ECE 445
SENIOR DESIGN PROJECT LABORATORY
DESIGN DOCUMENT

PawFeast: Food on Demand

Team No. 30

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I. Introduction

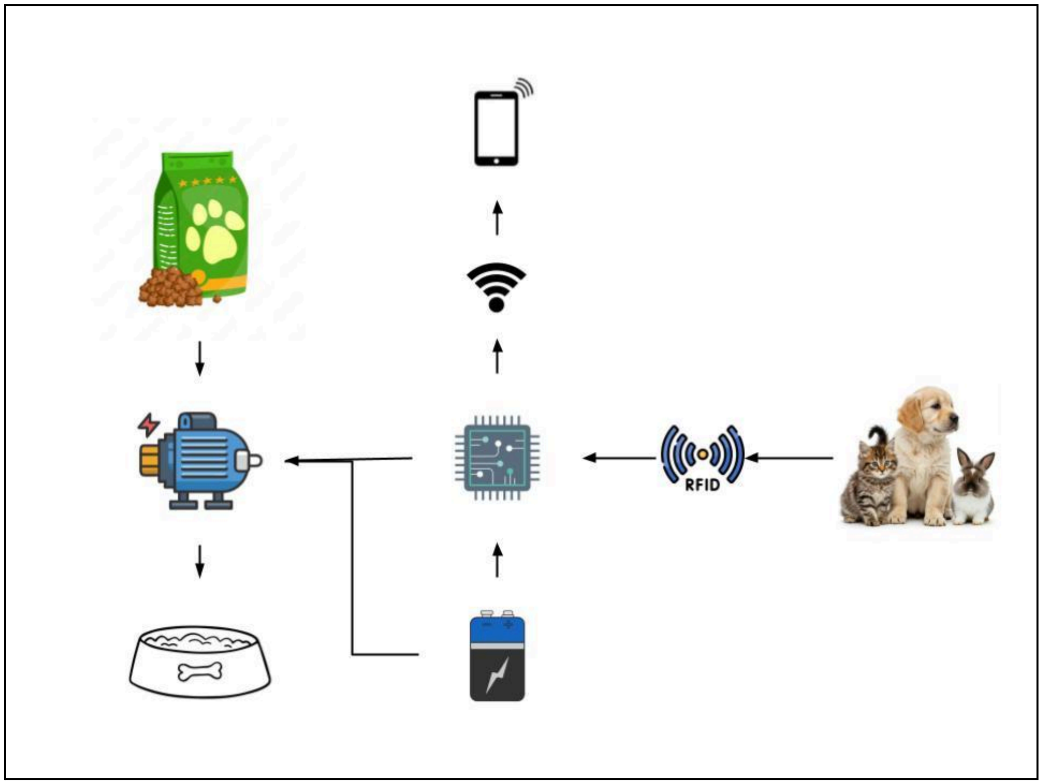
A. Problem

All pet owners must remember to feed their pets at set times during the day. There are times that people forget to feed their pets, double feed them when there are multiple people in the house and there is poor communication, or have trouble feeding them on time when they get home late if there are prior conflicts. In these times, pets either eat too much, too little, or irregularly. As a result, timer-based pet feeders have been created that release food at set times. However, this introduces a new problem, food that was sealed in an airtight container is now released into an open environment. When this food sits out for extended periods of time, this risks the food becoming stale or bugs getting introduced to the food.

B. Solution

We are seeking to solve this problem by having timers preventing overeating, coupled with a button and RFID component to release food. Given all of these conditions, the dispenser will release the food for the pet. This ensures that the food is not stale when the pet goes to eat. To ensure that the pet is fed on time, a chime will go off alerting the pet that it is time for them to eat. In addition, if the pet were to not eat all the food at once and leave the food dispenser, the pressure sensor will tell the dispenser to cover the food until the pet returns ensuring freshness and preventing bugs. In addition, our system will notify owners when the pet has eaten, or when the food dispenser has low levels of food.

C. Visual Aid



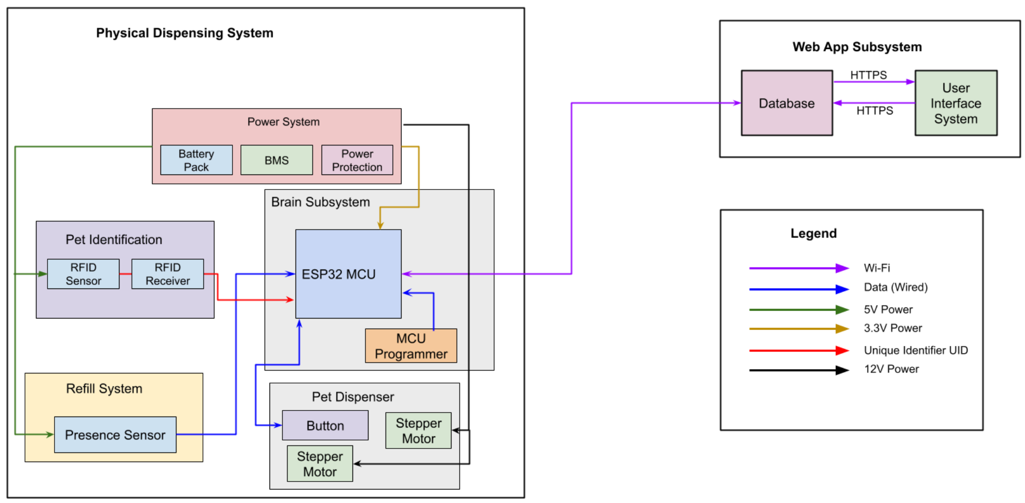
D. High Level Requirements List

For this project to be considered successful, our project must meet the following requirements:

1. The Pet Food Dispenser must not dispense food before user preset times, like 10 AM and 6 PM, daily, with a 10-minute tolerance.
2. The Pet Food Dispenser must dispense food into the designated food bowl upon detecting the presence of the pet via the button (load sensor) and the RFID tag on the pet's collar.
3. The user must receive notifications on the application we create detailing the pet's feeding status, low food store (20% & 10%), and unfinished meals.

II. Design

A. Block Diagram



B. Subsystem Overview

1. Subsystem 1: Refilling Food Store

The subsystem for checking if the food store is empty will include either an infrared presence sensor (Vishay TSSP77038) and/or a reflective object sensor (OPB710 Series) that is able to determine whether an object is present—this will serve to detect whether the food inside of the container is low and needs to be refilled. When the food store reaches a certain level, a signal will be sent to subsystem 7 (the brain), which will send an automated message to notify the owner to refill the food store.

2. Subsystem 2: Power System

The power system will supply energy to all of the various subsystems, including the microcontroller of subsystem 6, the stepper motor driver in subsystem 3, and the various sensors in subsystems 1 and 3. The low voltage buses will be 3.3V, 12V, and 5V, all of which will be powered by a combination of rechargeable lithium-ion batteries with voltage regulators and buck converters. This compact, custom 3s2p battery pack will allow the pet dispenser to be portable, even for family vacations or road trips—more importantly, it will provide a steady current, even when the pack voltage drops (unlike standard AA/AAA cells). The 12V to 3.3V regulator chip will be Monolithic Power Systems's MP2315SGJ-Z, which can take a 12V input and output up to 2.5A. The 12V to 5V regulator chip will be Monolithic Power Systems's MP2338GTL-Z. The 12V input into the motor driver IC circuit will come straight from the battery pack. There will also be a backup supply voltage of 5V from a typical barrel jack wall-outlet, integrated into the brain board. This will implement the AMS1117 LDO, which is perfect for 5V to 3.3V power conversion. Just to be clear, this 5V barrel-jack addition will just be included on the brain board as a backup power subcircuit in case of power shutdown.

3. Subsystem 3: Food Dispenser

   This subsystem will utilize a E Series Nema 17 stepper motor that will rotate a door to the food container when needed and allow a set amount of food through before rotating again to close the door. The motor will be controlled by a stepper motor controller IC (DRV8825) with a custom control circuit that takes in 12V and outputs 3.4V to the motor. We will define hard cut offs that will be coded for maximum amount of food to be dispensed and specify times at which food may be dispensed during the day.

   The main objective of this subsystem is to make the system an on-demand food system. We will utilize a large button for the dog to step on when hungry. When pressed, the system will start the motors to release food, on the condition that enough time has elapsed since it ate last. The pet would be trained how to ask for food using this button. Only when the button is pressed and enough time has passed, will food then be dispensed.

4. Subsystem 4: RFID for pet identification

   We will have a receiver for a minimum of 2 LF RFID tags 9662 Long Distance Passive Alien H3. The RFIDs would be used to signal which pet is using the dispenser, so the owner is able to utilize the same dispenser for one or more pets.

5. Subsystem 5: User Interface

   The subsystem for notifications will be a phone application that we will build that is able to connect with the pet feed dispenser system. For the application side, we will utilize React Native and Expo to create a user friendly method to check the pet's eating habits. This will notify users for when the pet has been fed, if the food tank is low and requires refiling, and if the food was covered due to an empty bowl or a partially filled one.

6. Subsystem 6: Brain

   The brain subsystem will take in inputs from all of the other sensor subsystems and output the according signals to the user interface (for notifications) and the food dispenser motor driver. This system will also track the amount of time that has passed and sound a soft chime for when enough time has passed for the pet to be able to eat. The ESP32 microcontroller, known for its wifi connectivity and security measures, would have a set of I/O pins for taking in these signals. This MCU programmer circuit and other control level circuitry—firmware or equivalent—would be incorporated onto this board along with a UART circuit to detect pet RFIDs (done with the UHF RFID reader JRD-4035).

C. Subsystem Requirements

1. Subsystem 1: Refilling Food Store
   a) Must utilize a presence sensor to determine how full the food store is.
   b) Must send readings to the UART located in the Brain Subsystems.

2. Subsystem 2: Power System
   a) Must be able to provide enough power to all components within a tolerance of ±0.2V for the 3.3V supply and ±0.5V for the 5V supply during the periods of operation.
   b) If there are any unsafe conditions, such as the supply reaching undervolt range or short-circuiting, the current will be cut-off from the rest of the subsystems to prevent damage and fire hazards.

3. Subsystem 3: Food Dispenser
   a) Implements a timer system to determine “feeding times” assigned by the user. Will not dispense food prior to these times within a small tolerance of ±10 minutes.
   b) Utilizes a button for the pet to step on to indicate the pet’s presence. Upon pressing, during the feeding time the stepper motor will start dispensing food to the food bowl.

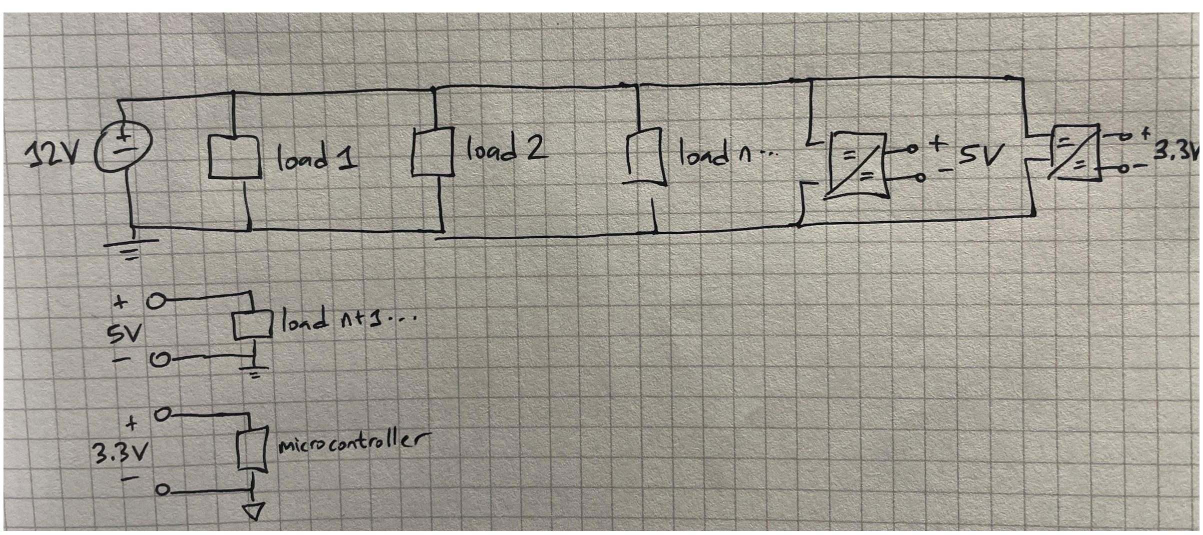
4. Subsystem 4: RFID for pet identification
   a) The RFID UIN will be detected by the brain microcontroller within a range of 6 inches.

5. Subsystem 5: User Interface
    a) The user interface will be able to connect with the Brain subsystem to receive different notifications.
    b) It must be able to push notifications to the owner's device.

6. Subsystem 6: Brain
    a) Takes in proximity/LED sensor reading from the Food Store to determine whether the store has gone below some capacity level. Will send a notification to the User via the User Interface Subsystem if the store is below a certain level (20% and 10%).
    b) Takes in a Unique Identification Number (UIN) signal from RFID Subsystem to determine if a pet is within range.
    c) Sends and receives UART signals to and from the other subsystems successfully.

D. Tolerance Analysis

1. The power subsystem poses the risk of being unable to deliver the intended power for all the other subsystems in the project—this total power can be estimated from component data sheets. This is done below in Part 1. Then in Part 2, the discussion moves towards losses, mainly in the stepper motor and in the switched-mode power components of the linear regulators (transistors). The diagram below is a general circuit representation of some of the main power sinks, and by no means considers all loss mechanisms.



1 Power Dissipation vs Supply Power

The power subsystem needs to supply power to multiple sensors, drivers, and the microcontroller. The ESP32 microcontroller dissipates a maximum RF power of:

$$P_{\text{ESP32}} = 19.5 \text{ dBm} = 0.0981 \text{ W}.$$

It is supplied with 3.3 V and can support input currents of 600 mA to 750 mA, leading to a maximum supplied power of:

$$P_{\text{ESP32 supply}} = 3.3V \times 0.75A = 2.475W.$$

The reflective object sensor has a maximum power dissipation of:

$$P_{\text{reflective}} = P_{\text{phototransistor}} + P_{\text{diode}} = 150 \text{ mW} + 75 \text{ mW} = 225 \text{ mW}.$$

The Vishay Presence sensor dissipates:

$$P_{\text{Vishay}} = 5V \times 5 \text{ mA} = 10 \text{ mW}.$$

The RFID receiver operates at 3.3 V with a peak output current of 200 mA, giving:

$$P_{\text{RFID}} = 3.3V \times 0.2A = 0.66W.$$

The two motor drivers each take a supply voltage of 12 V and drive up to 1 A, resulting in:

$$P_{\text{motor}} = 12V \times 1A = 12W \text{ per motor}.$$

For two motors:

$$P_{\text{motors total}} = 2 \times 12W = 24W.$$

Two load cells each take 5 V with 10 kΩ pull-down resistors, giving the following from the combination of Ohm's Law and P=IV:

$$P_{\text{load cell}} = \frac{5V^2}{10k\Omega} = 2.5 \text{ mW per sensor}.$$

For two load cells:

$$P_{\text{load cells total}} = 2 \times 2.5mW = 5mW.$$

Summing up the total power consumption:

$$P_{\text{total}} = 2.475W + 0.225W + 0.01W + 0.66W + 24W + 0.005W = 27.375W.$$

The battery pack is a 3s2p configuration with 3.7 V nominal 3200 mAh cells, giving:

$$V_{\text{pack}} = 3 \times 3.7V = 11.1V,$$
$$Q_{\text{pack}} = 2 \times 3200mAh = 6400mAh,$$

which results in an energy capacity of:

$$E_{\text{pack}} = V_{\text{pack}} \times Q_{\text{pack}} = 11.1V \times 6.4Ah = 71.04Wh. \tag{1}$$

This means the battery can theoretically supply:

$$P_{\text{supply}} = 71.04W \text{ for one hour.}$$

Since $P_{\text{supply}} > P_{\text{total}}$, the battery should be sufficient for at least an hour of continuous operation. We expect that in reality, the power process of detecting the RFID tag and pressing the button to dispense the food should take no more than 5 minutes. This means that the battery should theoretically last for 12 meals or 6 days of operation, though this estimate doesn't consider the power that is required to keep the microcontroller running (passive losses).

2 General Loss Discussion

In addition to the main power dissipation, we must consider the losses in the motor and driver system. The primary loss in the stepper motor follows the ohmic power dissipation:

$$P_{\text{motor loss}} = 2I^2 R_{\text{phase}}, \tag{2}$$

where:

- $I = 1A$ (current per phase) limited by us based on loss mechanisms and motor speed requirements,
- $R_{\text{phase}} = 30m\Omega$ (resistance per phase),
- Factor of 2 accounts for two active phases.

Calculating:

$$P_{\text{motor loss}} = 2 \times (1A)^2 \times 30m\Omega = 60mW \text{ per motor.}$$

For two motors:

$$P_{\text{motor loss total}} = 2 \times 60mW = 120mW.$$

Other losses such as PCB trace resistances, wiring resistance, and connection losses are considered negligible. Additionally, eddy current, windage, and hysteresis losses in the motor are also assumed to be negligible.

We also consider power lost in the switching components of the linear regulators. There are two primary loss mechanisms:

- **Conduction losses:** These follow the standard ohmic loss equation:

$$P_{\text{cond}} = I_{rms}^2 R_{\text{ds,on}} \tag{3}$$

- **Switching losses:** These depend on switching frequency and transition times:

$$P_{\text{switch}} = \frac{1}{2} V I f \frac{Q_{\text{gs}} Q_{\text{gd}}}{I_{gate}} \tag{4}$$

  where V is the voltage, I is the current, f is the switching frequency, and Q is the gate-to-drain and gate-to-source charge, and I_{gate} is the gate current.

For the linear regulators:

$$P_{\text{12V-3.3V}} = 1.25W, \quad P_{\text{12V-5V}} = 2.27W.$$

These values are given for continuous dissipation at 25 °C, but more precise values can be computed using datasheet parameters like the switching frequency, on resistance, and load current.

III. Ethics and Safety

1. As with any moving part, there is a small risk of the pet hurting themselves on the bowl lid closing mechanism, which opens/closes the pet bowl. The group plans on finding a way to mitigate this risk by slowing down the linear speed of the motor or adding a sensor which will stop/slow down when detecting objects nearby.
2. The power system is relatively low voltage, but still poses a risk to users in case of unintended operation, such as short circuits or spliced wires. The group plans on mitigating this risk by adding a power protection aspect to the board (overvoltage, overcurrent, reverse polarity protection) and rating the components (wire gauge, etc.) above a safety tolerance threshold.