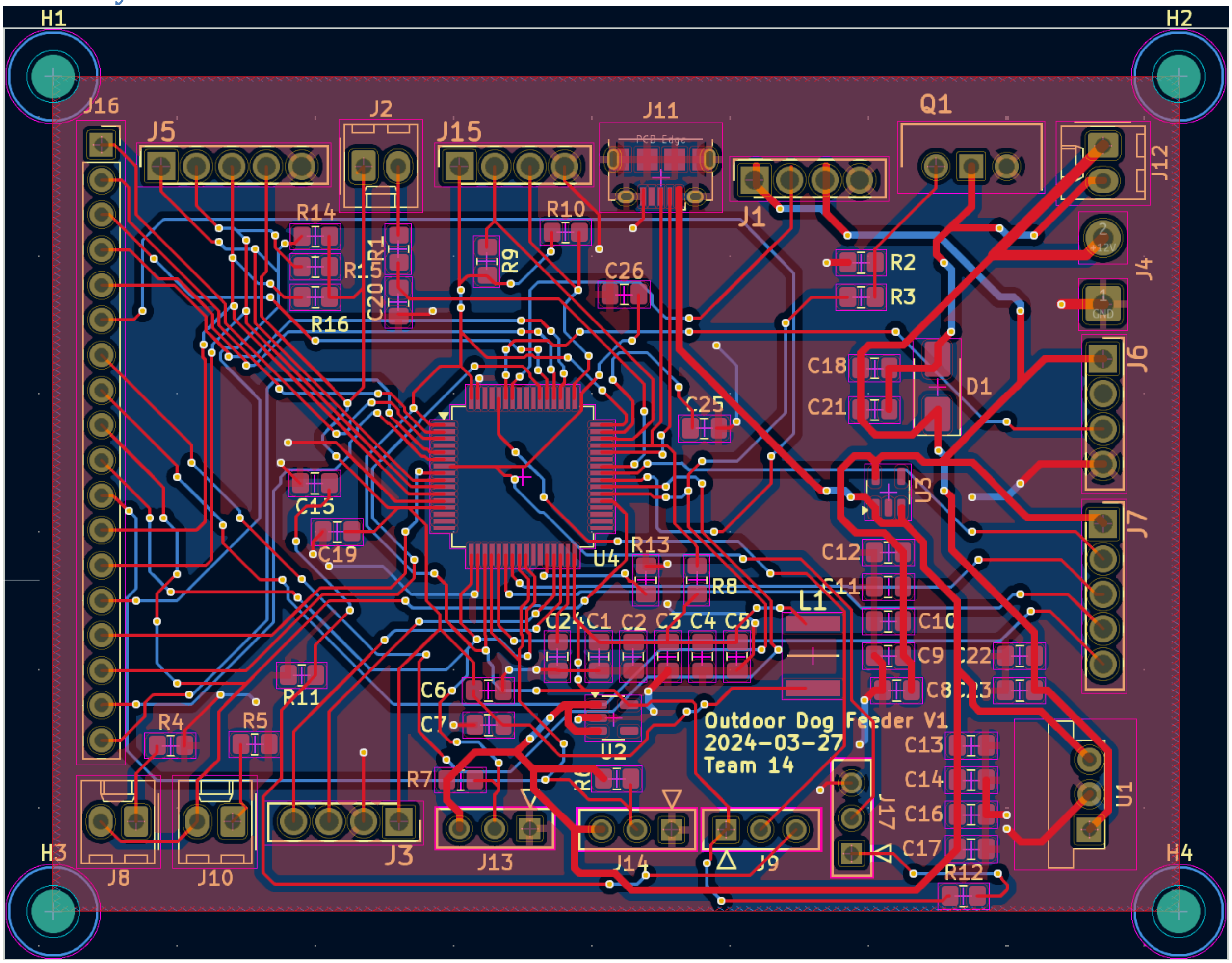

Figure 8 PCB Layout

2.3 Subsystem Overview

2.3.1 RFID Subsystem

There will be two RFID transponders for the dog collar and dog feeder, both with MCUs powered at 3.3V. The RFID on the dog feeder will continuously emit a signal for the RFID on the dog collar to receive when the collar is within 2 feet range from the feeder. Once the dog collar receives the transmission, the RFID will then emit a signal for the feeder to read. The dog feeder's MCU triggers the motor on the lid to open following receiving the dog collar's signal.

- **RFID subsystem requirements:**
  - The control system sends and receives a signal from RFID, upon 2 feet, and sends a signal to the MCU which triggers the stepper motor driver to open or close the lid.

2.3.2 Power Subsystem

The power subsystem supplies energy to the control subsystem through a 12v lead acid battery. To ensure consistent operation of the dog feeder, we will implement two 25V solar panels with two 12V solar charge controller modules to consistently charge the lead acid battery (EXP12180 12V 18Ah) once its energy decreases overtime. The voltage regulator in the power system manages the voltage consumption from the microcontroller (3.3V), motor drivers (12V), and RFID (3.3V) to make sure there isn't any excessive consumption of energy.

- **Power subsystem requirements:**
  - The solar panel should be transferring energy to the lead acid battery through a solar charge controller. Since the battery is at 12V, the solar panel should be 12V as well. To ensure the battery is sufficiently powered, the solar panel should have about 5W power.

2.3.3 Programmable UI Subsystem

The programmable subsystem is the user interface that will ergonomically walk the user through the set parameters for how the dog feeder will operate. The subsystem will accurately keep time increments of its clock cycle allowing the user to control the times the food will be delivered to the food bowl. The LCD screen will be the visual feedback of these settings. The inputs will be a rotary encoder for browsing and a push button for selecting. Users set the feeding quantity for each meal by holding the button as food is dispensed to the desired quantity measured by the digital scale. We will use a global variable that keeps track of the feeding quantity based on runtime of the suffer motor. Users can change the feeding quantity anytime they want, and the variable will be updated.

- **Programmable subsystem requirements**
  - The MCU can receive signals from the rotary encoder and button. The rotary encoder lets the user browse through the menu and time options, and the button lets the user select. Holding the button for 3 seconds will return to the main menu.
  - Properly display a menu on the LCD screen from MCU configuration. Menu should include set time, set feed times, set dispense duration.

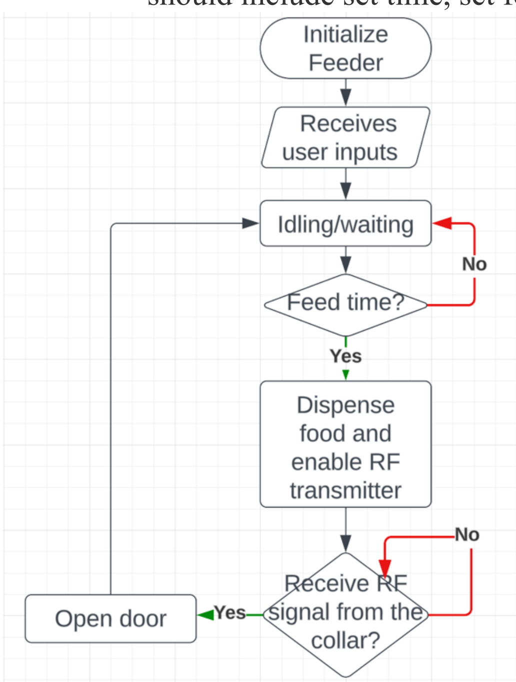

Figure 9 Flowchart of the Programmable Subsystem

2.3.4 Dispenser Subsystem

The dispenser subsystem will transfer the food from the container to the receptacle using the DC motor (powered at 12V) driven by the DC motor controller (powered at 12 V and triggered based on MCU programming). The Stepper motor, driven by the stepper motor driver, controls the rotation of the lid that protects the dog food, allowing lid to open or close based on RFID implementation. The stepper motor is also powered at 5V by the stepper motor controller, which the controller(12V) is triggered based on MCU configuration.

- **Dispenser Subsystem Requirements**:
  - Based on user settings, the microcontroller will send a signal to the auger motor driver to drive the auger motor which controls dispensing dog food. The auger motor should dispense at a constant rate.

2.3.4 Sensor Subsystem

The sensors subsystem consists of two infrared sensors, one that notifies the MCU of a full receptacle and another that notifies of an empty food container. The programmed feeding times sent to the microcontroller triggers the auger motor from the food container to run and dispense food based on the infrared sensor located at the top of the food bowl. The motor controller will not receive a run signal if the IR sensor shows logic low (100mV). This ensures the dog feeder does not overflow so the lid can close properly. If the receptacle does not receive any food upon dispensing time, the IR sensor located at the bottom of the food bowl will remain logic high (Vcc) and will indicate to the MCU a malfunction in the auger or an empty food container.

- **Sensors Subsystem Requirements:**
  - The Auger motor will stop rotating upon dispense time once receptacle is filled to IR sensor location.
  - MCU will notify user that food container is empty

2.4 Tolerance Analysis

An aspect of our design that posed a risk towards the project's completion is the implementation of RFID communication between the dog feeder and collar. Our goal was for the dog feeder to allow access to the food bowl when the dog with the correct active RFID tag approaches the feeder within 2 feet. The challenges were to design and program a collar to receive the signal from the dog feeder once it is in range and emit a signal in response. The feeder then transmits a signal during eligible feeding times. Then the dog's collar receives the signal, passively listening (sleep mode), once the collar is within 2 feet. Once the collar receives the feeder's signal it then transmits its RFID signal back to the feeder which then triggers the motors to open the receptacle. This 2-foot range may be difficult to calibrate. The current plan is to adjust the impedance of the loop antenna to decrease the gain to 'tune' the appropriate distance for collar to feeder communication. This will be the most uncertain error therefore we give a +15/-1.5ft radius to the active RFID.

Another aspect that posed challenges to our project is the food dispensing process. The motor responsible for dispensing the food is a geared DC motor. This is an open loop control, i.e. has no feedback to the controller. The motor will drive an auger that will agitate the otherwise stagnant food. These kinetic dry food pebbles will then funnel into the receptacle. While each dispenser cycle is not monitored, it is bounded by two extremes using two sensors. The IR sensor in the top of the receptacle will prevent the motor from running and overflowing the food bowl. The second IR sensor is at the bottom of the food reservoir. This will indicate to the MCU that the container is empty and needs attention from the owner. We have estimated the tolerance of dispensing volume cycle to cycle to deviate by 15 percent.

2.5 Design Alternatives

While building the feeder, we ran into problems with the IR sensor. The IR sensor could not read a solid logic high or low value on the program end because the IR signal received on the “OUT” pin had an amplitude of about 1.7V, which is in between 0V and 3.3V. Once the sensor is blocked by something, like hands, paper, credit cards, or sheet metal, the signal read was about 0.1V above of that when the sensor is not blocked. After some careful assessment of the difficulty of the proposed solutions, which will be addressed in the conclusion section, we decided to remove this feature from the feeder and move on building other important components.

Another drastic change that we have made was our PCB (Printed Circuit Board). After soldering the PCB, we realized the 3.3V and 5V voltage regulators footprint that we used in the original PCB design does not fit the actual components that we got. Missing the critical power management, we could not actually run the board. Since we placed our PCB order late, we could not make changes and order another version in time. Therefore, we had to adjust our design. We finished the rest of the circuitry on the breadboard and ran the program off the provided STM32 nucleo development board.

3. Design Verification

3.1. RFID Subsystem

The RFID was verified and had a range of 2ft. The feeder would not open the door until the collar approached the 2-foot range.

Figure 10 RFID Verification

Seen in the image above is the collar (in blue) on the edge of the communication range between the transmitter/receiver modules on the feeder and the modules on the collar.

3. 2. Power Management Subsystem

These values were collected experimentally and show that the feeder can operate under realistic conditions. This verifies adequate power management.

POWER USE AND PRODUCTION		ENERGY PER DAY
IDLE (24hr)	1.8 W	43.15 Wh
RUNNIG (max use)	18.5 W	18.5 Wh
SOLAR (8 hr)	10 W	80 Wh

Figure 11 Power Usage

The rows in red are the consumers and the green row is a producer of power. The sum of consumption is nearly 25 percent less than what the solar panels can produce in an 8hr duration of direct sunlight.

3.3. Programable UI Subsystem

Shown in the image below is the working OLED display for the setup mode of the dog feeder. It collected the data from the user input and stored it in memory. When feed times matched the time on the clock the feeder would dispense the amount the user set. Running it through many trails the user programming of the feeder was verified.

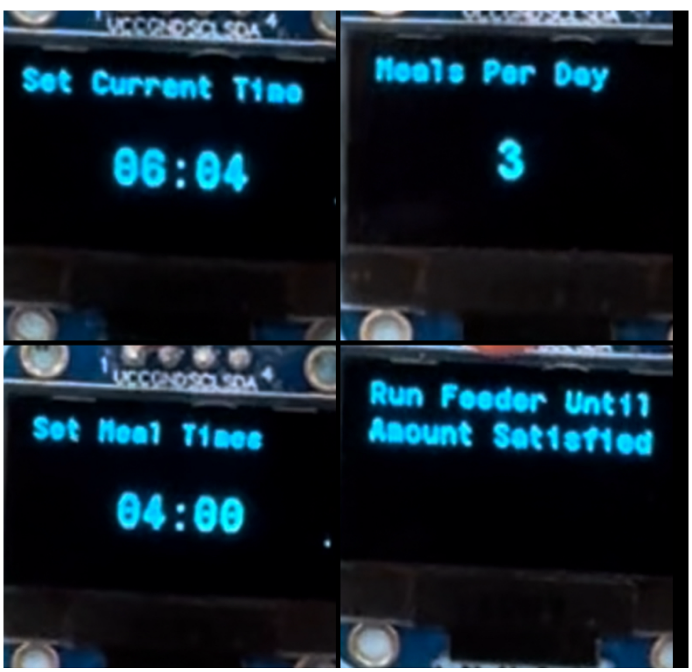

Figure 12 User Interface Verification

4. Costs and Schedule

Table 1 Costs of Parts and Labor

Part	Description	Qt	$/Unit	URL	
Galvanized Steel Trash Can, 20 gallons	The main body of the feeder	1	$29.99	amazon	
8-Inch x10-Feet Galvanized Flashing	Material to modify the can into a feeder.	1	$18.94	amazon	
Stainless Steel Pop Rivets	Fasteners for the feeder	1	$9.98	amazon	
12V PV Charge Controller	Pre-fabed charge controller for panel to battery protection.	2	$9.99	amazon	
25V 500mA Solar Panel	Small Mono-Crystalline solar panel	2	$12.19	amazon	x
EXP12180 12V 18Ah	Sealed Lead Acid 12V Battery for feeder	1	$34.40	amazon	
3V Lithium Battery	Button Battery for the collar	1	$5.39	amazon	
L298N	Motor Controller Stepper	1	$6.99	amazon	
BQLZR	12V DC 25 RPM Gearbox Regulated Geared motor (auger)	1	$13.89	amazon	
Nema 17 Stepper Motor	Stepper motor to control the door on the reciprocal.	1	$9.99	amazon	
Infrared Emitter	It is used to transmit infrared signals from the microcontroller.	2	$0.95	Sparkfun	
Infrared Detector	IR Sensor Module	2	$0.95	digikeys	
RE Module	Rotary encoder	1	$2.12	micro center	
RP3502MBBLK	E-switch push for selection	1	$3.92	digikey	
RR3112ABLKBLKNFF0	POWER SWITCH	1	$1.49	digikey	
WEA012864DBPP3N00003	OLED 128x64 BLUE display for user interface	1	$8.14	digikey	
STM32F205RCT7	ARM® Cortex®-M3 STM32F2 IC 32-Bit Single-Core 120MHz 256KB (256K x 8) FLASH 64-LQFP (10x10)	2	$10.89	Digikey	
7805SR-C	DC DC CONVERTER 5V 2W for the 12V station	1	$11.43	digikey	
MC7805ABD2TR4G	Linear Voltage Regulators 5V 1A Positive	2	$0.83	Mouser	
MIC5320-SSYD6-TR	Linear Voltage Regulators 3.3V Positive	2	$1.10	mouser	

QIACHIP RX480e 433mhz RF Wireless Transmitter and Receiver Module Kit	For Active RFID communication. For Arduino,Wireless Remote Control Radio Switch 1527 Learning Code for Arduino, access control	1	$10.99	amazon	
Passive Components and Connectors.	1k, 10k ohm (R), 47uF, 100nF,1nF (C), 3uH (L), Conn-01x02,03,04,05	x	$10	x	
Labor	3 Electrical and Computer Engineers 12 wks at 15 hrs/wk	360	$40	LABOR COST: $21600	
Components Total	$291.46				
Labor Total:	$21,600				
Grand Total	$21891.46				

Table 2 Schedule

Week	Tasks	Contributors
February 22nd	Finish project proposal Finish Design Document Obtain rest of project materials Prepare for Design Review	all
February 29th	Prepare for PCB review	all
March 7th	Design pcb initialize servomotors' speed	T'Andra Lucas Kevin
March 14th	Finish designing pcb Build dog feeder structure	Kevin T'Andra Lucas
March 21st	Build dog feeder structure	all
March 28th	Test sensors, servos and rfid functionality with pcb	all

	Test LCD screen programming	Lucas T'Andra
April 4th	Test sensors, servos, user input, and rfid functionality with pcb Test LCD screen programming	T'Andra -rfid Lucas - sensor Kevin - servo all
April 11th	Test sensors, servos and rfid functionality with pcb Mock presentation and demo preparations	T'Andra -rfid Lucas - sensor Kevin – servo all
April 18th	Mock presentation and demo preparations	all
April 25th	Prepare for presentation Work on final paper	all
May 2nd	Finish up final paper if needed Clean up notebooks	all

5. Conclusion

5.1 Accomplishments

Throughout this fun and challenging project, we have learnt a lot about the process of developing PCB, careful design consideration, choosing electronic components, and cooperating as a team and sharing responsibility. In terms of the result of our project, we are proud of what we have accomplished. Besides the change of our design, excluding the detection for overfill and emptiness of dog food with infrared emitters and detectors and the actual PCB use, we implemented everything else, and they functioned as we intended.

5.2 Uncertainties

One thing that we were unsure of was how the stepper motor functions. The lid could not open smoothly, and it makes rattling noises as the motor tries to drive the lid open. We have observed and confirmed the functionality of the stepper motor when the program is only running stepper motor functions alone. Therefore, we diagnosed that it was a mechanical issue that caused the unsmooth motion of the lid. Since we used sheet metal fabricating the receptacle and lid, the bending and shaping of the lid and receptacle presented quite of a challenge to us.
Another uncertainty was the infrared sensor. We had underestimated the complexity of using IR for empty/overfill detection and spent a significant amount of time testing and debugging the IR sensor circuit. The IR sensor we had could not distinguish between logic high and logic low upon observing values printed to the console. We then probed the signal pin on the oscilloscope, and here's what we've found: when the sensor is not blocked, the signal read has an amplitude of about 1.7V, which is in between 0V and 3.3V; when the sensor is blocked, the amplitude goes up about 0.1V. So, the digital value read by the program is always logic high. We have thought about two solutions to this: 1) using an operational amplifier to amplify the amplitude difference between two states; 2) reading analog values so we could distinguish them. However, due to time constraints, we abandoned this portion of the design and focused on other components.

5.3 Ethical considerations

The project utilizes 13.56 MHz transceivers and is committed to ethical principles, particularly compliance with FCC regulations. We pledge to adhere strictly to FCC guidelines, ensuring safety, minimizing interference, and maintaining transparency regarding our project's technical specifications and regulatory compliance status. Continuous monitoring and improvement will be undertaken to uphold these ethical commitments, reflecting our dedication to responsible research and innovation in the development and deployment of our technology.

Safety and Welfare (IEEE Code): The wellbeing of dogs must be a primary concern. We aim to ensure that the feeder operates safely under various conditions through rigorous testing and quality control.

Sustainability (IEEE Code): Using solar energy is a sustainable choice, but we also want to consider eco-friendly materials and design the product for longevity and recyclability.

Food Safety Standards: The material in contact with dog food is galvanized steel, which meets FDA standards for food safety.

Electronic Safety Standards: In our design, we estimate that the potential electrical hazards are relatively low since we are using a power subsystem isolated and separated from the main system and outdoor environment. One thing to note is that the lead-acid battery may cause explosions if it is sealed since it releases gases like hydrogen and oxygen which could potentially cause explosions. To prevent that, we will implement a vent next to the battery to make sure gases don't accumulate.

Animal Welfare Regulations: We want to consult with legal experts to ensure compliance with all relevant animal welfare laws, which may include state and federal regulations regarding pet care products.

5.4 Future work

For the future work, we will focus on polishing the feeder system's overall functionality, particularly the smoother motion of lid opening and closing. We will also try to get the empty and overfill detection implemented with two pairs of infrared sensors and detectors.

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Appendix A Requirement and Verification Table

Table 3 Requirements vs Verifcation

DESCRIPTION OF REQUIREMENT	METHOD OF VERIFICATION	Verification status (Y or N)
The control system sends and receives a signal from RFID, within 2 feet from dog feeder, and sends a signal to the MCU which triggers the stepper motor driver to open or close the lid	We can verify this by simulating the RFID communication and measuring the distance. The dog collar with RFID transceiver will be placed at different distances (out of range, within range, and edge cases) with respect to the dog feeder. Our tests will be documented in a table of data to verify this requirement.	Y
The solar panel should be transferring energy to the lead acid battery through a solar charge controller. Since the battery is at 12V, the solar panel should be 12V as well. To ensure the battery is sufficiently powered, the solar panel should have about 5W power.	We verify this by taking momentary power measurement using a digital multimeter of the idle state of the feeder and operating state of the feeder, and we can calculate the approximated power consumption and compare to the value we found in our tolerance analysis. This will be recorded in a table of data as representation of verification.	Y
The MCU can receive signals from the rotary encoder and button. The rotary encoder lets the user browse through the menu and time options, and the button lets the user select. Holding the button for 3 seconds will return to the main menu.	The success of the rotary encoder and button's programming can be verified by simply performing a test run on setting the inputs of the dog feeder. Rotating the encoder should scan through the three main options (time, feeding times, and feeding amount) and their secondary options. Pressing the button should select the options as well as return to the main menu if held for at least 3 seconds.	Y
Properly display a menu on the LCD screen from MCU configuration. Menu should include set time, set feed times, set dispense duration.	We will compare the function of code that prints the screen options and user's selection to that's being viewed on the LCD display. If the screen mimics the strings made by the programmer, the LCD properly displays the menu.	Y
Based on user settings, the microcontroller will send a signal to the auger motor driver to drive the auger motor which controls dispensing dog food. The auger motor should dispense at a constant rate.	We can verify this by performing a test run between user inputs and the auger motor, assuring that the auger runs at the times displayed on LCD (while keeping track of time). We will use the select button and rotary encoder to set time, feeding time, and feeding amount. We will then compare the results with our user expectations (keeping record via a data table) by checking how long the auger motor runs (verifies how much food is dispensed), and the times that the auger dispenses food.	Y
The Auger motor will stop rotating upon dispense time once receptacle is filled to IR sensor location	Manually run the DC motor until the receptacle is filled. Set a dispense time to MCU and record results, assuring that motor no longer runs once IR sensor signals a full receptacle.	N
MCU will notify user that food container is empty	Initiate a test run with an empty food container. Set a dispense time to mcu for auger to run. IR sensor should signal to MCU that there's no food to dispense. The OLED screen can be repeatedly flashed to visually notify the user.	N