WHEELCHAIR-MOUNTED DOG

TREAT DISPENSER

Final Report

v1.0

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Service Dogs of Virginia

Ⅰ Introduction

Our Mission

This project was undertaken at the request of The Service Dogs of Virginia, a non-profit organization that raises, trains, and places dogs to assist people with disabilities due to the failure of several designs that have attempted to ameliorate the burden to create an effective standard of assistance. This project aims to provide a much needed tool to assist those who cannot easily reward their service animal's in a simple and repeatable fashion. The rewarding aspect that service animal's use with their owners is a key part of the relationship and helps enforce good behavior. The success of this project will result in more service dog owners being able to repeatedly reward their assigned dog treats for their correct actions. This positive and repetitive action will help positively increase the relationship with the service dog owner and ensure that the dog's original training doesn't drift from what it was originally taught. While this tool is originally targeted towards the Service Dogs of VA it is a common issue that is faced with anyone who is in a wheelchair and cannot repeatedly reward their service animal in a common and easy manner. One of the key focuses of this project was to ensure that every single part was sourced from a location or vendor that can be procured easily either off-the-shelf or from a simple online order.

Existing Work

Previous attempts at this project have been done over the course of several semesters. To validate and ensure the design would succeed where other projects failed the design group evaluated each previous design and took note of each fault that were found so that the current design iteration would solve any and all problems that the previous designs failed on so that this design would be successful. Reviewing several of the past designs it became clear of the faults and success each device had and where things could have improved. For this implementation the success and failures of past projects and leverage them to create a new solution that addresses both functional requirements and the faults the previous system had.

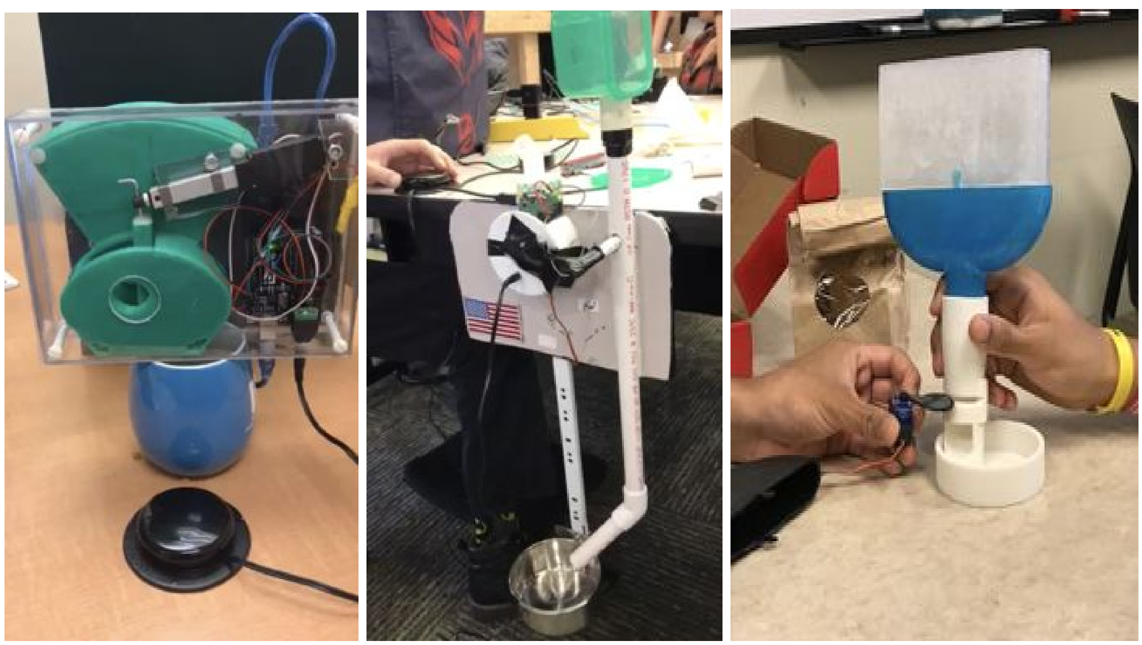


Fig 1: Previous Attempts of Dog Treat Dispenser.

The design will address the major issues faced by the previous designs such as: ease of reproduction, constant number of treat dispensing on every click, food safe materials, sturdy design and flexible mounting.

Treat Dispenser Requirements

Functional Requirements:

1. The device will hold up to at least a cup of treats at a time to provide rewards for the service animal throughout a day's time.
2. The device shall use an accelerometer-based control input so that someone with limited physical abilities will still be able to operate the dispenser.

Operational Requirements:

1. The device will operate while mounted on a wheelchair.
2. The device shall be vertically fitted onto the wheelchair to ensure that the device can operate properly, and the owner of the wheelchair can still fit through the same spaces.
3. The device will dispense a varying number of treats depending on the operators input.
4. The device shall have a self-healing method of unjamming itself to ensure that it can dispense food without much assistance from the owner or other party.
5. The device must be easy to clean

Input / Output Requirements

1. The device will accept input from the operator. The physical input device will

vary, however, the interface with the primary device will be consistent no matter what.

2. The device will accept dog treats into a storage container inside the device.

3. The device will output dog treats through a pipe system that will deliver the food to a food tray.

Proposed Solution

Upon examination of the previous designs, patents and overall requirements, the team decided to use a modular approach shown in Figure 2, to design and assemble the treat dispenser.This makes it possible to modify individual modules without influencing the overall design. This was done by first creating and identifying each module. Next, analyzing and evaluating how the modules are coupled or joined together. The modules may be tightly-coupled i.e. they are constrained by how they interact with other modules in the overall system. Or, they can be loosely-coupled and have a higher degree of autonomy. Finally, designing and assembling and conducting experiments with each module.

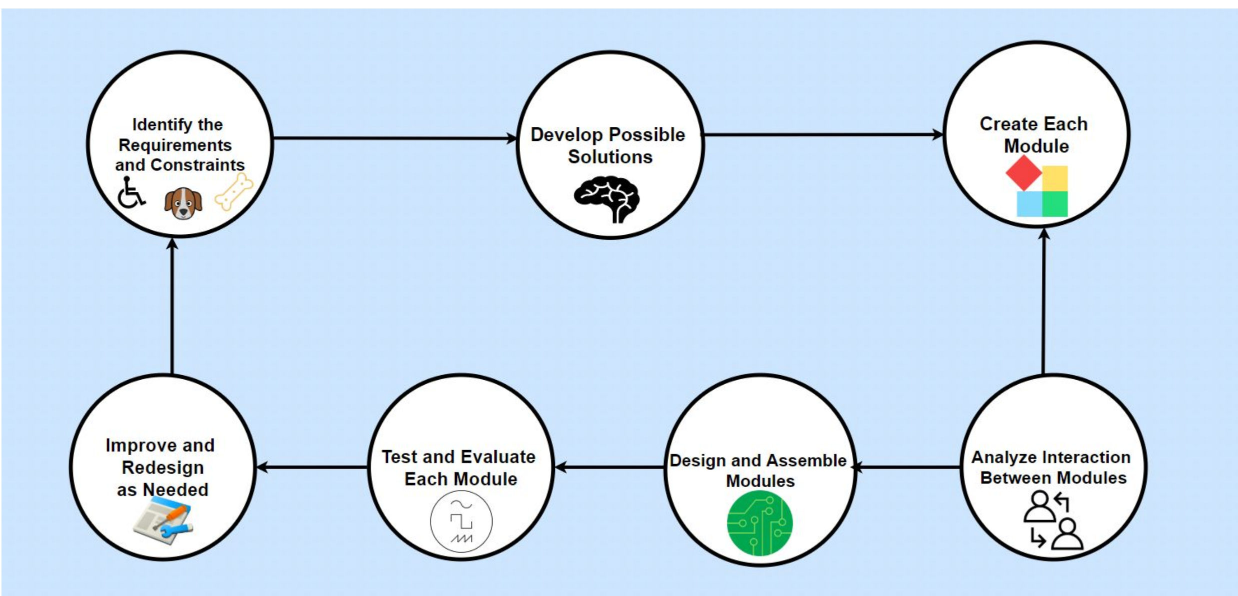


Figure 2 : Modular Approach

A modular approach allows for the dispenser to be much more efficient, sustainable, user-friendly and completely customized to meet the customers needs. Damaged modules can be easily repaired or replaced to increase the lifetime of the dispenser. The modular approach was necessary since the team was tasked with designing two variations of the treat dispenser that differed only in the control mechanism, the MCU variant that utilizes a RaspberryPi Zero W and the PCB variant that utilizes 555 Timers.

The System Architecture for the Automatic Treat Dispenser is shown in *Figure 3* below.

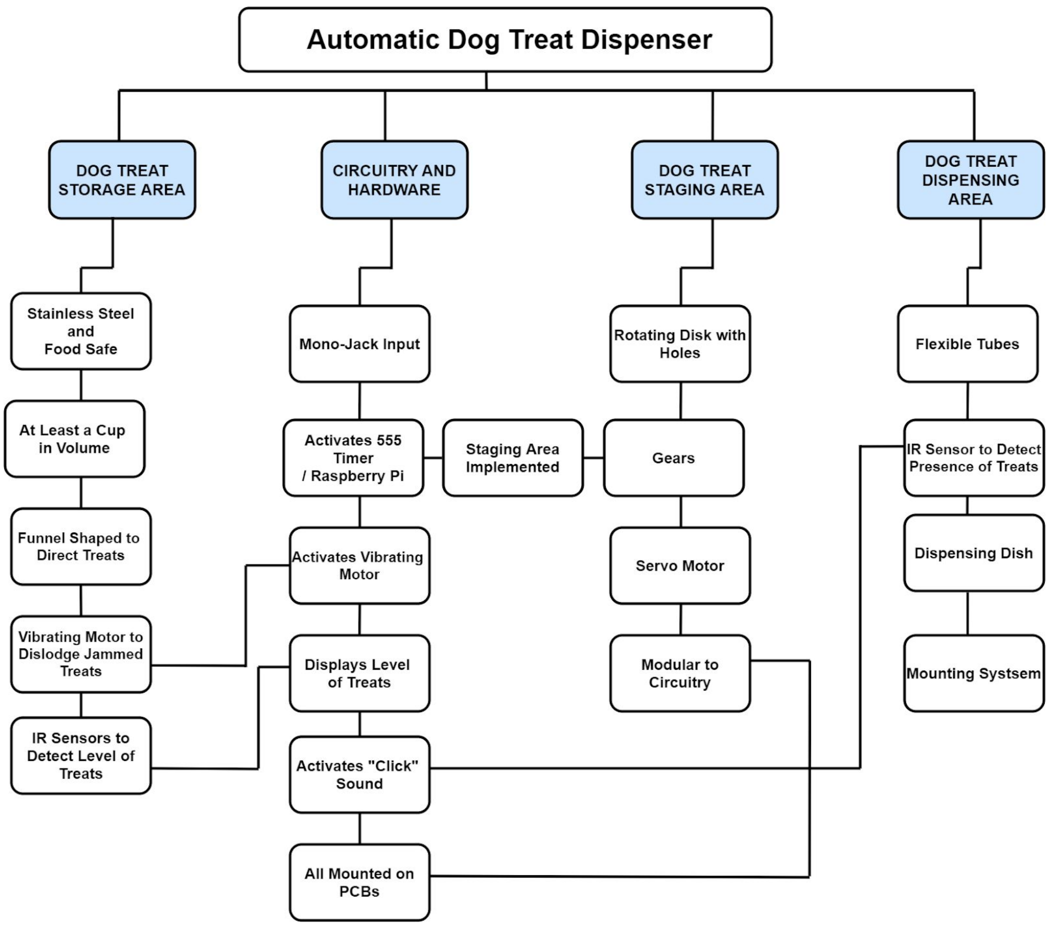


Figure 3 : Treat Dispenser System Architecture

The main components of the dispenser are the “Dog Treat Storage Area”, “Circuitry and Hardware”, “Dog Treat Staging Area” and “Dog Treat Dispensing Area”. The solid lines show how all four components interact to ensure that the dispenser operates properly.

Alternative Designs

Raspberry Pi 4 Model B

Currently, The Raspberry Pi Zero W is the best choice for this project. Due to its size, it is easy to fit into the current design, does not add unnecessary weight, and also completes the basic computations without using additional resources. However, any Raspberry Pi Model that has GPIO Pins will work. We chose the Raspberry Pi Zero because of the reasons mentioned above, but that does not mean the designer must use that specific microcontroller to carry out this design. One such alternative for implementation would be the Raspberry Pi 4 Model B. Although this is the largest out of all of the current Raspberry Pi models available for purchase, it also has pre soldered GPIO pins and has a readily available Audio output jack.

Figure 4: Raspberry Pi 4 Model B See [1]

As can be seen in the picture above, the size is much larger than the Raspberry Pi Zero W and also has a larger power consumption. The power consumption of the Raspberry Pi 4 Model B at an idle state is 180 mA as compared to the Raspberry Pi Zero W at 80 mA [2] . The current code that is to be installed for this project utilizes the idle mode unless an event is detected, so most of the time the Raspberry Pi will be operating under this power consumption which saves battery life. Although the Model B eats up 100 more mA when in its idle state, the design group still believes that this design will work okay, it is just not ideal for an embedded system as such.

Another feature of the Raspberry Pi 4 Model B that is actually very nice to have is the aforementioned audio output jack. Because this is pre-installed and ready to use out of the box, there is no need for any of the I2C audio driver code that is required for the Raspberry Pi Zero W, as well as no need for the external amplifier to drive the speaker. This specific model of the Raspberry Pi (4 Model B) will only need the small speaker to be plugged directly into the audio output jack and the “click sound” will occur once a treat has been dispensed.

As another example, another main feature that is imperative that the Model 4 B contains is the pre-soldered GPIO pins. Not only are there the same 40 pins with the same mapping that is required for this design and the main driver code, but it also alleviates the user from having to purchase a soldering iron with a fine tip to solder the tiny pins onto the board. This is a real benefit of the Model 4 B because all Raspberry Pi’s are relatively expensive, and also delicate. Applying too much heat to the board could damage the board and possibly render it useless for the project.

Moreover, the other thing to keep in mind when seeking alternatives for the microcontroller design is simply the price. The Raspberry Pi Zero W was chosen for its cheapness and for the functions it offers. Currently, the Raspberry Pi 4 Model B is offered at a price point of $35 dollars [3]. This is a significant price jump from the Raspberry Pi Zero W offered at $10 [4]. On the other hand, if the designer has an old Raspberry Pi laying around, it is still a valid option to use for this project to save the money and reduce environmental waste.

Raspberry Pi 3 Model A+

Yet another great choice as an alternative microcontroller for the treat dispenser project would be the Raspberry Pi 3 Model A+. This model has all of the same features as the currently used Raspberry Pi Zero W with the addition of the audio output jack, pre soldered GPIO pins, and even lower power consumption than the Raspberry Pi 4 Model B.

For example, when seeking this board as an alternative, one of the nice features is the lower power consumption. In a pure idle state, this model is only drawing 80mA of current which is the same as the currently used Raspberry Pi Zero W [5]. However, although the power consumption is the same at the idle state, there is a small change when it is in an “active mode” executing code. This would raise the power consumption to 160mA as compared to the 120mA on the Raspberry Pi Zero W. This power consumption jump is actually quite minor and the design group believe there should be no noticeable issues regarding battery life for the whole system.

Figure 5: Raspberry Pi Model 3 A+

Frankly, the reason why this is more of an alternative as compared to the Zero W the design is currently implementing is once again due to price and size. This model is about 2 times larger than the Zero W, and also costs $25 dollars [6] . Although it is only 15 dollars more, for the current application, the group believes that it was a better decision to stick with the Zero W model as compared to this one. However there are 3 main benefits of this board just like the Raspberry Pi 4 Model B such as the pre-soldered pins, output audio jack, and also the smaller size as compared to the Raspberry Pi Model 4.

Please refer to the above paragraphs as they outline why exactly it is ideal for the two aforementioned boards to contain the presolderd GPIO pins and the ready-to-go output Audio Jack.

These two alternatives are the best boards to use because of their ability to run the necessary python driver code, ease of use, and functionalities of wifi/ ssh enablement.

Other Alternatives:

Essentially, any other microcontroller board may be used that supports python code, I2C communications (for the Audio), and GPIO pins. However, the challenge of porting the currently provided code exists as well as memory issues. All of the previously mentioned alternatives all support these functionalities and all have enough memory to run the main driver code without loading the board to heavily causing latency issues. Although speed is not an essential factor of this design, for the modules of perhaps the hall effect sensor may be affected if any additional latency is added.

The main issue with using another microcontroller is simply the language that may be installed to run on the device itself. Many other microcontrollers exist that may be able to work with the current design, but Python code is not only very friendly and easy to use, but it is easier to debug as well.

For example, the MSP-430 is another great alternative, but out of the box it only supports the C language. Additional steps must be taken to implement Python code on the device, and on most MSP-430 boards there is not an external audio output jack currently installed, and memory is even more limited on such a device.

Thus, the design group believes that sticking to the Raspberry Pi devices will offer the best flexibility and utility for the current design.

Infrared Sensor Alternatives

Light Dependent Resistor (LDR) Sensor

One primary responsibility of the treat dispenser is to output a "click" that is identical to the clicker used to train the dogs at Service Dogs of Virginia to notify the service dog that a treat has been dispensed. The second is to notify the user visually whether the treat storage compartment is empty or not via LEDs.The treat dispenser uses IR sensors to detect whether a treat has been dispensed or not and to indicate the level of treats in the storage compartment which are full, low and empty. An alternative sensor that could be used in place of the The Feedback Circuit is a light dependent resistor (LDR).

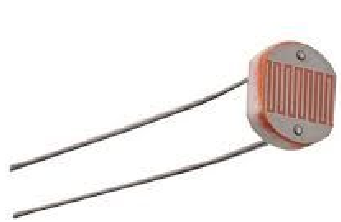


Figure 6 : Light Dependent Resistor (LDR) Sensor

The resistance of an LDR changes depending on the amount of light that falls on its surface. They require very little power and voltage to operate [7]. A "darkness" sensor circuit could be used to detect whether a treat has been dispensed or not. Once a LDR detects a treat the voltage at the base of the transistor would increase. The voltage increases until it exceeds the threshold voltage at the base of the transistor. Finally an LED would light up to indicate that a treat has been dispensed.

Ultrasonic Sensor

Ultrasonic level sensors can be used for non-contact level sensing of solids and highly viscous liquids. These sensors can be used to measure the distance to an object using ultrasonic waves. The HC-SR04 could be used as an alternative to The Treat Level Sensing Circuit and can be easily integrated into both the PCB and MCU designs. It has four pins VCC, GND, Trig (Trigger) and Echo (Receive).

Figure 7 : HC-SR04 Ultrasonic Distance Sensor

The HC-SR04 measures the distance of the object by emitting ultrasonic sound waves and converts the reflected sound into an electrical signal. The Trig pin emits the sound and the Echo pin encounters the sound after it has travelled to and from the object This module is low in cost and retails for about $1.05. However these sensors are sensitive to external conditions such as temperature. They also have difficulty reading reflections from small objects such as dog treats. Therefore the group has decided to use IR sensors since they can detect obstacles and measure the distance to an object [8].

Solenoid Actuator

Figure 8: Solenoid Actuator

The idea behind using the solenoid actuator was simply to use its pull push stroke to stage and dispense the treat. The push pull stroke of the solenoid is created by the magnetizing and demagnetizing of the coil. Whenever, the current is rushed through the circuit, the coils get magnetized and the plunger moves towards the coil. When the current flow is stopped, the energy stored in the spring moves the plunger back to its original position creating a push pull motion.

The senior design team tested the solenoid for its functionality and found it to be less effective than servo for a number of reasons:

1. Push pull force was not strong enough to dispense the treat.
2. The stored energy in spring didn't provide enough momentum to restore plunger back to its original position causing the mechanism to jam.
3. Solenoid actuators draw high amounts of current as compared to servo motors.
4. The actuation failed for almost 50% of the time during testing.

<u>RC Control</u>

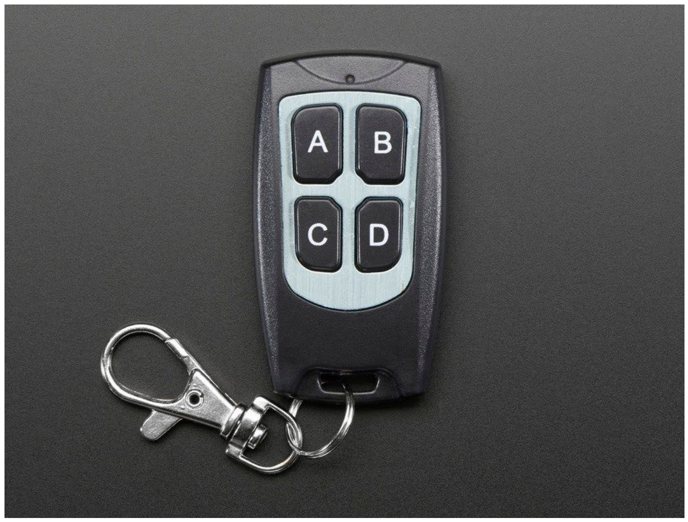


Figure 9: RF Remote Controller

Key fob 4-Button RF Remote Control - 315MHz

This 4-Button RF Remote Control adds one to one link to operate different modules of the treat dispenser. Whenever a button is pressed the matching pin goes high and activates the corresponding module [9]. For instance, when button A is pressed the matching pin goes high triggering the module to dispense the treat. Similarly, button B is matched to activate the treat level sensor. Button C to operate the vibrating motor and Button D to activate the click sound module. There is no microcontroller required for this transmitter and receiver connection. This Key fob uses two CR2016 coin cells for the power.

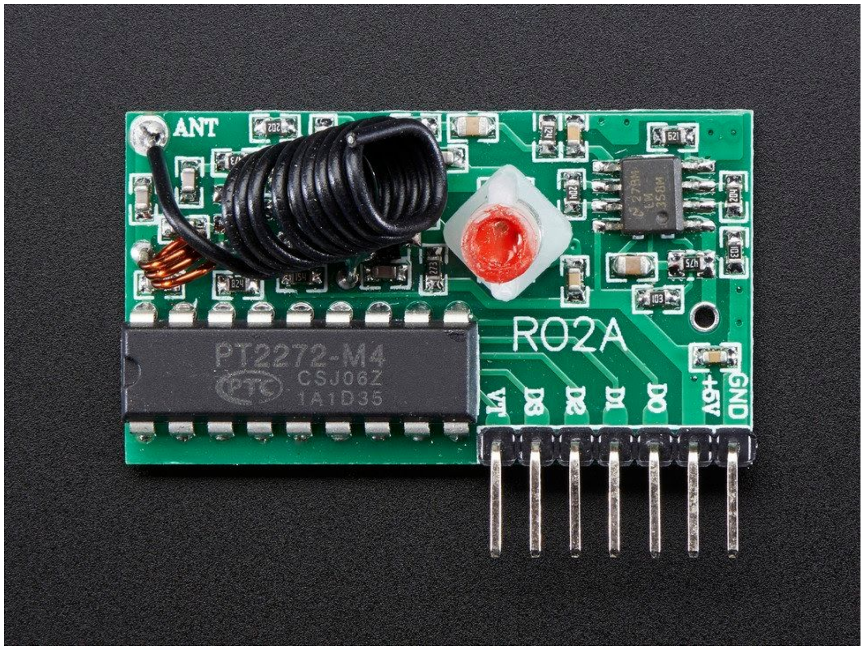


Figure 10: RF M4 Receiver

Simple RF M4 Receiver - 315MHz Momentary Type

This M4 receiver goes together with Key fob RF remote control. The matching transmitter and receiver work at 315 MHz frequency and can work from across the room. This is a momentary type receiver so the pins act like a push button [10]. The pins go high as long as the button is pressed and once the button is released it goes back to low. Here, button A of key fob is matched with D3 pin, button B with D2, C with D1, and D with D0. It operates with a DC voltage supply of 5v.

The final revision of the Dispenser circuit will be designed with the option to add the RF remote control for the dispensing.

Team Responsibilities

Adam: Stand up the Raspberry Pi integration with the Servo motor and stand up the AtoD converter so input from sensors could be read into the Pi.

Jachan: Create the base PCB board that will interface with the Servo and later interface with the other sensor pieces by leveraging a 555 timer.

Gage: Taking the Raspberry Pi integration with the servo and tuning it to ensure that the rotation and output are consistent, ensure Raspberry Pi interfaces well to a variety of sensors, overall software design.

Robby: Designed the central housing unit that would act as the storage for the central processing board and the sensors.

Zainab: Developed both of the sensors needed to report back to the PCB and RPi to verify whether or not a treat was deployed and ensure the sensors had an accessible location to ingest the feedback.

Ⅱ Technical Section

Functional Block Diagrams

The figures below are the final detailed designs for the treat dispenser. *Figure 11* shows the Level 0 Design, highlighting the overall inputs and outputs of the system.

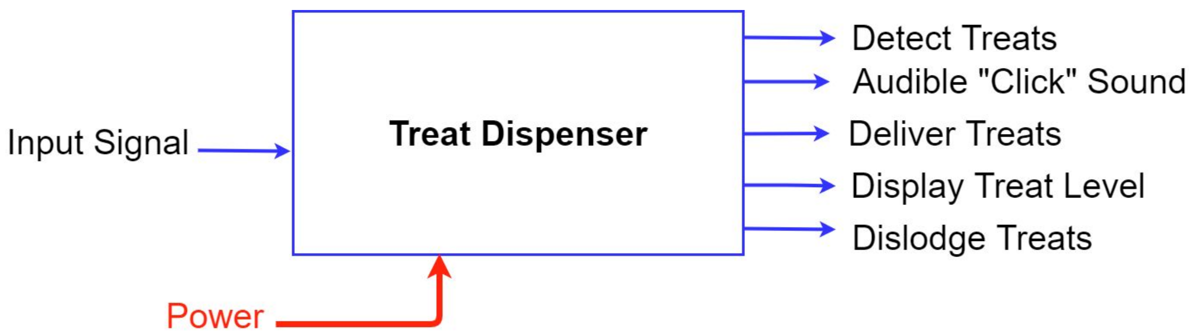


Figure 11 : Level 0 Design

The Level 0 Design shows the functionality of the dispenser from the user's perspective. *Figure 12* shows the Level 1 Design. This exhibits the systems modularity in design. These modules were developed independently and were then plugged together.

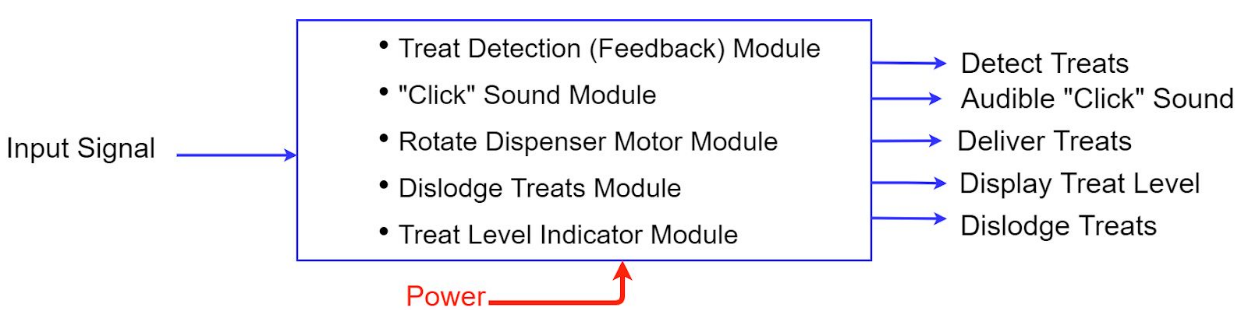


Figure 12 : Level 1 Design

The Level 2 Design shown in *Figure 13,* the input signal activates the control systems. The dc motor allows the user to dislodge treats in the event that they become jammed. This input signal also activates the servo motor to rotate the dispensing disk. After the disk rotates, a treat is dispensed. The IR sensors placed in the dispensing tube will detect whether a treat has been dispensed or not. Then, a PWM signal will be generated by the PWM block. The PWM signal will generate an audible sound that is identical to the “click” sound that is used to train the dogs.

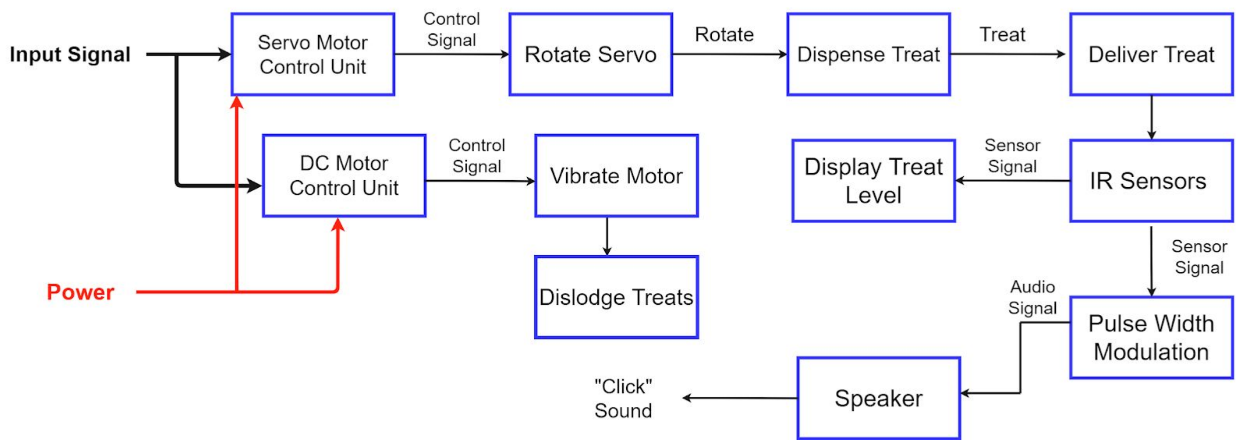


Figure 13 : Level 2 Design

A pair of IR sensors placed on the inner part of the treat compartment lid will also detect the level of treats available. All of the components are powered by a 12V DC battery pack that includes a 5V USB output that can be used to supply power to the Raspberry Pi.

Conceptual Design

As designed, the Wheelchair-Mounted Treat Dispenser consists of four main parts: the dog treat storage area, the dog treat staging area, the dog treat dispensing area, and the circuitry/power area. The idea was to make all these parts modular and detachable so the device can be easily cleaned without damaging the electronics.

The overall conceptual design is as shown in Figure 14 below, and provided during the first update. The treat dispenser still maintains this overall design, but some slight differences have been made during construction due to feasibility and practicality.

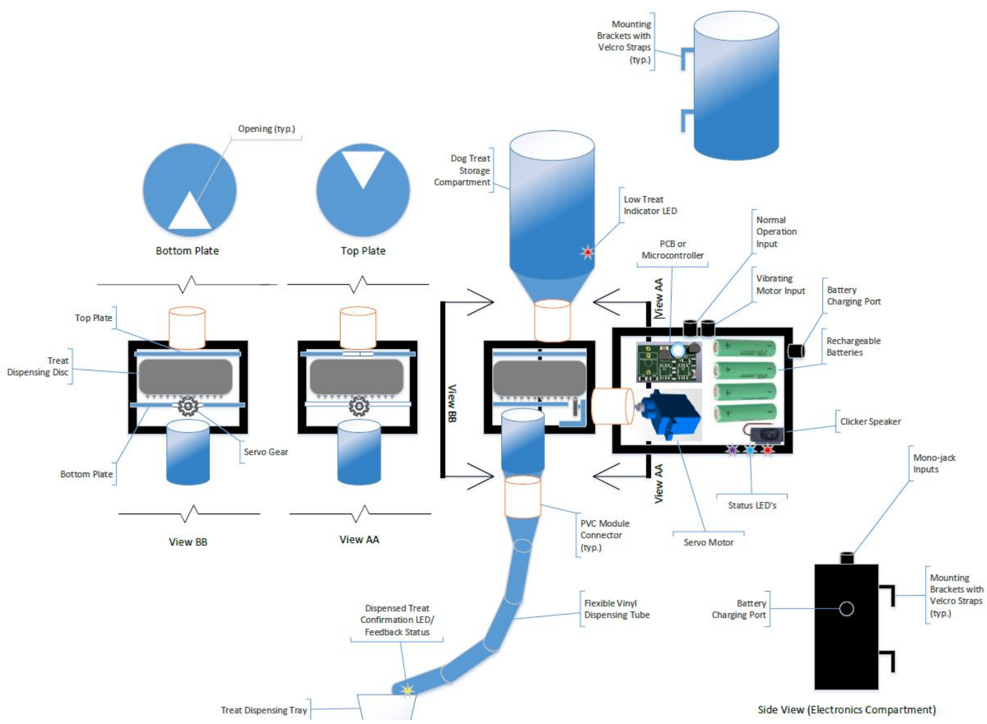


Figure 14 : Conceptual Design

Housing Design

The treat dispenser housing has been developed from easily found materials so that no items would need to be manufactured. The design is inspired by a coin operated gumball dispenser, and actually utilizes the dispensing components from the coin operated gumball dispenser. Due to repetitive successful testing by Service Dogs of Virginia as well as previous design groups of the gumball dispensing mechanism, the goal was to transplant this mechanism into a lightweight, and low profile housing. The housing needed to be slim and allow for mounting at multiple points on an electric wheelchair. Using the Conceptual Design as shown in Figure 14 above, the prototype treat dispenser housing as shown in Figure 15 below as developed.

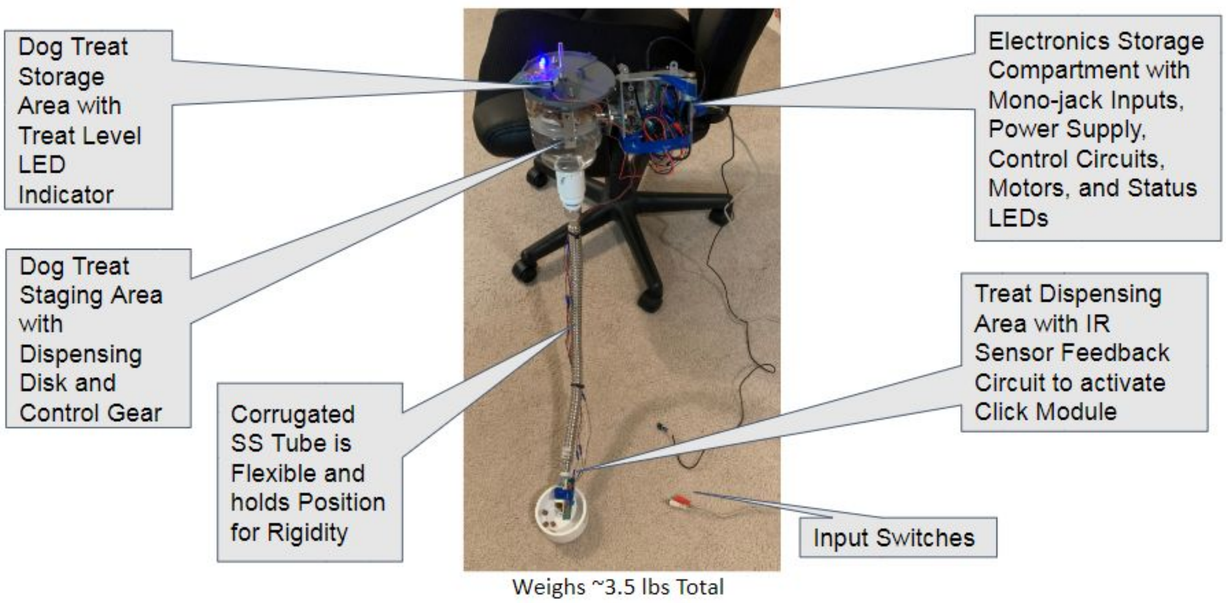


Figure 15 : Prototype Wheelchair Mounted Automatic Dog Treat Dispenser

As can be seen in Figure 15 and as described in the proposal, the treat dispenser is composed of four main parts: the Storage Area, Dispensing Area, Staging Area, and Electronics Area.

Dog Treat Storage Area:

The dog treat storage area is comprised of three main pieces as shown in Figure 16 (left) below: 3” PVC Cap, 3” PVC Pipe, and 3” to 3/4” PVC Reducer. The ¾” reducer then fits into the hole in the top cap as shown on the right side of Figure 16. This will allow the treats to be fed directly to the loading zone in the dispensing disk.

Figure 16 : Planned Dog Treat Storage Area

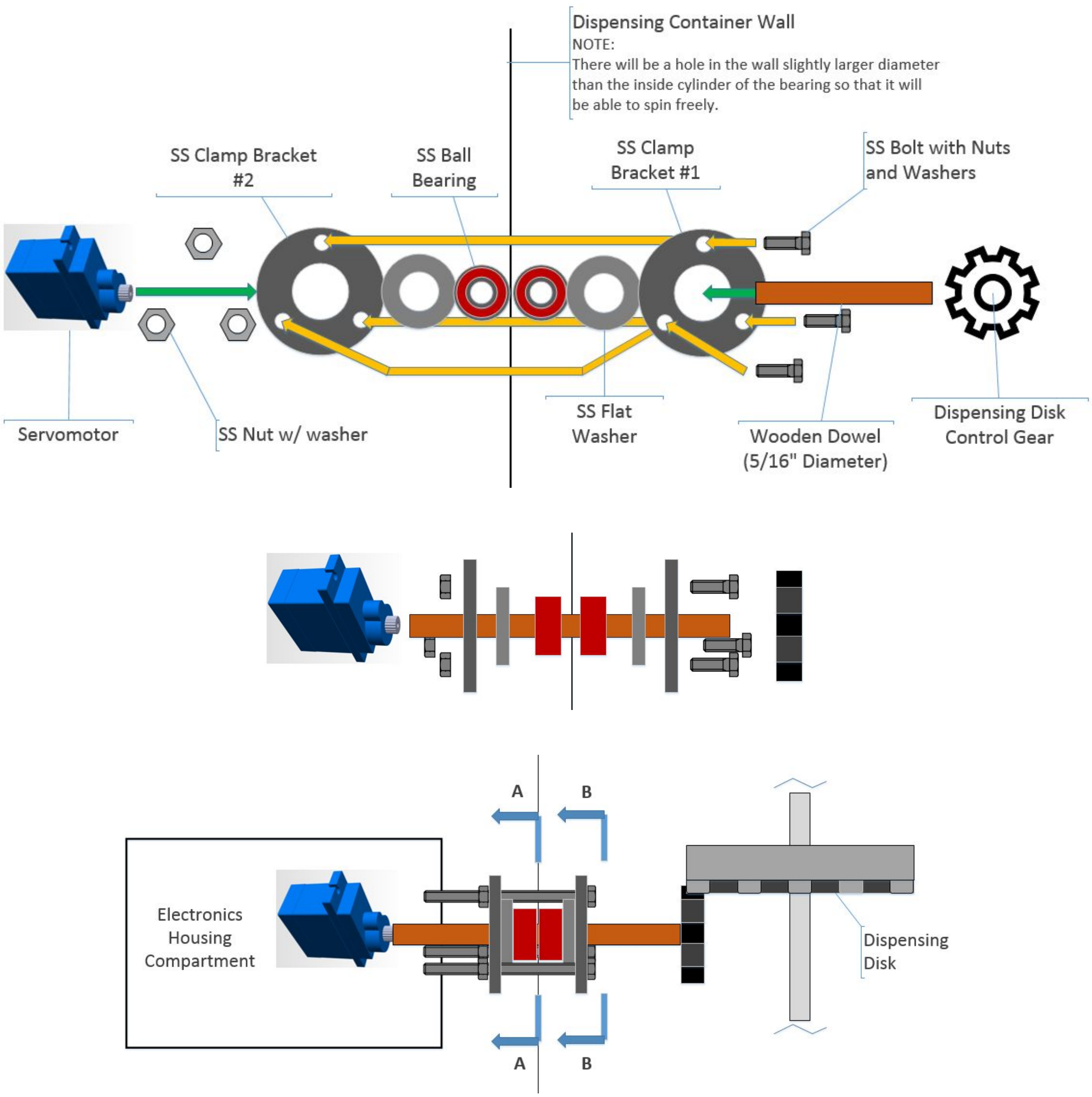
The 3” PVC Cap is to be fitted with the treat level sensor consisting of two IR sensors and two LEDs. The two IR sensors will face down, into the container while the two LEDs will face up to be visible by the user. The circuit board for these sensors and LEDs will be located in the Electronics compartment and only the IR sensors and LEDs will be mounted on the cap. The treat dispenser storage area holds at least a cup of dog treats at a time. When both LEDs are illuminated, the storage area should be full of dog treats. It will also have hooks and straps for wheelchair attachment in order to keep the device mounted at the highest point and keep from toppling off the wheelchair.

Dog Treat Staging Area:

This portion of the treat dispenser is the most difficult to put together as it has all the moving parts. The treat staging area is responsible for taking treats in from the storage area, taking input from the servo motor in the electronics area to turn the gears, and for dropping treats to get them to the dispensing area successfully. Thus, this is the heart of the design and the connection point for the other three modules. This piece is comprised of the following components :

- Food safe plastic bottle (potentially to be replaced with 3” PVC tube later)
- Top plate
- Gumball machine dispensing disk
- ¼-20 x 3” all thread stainless steel rod for alignment (2ea.)
- ¼-20 x 6” all thread stainless steel rod to function as spinning axis for dispensing disk
- L-bracket supports (2ea.)
- Gumball machine “receiver” piece
- Bottom plate with hole for dropping treats
- Gear, wooden dowel, and bearings for attachment to servo motor

There are two axes that must be perpendicular to each other in order for the device to work correctly. These axes are the dispensing disk axis and the control gear/servo motor axis. Again, this is one of the more difficult parts to put together since space is limited and there are moving parts. The first axis to be considered will be the control gear axis controlled to the servomotor. This axis must extend from the dog treat staging area all the way to the electronics compartment for connection to the servo motor. The construction of this axis is as shown in Figure 17 below.



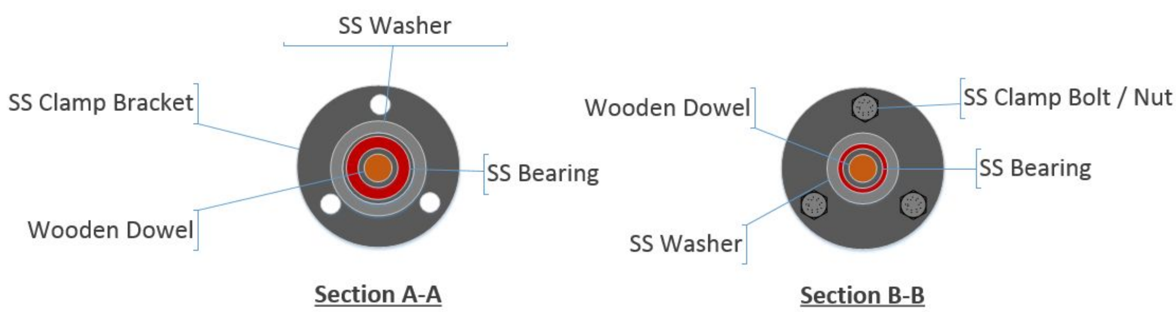
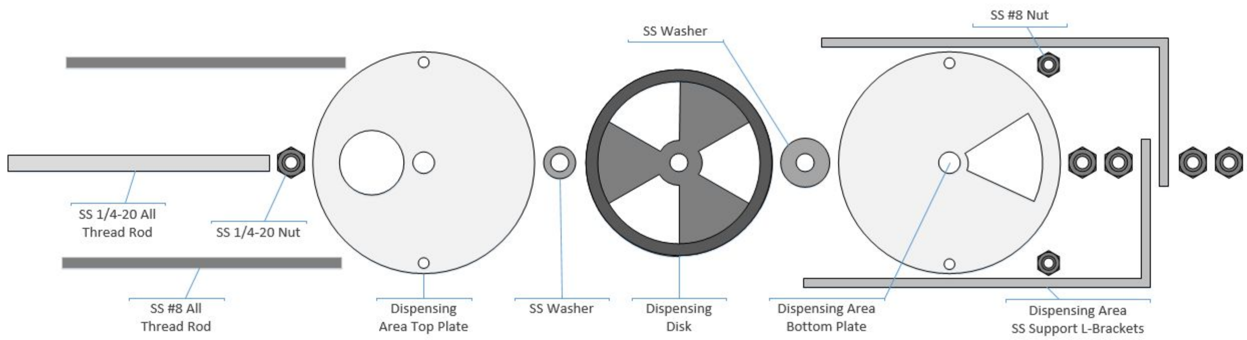


Figure 17: Control Gear / Servo motor Axis Construction

A hole is drilled in the side of the plastic bottle to allow insertion of the wooden dowel that will be controlled by the servomotor. This hole should only be slightly larger than the diameter of the dowel so it can spin freely. A bearing will be placed on either side of the plastic bottle and the dowel will be slid through these to keep them straight. A clamp will be used to hold the bearings tight against the wall of the plastic bottle to keep the gear at a 90 degree angle to the spinning disk.

Next, the construction of the Dispensing Disk axis will be considered. The details of this axis are as shown in Figure 18 below. The top plate should have 4 holes in it as shown in Figure 18: 2 for the ¼-20 x 3" all thread rods, 1 for the ¼-20 x 6" all thread rod, and 1 for the ¾" input from the treat storage area. The longer all thread rod will be centered and used as the center axis for the spinning disk. The shorter all thread rods will be on either side of the center and will be slightly farther from the center than the radius of the spinning disk. These are responsible for keeping the dispensing area top and bottom plates in place so they will not misalign when the dispensing disk is spun.

The bottom plate is made of a slightly flexible, but rigid plastic and will be responsible for keeping the spinning disk at the right height as well as not turning so as to keep the dispensing hole in place at all times. There should be two holes and a notch in this plate. The center hole should be ¼" to accept the center all thread rod, and there should be a roughly 1" diameter hole on the side that treats will drop from. On that same side, a notch should be cut out on the edge to allow for the servo motor gear to spin freely.



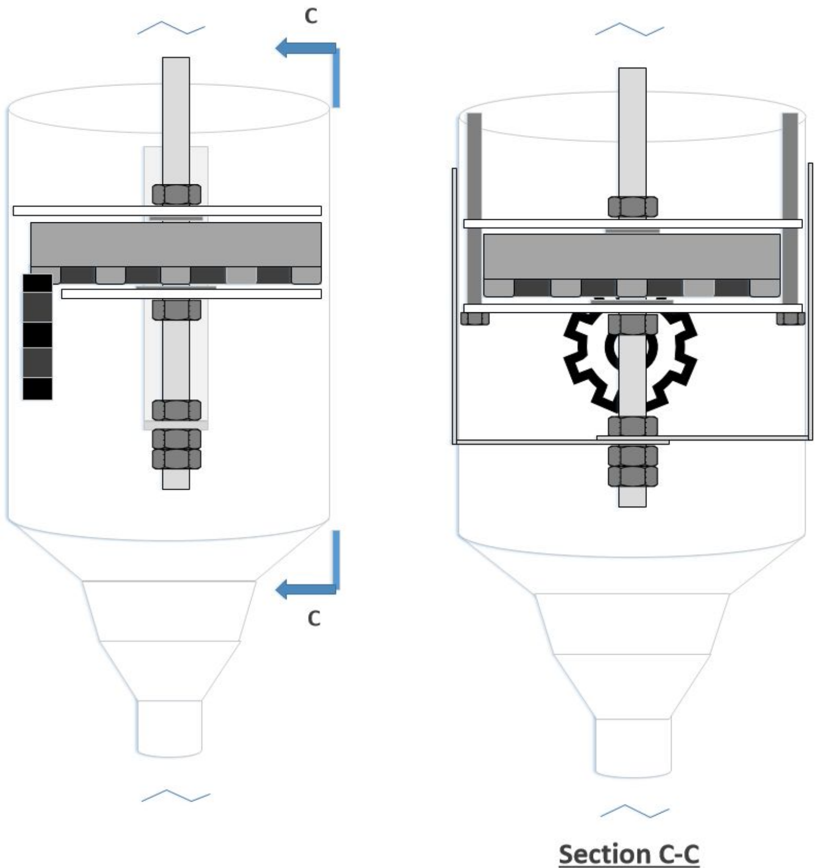


Figure 18: Dispensing Disk Axis Construction

There will be ½" notches cut into the side of the food safe plastic bottle to allow L-bracket insertion on opposite sides of the bottle and 90 degrees to where the servo motor dowel will be attached. These should meet in the middle and receive the center all thread rod to help keep it centered and anchored at the bottom. The center rod is anchored at the top plate and at these L-brackets to keep everything together.

By using nuts and washers along the all thread rods, the different pieces can be held at their correct heights. During testing, this optimal height is still being established, but everything should be placed so the spinning disk does not move vertically and can still spin freely.

The bottom of the plastic bottle is cut off to allow a large opening to insert all the mechanical pieces. The bottom then becomes the top of the staging area. By turning the bottle over, there is now a funnel shape at the bottom that can direct the treats to the dog treat dispensing area. The dispensing area will be connected to the bottle using the bottle cap threads, utilizing some plumber's tape if needed to ensure a tight connection.

Electronics Storage Area:

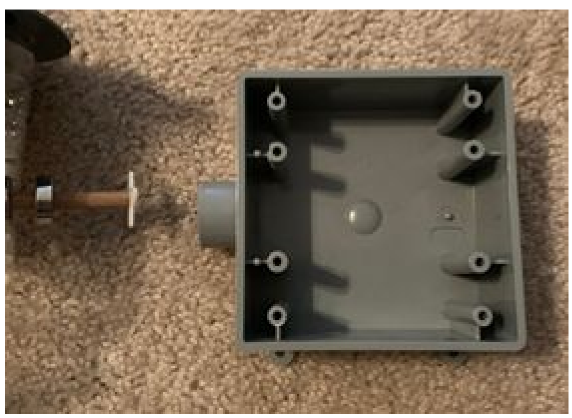


Figure 19: Electronics Housing Compartment

The Electronics storage area will be made of a square PVC gang box as shown in Figure 19 above. There is a ¾" hole in the side that the servo motor dowel can be inserted through. The servomotor is then mounted to the inside of the electronics housing and cannot move. This piece needs to remain as square to the opening as possible to ensure the dispensing disk is operated correctly.

This piece will be covered with a flexible, translucent piece of plastic with some rubber gaskets to help keep the electronics safe from the environment. The battery will be velcroed to the backside of the electronics compartment to allow for easy charging and power access as shown in the images below. On the opposite side of the opening for the servo motor control dowel, there will be another ¾" opening to allow ingress of the power cable from the battery pack as well as allow access to the 3.5mm mono-jack ports.

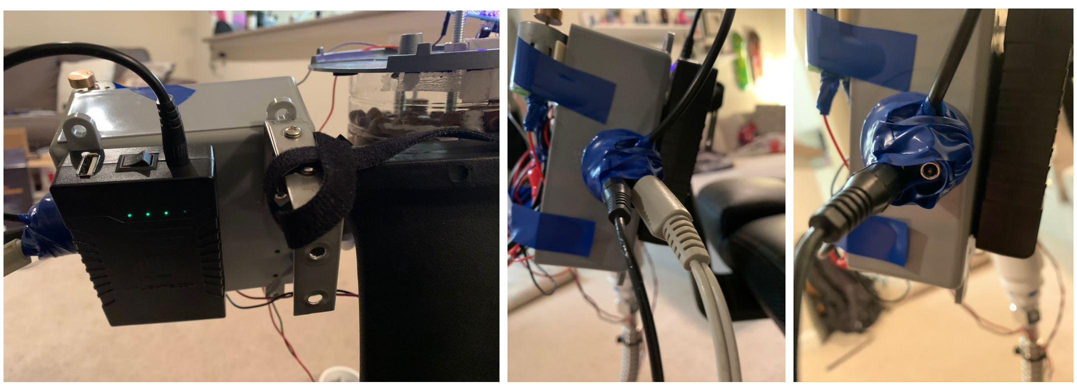


Figure 20: Electronics Housing Compartment from Prototype

There will also be hooks on the back of this storage area with Velcro straps to allow attachment to the wheelchair. It is important to keep this piece somewhat tight against the wheelchair so the electronics do not rattle too much and become damaged throughout a day.

This area will house the one circuit board needed for the 555 timer design or the Raspberry Pi and associated components for the microcontroller design along with the servo motor.

Treat Dispensing Area:

The treat dispensing area consists of PVC and Stainless Steel pieces. The PVC is used to connect the dispensing area to the staging area. The dispensing area is made mainly of a 2' stainless steel corrugated tube that is flexible and maintains position once set. This gives the user flexibility when installing on their wheelchair, allowing the treats to dispense almost wherever needed. The end of the dispensing area will be fitted with a small dog food bowl to catch the treats and present them to the service dog.

Figure 21: Dispensing Area of Treat Dispenser

Dispensing Area is flexible for an array of mounting options while maintaining rigidity to hold position. It can be easily detached from the Staging Area for cleaning or clearing of jams (if needed). There will also be mechanisms added to the end of the dispensing area to attach it to a wheelchair and keep the food dish securely in place.

Hardware Design

555 Timer Circuit:

Figure 16 shows a block diagram of the main components of the Servo Control Circuit. This circuit utilizes two 555 timers and a NPN transistor to control the servo. Servo control is achieved by sending a pulse-width modulation (PWM) signal to the servo where the duty cycle is equal to 2*0.693*R3*C3.

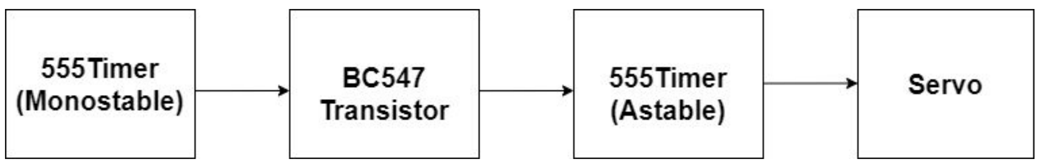


Figure 16 : Servo Control Circuit Block Diagram

Servo control circuit is designed with two 555 timers. The first 555 timer is set up for monostable operation and is triggered by a push button (mono input). The second 555 timer is set up for astable operation as to provide the necessary duty cycle for the servo to operate. Astable operation is activated when Q1 (NPN transistor) is turned on by the monostable operation of the first 555 timer. The time duration of the rotation can be adjusted by varying the value of RV1 potentiometer. The output pulse width is calculated by T=1.1*R*C(seconds). In this circuit, T= 1.1 * RV1 * C2 (seconds).

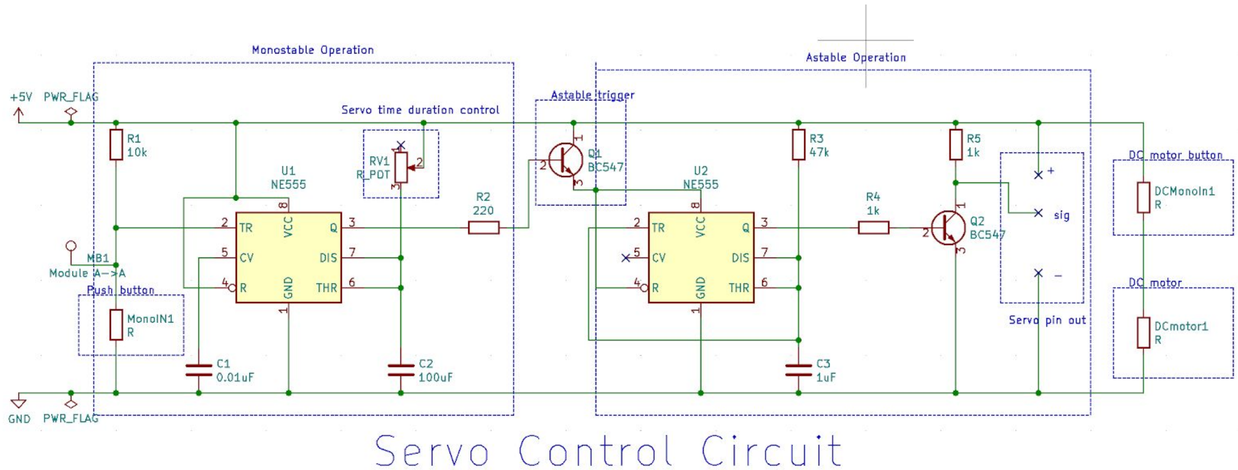


Figure 17 : Servo Control Circuit Schematic

The Servo Control PCB shown in Figure 17 also included a DC motor that is connected to a switch, allowing the user to dislodge the treats whenever they become jammed.

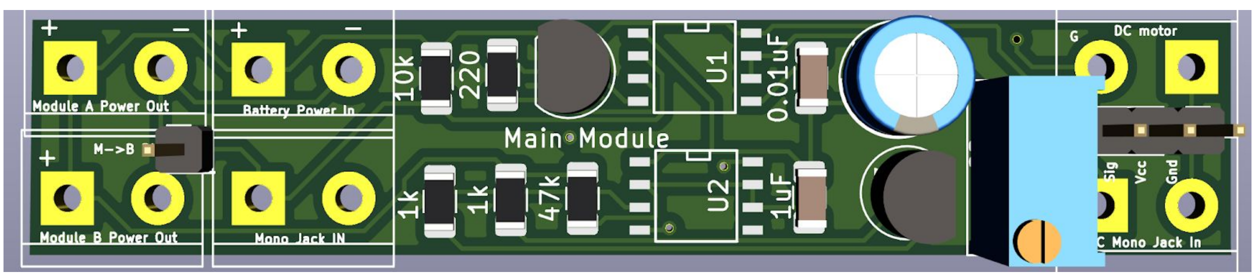


Figure 18: Servo Control PCB

Feedback Circuit:

The Feedback Circuit will be deployed in the dispensing tube. After a treat is dispensed and sensed by the IR sensors, the Icstation Sound Module shown in Figure 19 will output a “click” sound to notify the user and the dog that a treat has been dispensed.

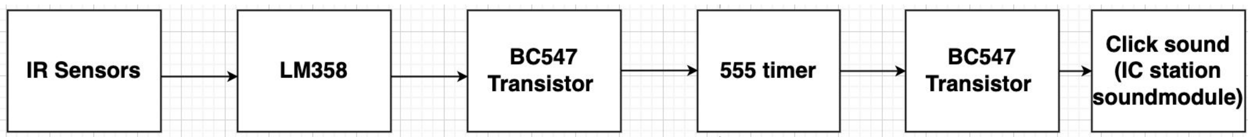
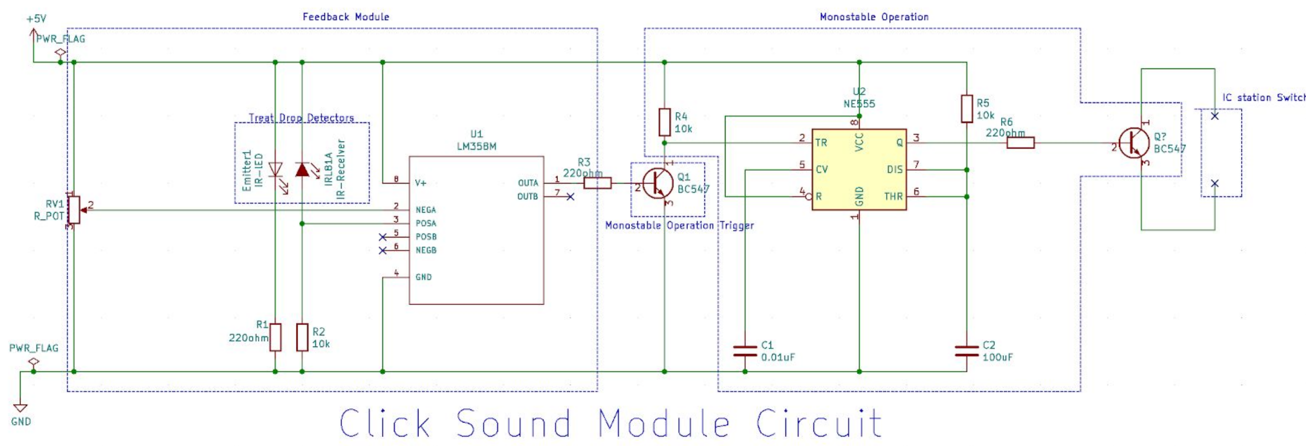


Figure 19 : Feedback Circuit Block Diagram



The Feedback Circuit consists of a pair of IR sensors, a 555 timer, a LM358 operational amplifier and the Icstation sound module. The op-amp functions as a comparator and compares the voltages at pins 3 and 2. Once a treat is detected, it triggers the 555 timer which is set to operate in the monostable mode.Finally the Icstation sound module outputs a “click” sound from the speaker to notify the user and the dog that a threat has been dispensed.

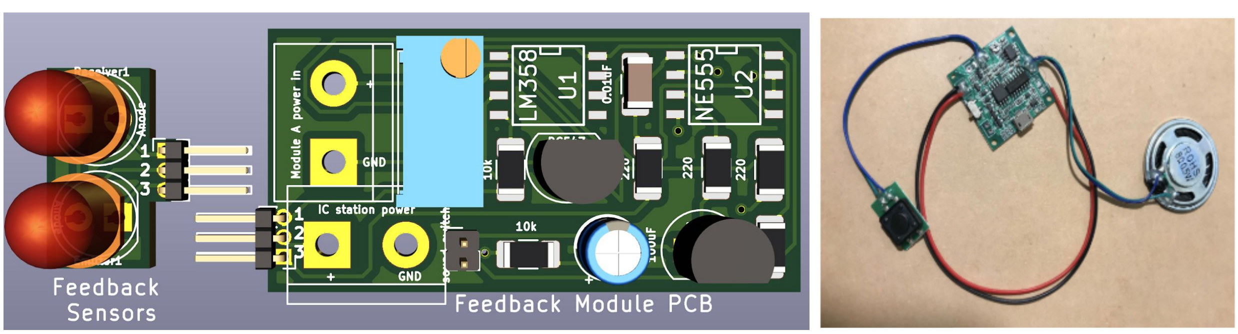


Figure 20: Feedback Module PCB and Icstation sound module

The MCU variant utilizes the ADS1115 analog to digital converter to convert the analog voltage into a digitized output that can be read and processed by the Raspberry Pi. The analog to digital converter allows us to import voltage readings and measure them in a digital format. This conversion allows the design team to perform headless monitoring and setup alerts in the workflow as triggers that can take action based on sensor feedback without human interaction. In our design we leveraged a python library provided by AdaFruit to do so here so that when the converter read a HIGH value that was above average it would then signal the click sound to take action afterwards.

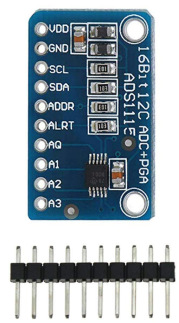


Figure 21: ADS1115 Analog to Digital Convertor

Treat Level Indicator Circuit:

Figure 22 shows the main components of The Treat Level Indicator Circuit which will be placed on the inside of the dispensers lid. It consists of a 555 timer operating in the monostable mode, IR sensors, a LM358 operational amplifier and a pair of LEDs to display the level of treats in the treat storage container.

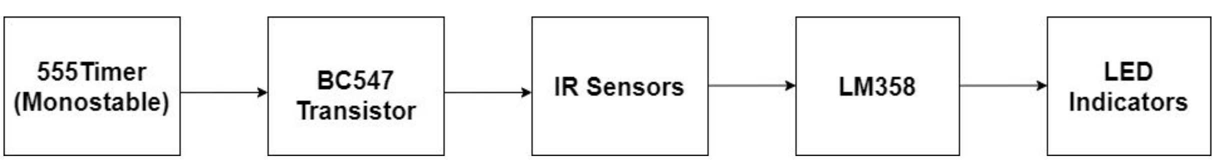


Figure 22 : Treat Level Indicator Circuit Block Diagram

The circuit also contains an on/off button to reduce power consumption. The 555 timers ensure that the circuit stays on for 5 seconds by using the following equation, T=1.1*R2*C2 which is equal to 5.17 seconds.

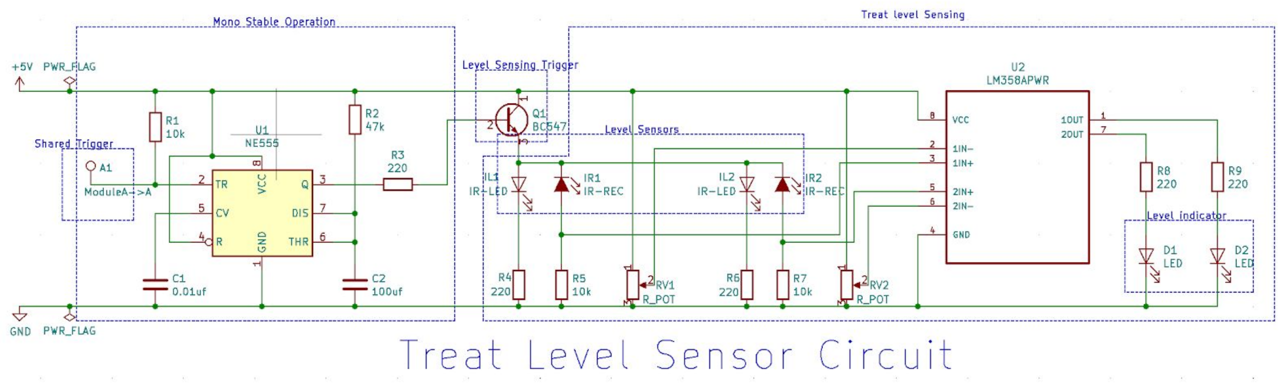


Figure 23 : Treat Level Indicator Circuit Schematic

When the user pushes the button the circuit will turn. 1 LED indicates that the container is 50% full, 2 LEDs indicate that the container is 100% to 50% full. If none of the LEDs turn on this means that the container is empty.

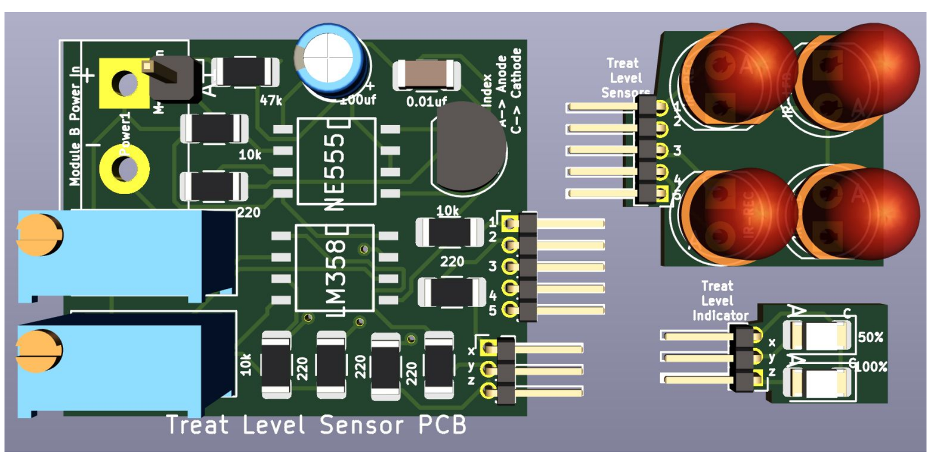


Figure 24 : Treat Level Indicator PCB

Final Circuit with RF Remote Control :

The PCB belows shown all of the modules combined into a single PCB with RF remote control. This circuit allows the user to control the dispenser wirelessly and no programming is involved.

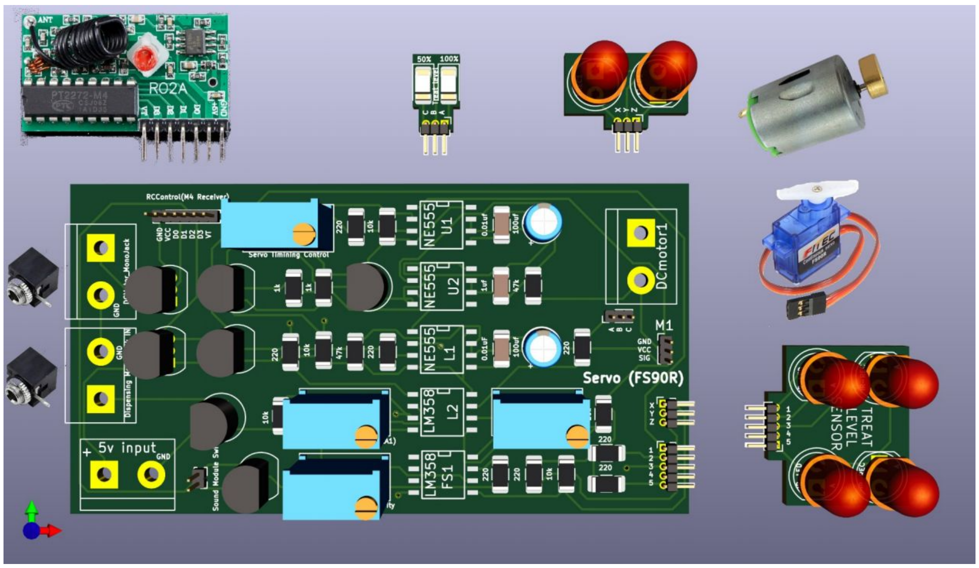


Figure 25 : Final Circuit with RF Remote Control

The RF receiver shown in Figure 26 comes with a matching RF keyfob remote. Option A allows the user to dispense the treat, display the level of treats and activate the “click”sound . Option B displays the level of treats. Option C allows the user to operate the vibrating motor. Finally, Option D activates the “click” sound.

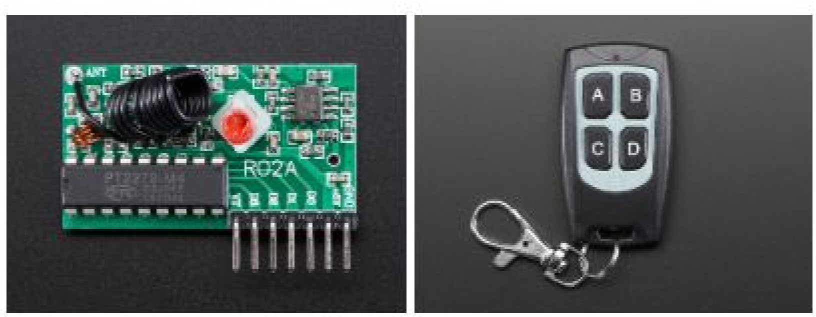


Figure 26 : Simple RF M4 Receiver - 315MHz Momentary Type and Key Fob 4-Button RF Remote Control - 315MHz

Final Circuit with the Raspberry Pi:

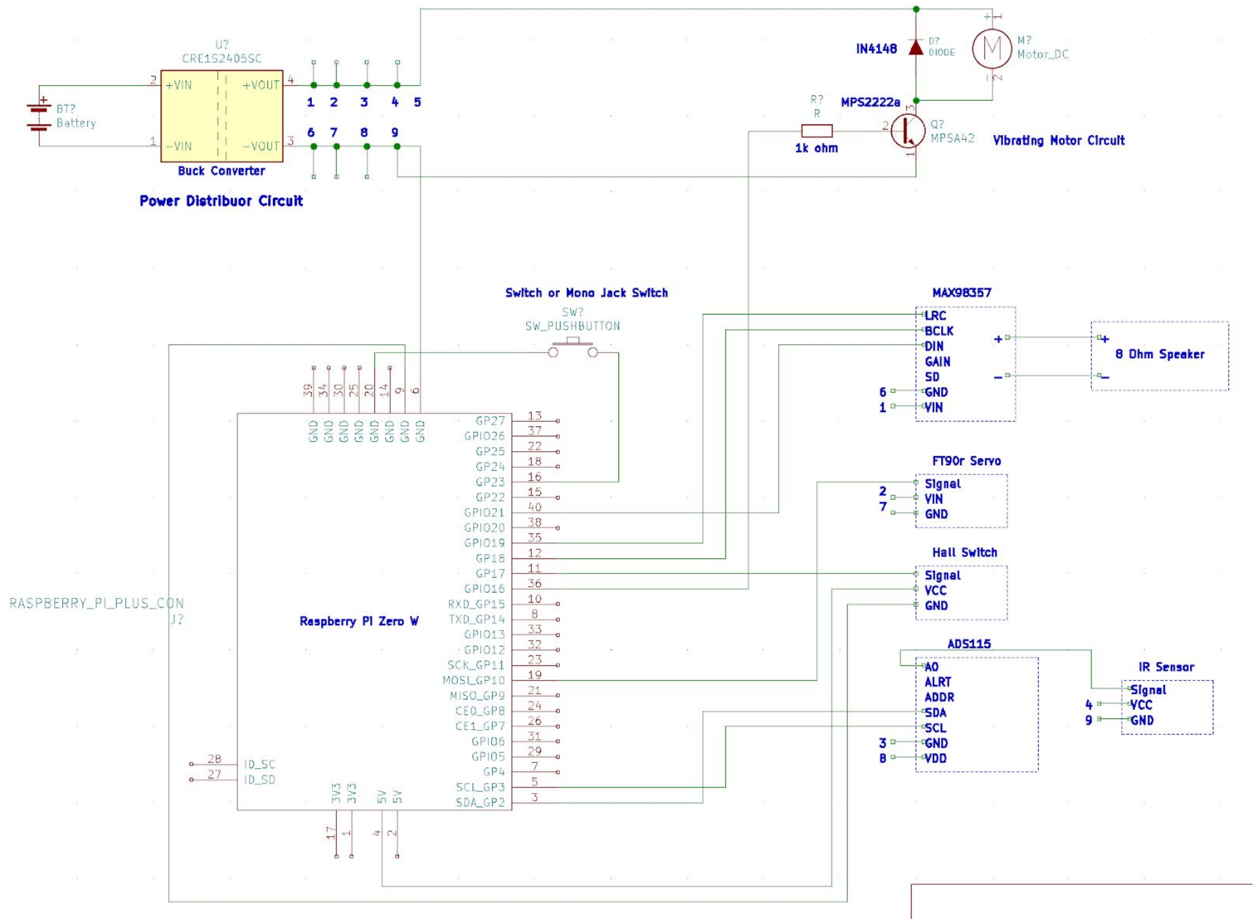


Figure 27 : Final Circuit Schematic with the Raspberry Pi

Software Design

Flow Chart:

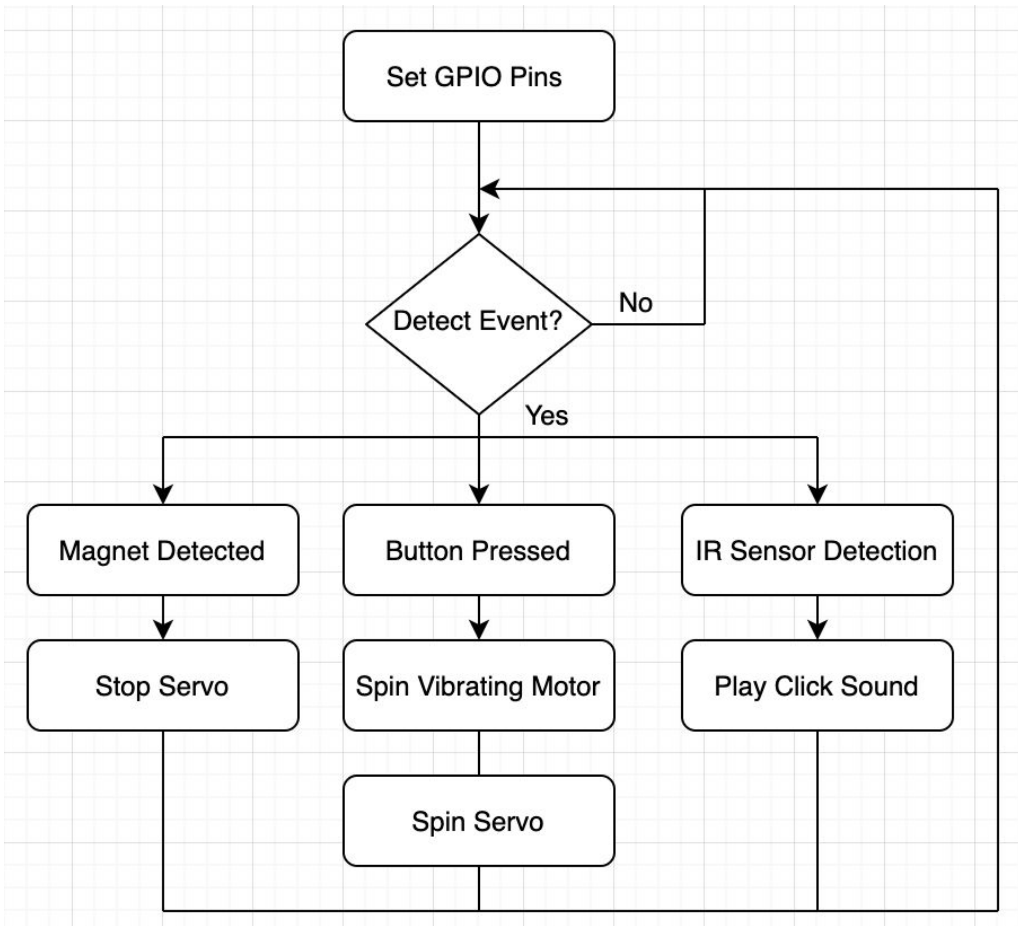


Figure 28 : Software Flowchart

From the flowchart above, the software design is relatively simple for the microcontroller to carry out the required functions of the project.

First, upon bootup, the Raspberry Pi will set all of the GPIO pins to their respective assignments, and also set up certain events. These events include if a magnet is detected, if a button is pressed, or if the IR sensor detects a treat has passed by.

The “Button Pressed” block is used to show that when a user has provided the system an input to dispense a treat, the vibrating motor will spin to dislodge any treats and the servo arm will start to spin. The servo spinning will then spin the rotary mechanism to allow a treat to be dispensed. This will then loop back to wait until another event is detected.

Next, the “Magnet Detected” event will happen because the magnet that is attached to the axle of the rotary mechanism will see that a magnetic field is present to the hall effect switch. The hall effect switch is simply a feedback loop that detects if the servo has spun exactly 360 degrees to ensure the same amount of treats are dispensed each and every time. Once the hall effect sensor sees that a magnetic field is nearby, the sensor will send a signal back to the microcontroller to indicate that there has been one full spin of the servo, thus, in response to the sent signal, the microcontroller will stop the servo from spinning. Once the appropriate commands have been given, the microcontroller will wait until the next event happens.

Finally, once the treat has been dispensed through the tube, the IR sensor will notice that the voltage has dropped (because a treat has passed by the IR sensor). This block has been denoted as “IR Sensor Detection” above. This will cause the microcontroller to use this data in order to play the click sound. The click sound is important to only go off once this happens (as treats may be stuck for some reason) and not confuse the service dog to a successful dispensement of a treat. Finally, this loop will continue to repeat until the system has been removed from power.

For Raspberry Pi set-up and making appropriate connections, please see **Appendix D** labeled “Treat Dispenser Manual.”

Software Data:

Other than the basic coding skills used to allow the software to run (e.g. set up, event detection, and simple loops), an essential part of the software design is understanding Pulse Width Modulation (PWM), event debouncing, and Analog to Digital Conversion (ADC) of raw data.

PWM:

For the software side with the current design, the design required two separate PWM objects to drive the vibrating motor and the servo. When coming up with the calculations to obtain the correct signals to send to the vibrating motor and servo, specific values must have been set up and fed to the hardware components in order to make them rotate properly.

To figure out the correct duty cycle to set each of the PWM signals:

Duty Cycle = (length/period) , where length is the amount of time the signal is high, and period is the period of the signal.

For example, the first PWM object that was considered was for the servo arm. Based on the servo requiring a base frequency of 50 Hz, the servo spins clockwise with a set duty cycle of 7. The duty cycle states how long (in percentage) the signal will remain high for the whole cycle [11]. In this case, the servo arm spun at 80 rpm with the defined 7% duty cycle at 50 Hz.

As another example, the second PWM object that was considered was for the vibrating motor. Since the vibrating motor merely had to just turn on at full speed by using a duty cycle of 100% at 207Hz to make the vibrating motor spin. In the software design, it is on a timer to allow the vibrating motor to spin at full power for 1 second to dislodge any dog treats that may be stuck in the design.

Event Debouncing:

To ensure that the event detection portion of the code would not give any erroneous data, when an event was detected, a debounce timer is used so the software would not just “jump” to conclusions. The bounce times were set by mere opinion because they each required a subjective time to react.

For example, the event debounce time set up for the Hall sensor was only 50 milli-seconds because it must stop the servo arm from rotating very quickly. The faster the signal is sent back to the microcontroller, the faster the microcontroller could respond and turn off the servo motor from rotating.

As another example, the debounce time set up for the button being pressed was 600 milli-seconds because the system is not active at a time before the button is pressed. In an effort to reduce a false activation, the debounce time of 500ms was determined to be sufficient after various tests.

ADC Voltage Conversion:

For the ADC to give the Raspberry Pi solid values, the libraries installed with the ADC works flawlessly to not just give raw data out, but also the converted voltages. Thus, based on testing data when in close range to the IR sensor, the IR sensor was able to output a spike in the voltage received once the treat was within 1cm of the sensor. This way when a treat passed by the IR sensor within 1cm, the data read in by the IR sensor at the ADC would output a voltage value of 2.3-3V. This is why the code states if any voltage above 2V is obtained by the sensor, the click sound module is activated.

Ⅲ Experimentation and Results

Power Analysis

After some initial testing of the circuits using an ammeter, the following power draws were found on the 555 timer circuit design:

Circuit Load	Min. (Watts)	Max. (Watts)
Treat Level Sensor (Yellow LED On, Blue LED On)	0.39	0.41
Treat Level Sensor (Yellow LED On, Blue LED Off)	0.375	0.395
Treat Level Sensor (Yellow LED Off, Blue LED On)	0.37	0.38
Treat Level Sensor Off (Idle Circuit)	0.3	0.325
Servomotor Activation (LEDs On)	1.125	2.445
Clicker Sound Module with Sensor (LEDs On)	0.79	1.29
Clicker Sound Module (LEDs On)	0.89	0.935
Clicker Sound Module Sensor (LEDs On)	0.625	0.645
Vibrating Motor (LEDs On)	0.65	0.695

Table 1: Circuit Load Power Draws

Since all of the modules operate separately with the treat level sensor, the worst case scenario is that the treat level sensor has both the yellow and blue LED on indicating that the treat storage compartment is full while the Servomotor is being activated. This load is 2.445 Watts.

Thus, with a 12 VDC battery pack output, the max output current needed is 2.445 W / 12 V = 0.204 A. Since batteries only have a certain efficiency (around 95%), there should be a safety factor applied as well as a slight conservative threshold. Thus, multiplying 0.204 by 1. 2 gives a 20% safety factor and means the battery pack will need to be able to supply a current of up to 0.245 A. Round this up to 0.5 A at 12 VDC to ensure the battery will be strong enough to power the dispenser.

Below is the decision matrix on which type of battery would be best for the device. As can be seen, there were two battery types that seemed to be the best fit. These are Nickel-Metal Hydride and Lithium Ion batteries.

	Criteria and Weight of Importance for Design						
Battery Type	Voltage [1]	Cost [2]	Availability [4]	Weight [5]	Capacity [3]	Environmental [6]	**Totals**
Alkaline	1	5	5	5	1	1	65
Nickel-Metal Hydride	5	3	4	4	5	4	86
Nickel Cadmium	3	3	3	2	2	3	55
Lithium Ion	5	4	4	3	4	5	86
Nickel Zinc	4	1	1	4	3	5	69

Table 2: Battery Type Decision Matrix

Originally, it was determined that the design would use Nickel-Metal Hydride batteries for the 555 Timer Circuit solution and the Lithium Ion batteries for the Microcontroller solution. After some research, a Lithium Ion battery pack was found that would work for both solutions. The specifications and data sheet on this battery can be found in Appendix A. The battery pack is unique for this project in that it has a 5V USB output that can be used to power the Raspberry Pi W Zero and a 12 VDC output that can be used to power the 555 timer circuit. The device is easy to use, should power the circuits without issue, and has a fairly quick charge time (~12 hours for a full charge based on specifications).

This battery has sufficient output power (3A at 12 VDC) to drive the circuitry as shown with the power draws of the different modules as shown above. The battery is a 2800 mAh unit. To see if this will be enough to power the treat dispenser based on the power requirements as listed above, a profile of how the device will be used needs to be created. This will be as follows:

> Within 18 hours, the device will be activated at least 50 times. The treat dispenser will be assumed to be full of treats for the duration of the 18 hours. Vibrating motor will be assumed to be run for an average of 1 minute a day. The vibrating motor does not need to be activated long to perform its task of dislodging a stuck treat. 1 minute would coincide with around 30 activations.

Thus, the modules will be active for the amount of times as shown in Table 3 below.

Circuit Load	**Device Usage Profile Times**
Idle Current (Yellow LED On, Blue LED On)	18 hours
Servo Motor Activation	100 seconds
Clicker Sound Module with Sensor	100 seconds
Vibrating Motor	60 seconds

Table 3: Device Module Run Times for Power Profile

The servomotor and clicker module were estimated to be active for around 100 seconds since they are active for around 2 seconds per activation (50 activations x 2 = 100). From this, the average power draw of the device over 18 hours can be given by:

$$Average\ Power\ Draw = \frac{[(0.41 * 18 * 60 * 60) + (2.445 * 100) + (1.29 * 100) + (0.695 * 60)]}{18 * 60 * 60}$$

$$= 0.416\ Watts = 0.0347\ Amps\ at\ 12\ VDC$$

Again, it is good to be conservative. Estimating the Average Power Draw at 0.1 Amps at 12 VDC will be used to provide plenty of overhead. According to the specifications in Appendix A, the runtime of the battery can be found by dividing 2.8 Ah by the Average Power Draw of 0.1 Amps.

$$Estimated\ Run\ Time = \frac{2.8\ Amp - hours}{0.1\ Amps} = 28\ hours$$

This battery pack was purchased and testing was performed to ensure it would measure up to these estimations. The battery was tested twice from full charge until it completely died.

Test 1:

The battery was first depleted according to the following testing parameters.

Time	**Activations**	**Treat Dislodging (Vibrating Motor Active Time)**	**Battery Level (Given by LEDs)**
8:30 AM	3		4 LEDs
1:00 PM	3	10	3 LEDs
9:00 PM	30	10	2 LEDs
10:00 PM	30	10	2 LEDs
11:00 PM	30	10	1 Solid 1 Flashing LED

1:20 AM	10	10	1 Solid 1 Flashing LED
8:15 AM	5	10	1 Solid 1 Flashing LED
9:00 AM	20		1 Solid 1 Flashing LED
10:20 AM	20		1 Solid 1 Flashing LED
11:20 AM	5		1 LED
1:01	5		1 LED
2:00	BATTERY DEAD		0 LEDs

Table 4: Battery Strength

Then, the battery was recharged to see if the 12 hour charge time was accurate. This timing is shown below.

Time	**Battery Level**
6:00 PM	Start
6:37 PM	1 LED
8:00 PM	2 LEDs
9:30 PM	3 LEDs
6:00 AM	Fully Charged

Table 5: Time vs. Battery Level

Based on the above test, the device was activated 161 times, which is 3 times more than necessary on one charge. The battery lasted well over 18 hours dying after staying active for around 29.5 hours.

Test 2:

The battery was again depleted, this time according to the following parameters. This test shows sporadic testing to simulate a user going throughout their day. They probably do not give treats to their dogs at the same time every day, so it is good to mix it up like this for the best outcomes. If the device can handle sporadic usage, it should be able to meet the user's needs.

Time	Activations	Treat Dislodging (Vibrating Motor Active time)	Battery Level (Given by LEDs)
8:30 AM	10		4 LEDs
11:35 AM	5		3 LEDs
1:00 PM	20	30	2 LEDs
2:00 PM	20		2 LEDs
7:35 PM	20	30	1 Solid 1 Flashing LED
8:00 PM	10	20	1 Solid 1 Flashing LED
9:00 PM	20		1 Solid 1 Flashing LED
10:30 PM	20	60	1 Solid 1 Flashing LED
8:30 AM	20		1 Solid 1 Flashing LED
11:00 AM	20		1 LED
1:00 PM	BATTERY DEAD		0 LEDs

Table 5: Battery Strength

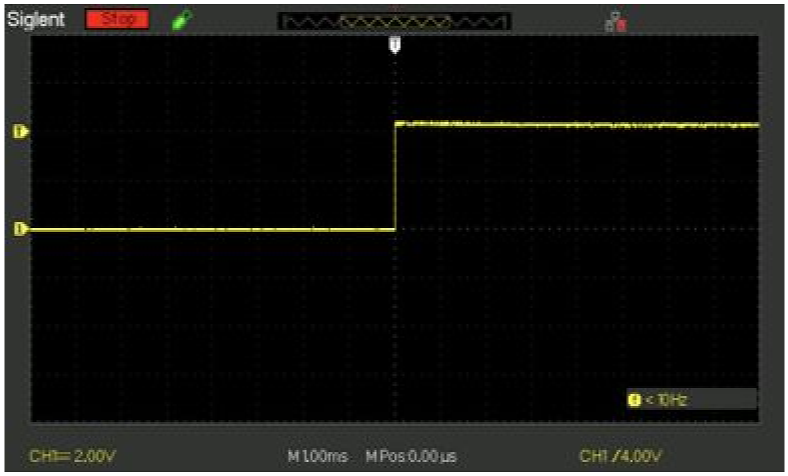
Again, the battery was recharged to see how long it would take as shown below.

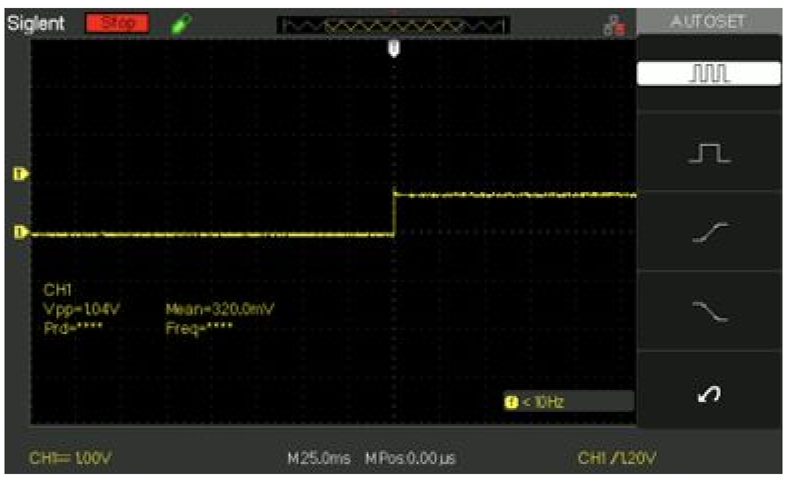
Time	Battery Level
2:00 PM	Start
2:30 PM	1 LED
3:00 PM	2 LEDs
6:46 PM	3 LEDs
8:30 PM	4 LEDs

Table 6: Battery Strength continued

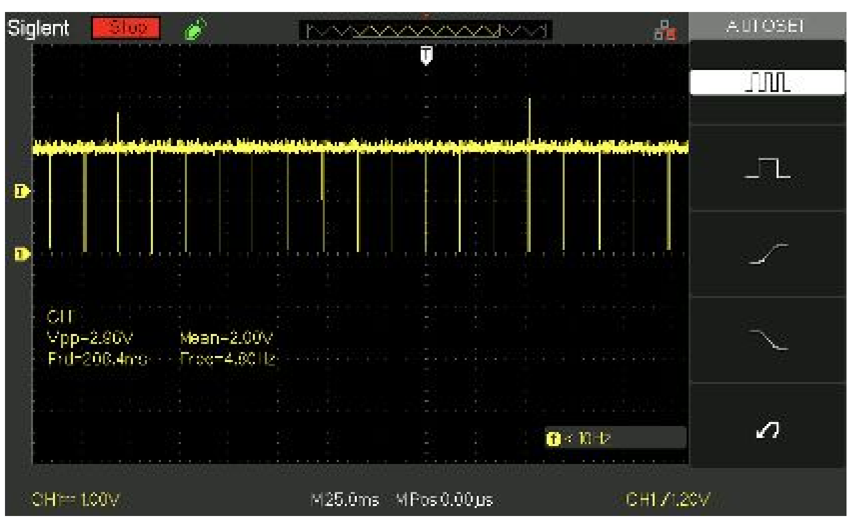
Based on the above test, the device was activated 165 times and died after around 28.5 hours. This time, however, the battery seemed to be fully charged after only 6.5 hours.

It can also be seen that, since a 75% charge will allow for over 50 activations and over 24 hours of run time, only a 4.5 hour charge is really needed for a user to get through an 18 hour day. Thus, the battery meets all the requirements as listed in the beginning of the document.





Clicker Module Voltage Change During Activation



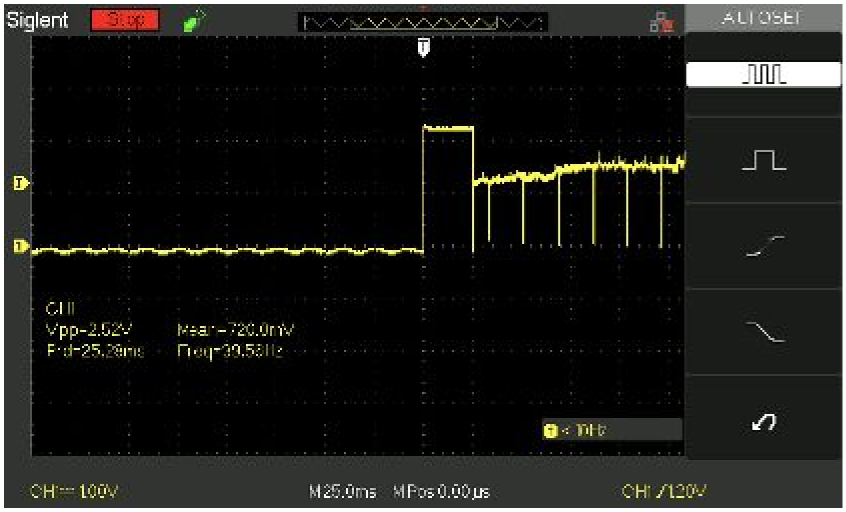


Figure 29: Servomotor Voltage Draw (555 Timer Output During Activation)

Similar tests were performed for the MicroController design solution and those loads are as shown in the following table.

Circuit Load	Min. (Watts)	Max. (Watts)
Idle Load (No activation)	0.25	0.25
Servo Motor Activation (Includes Vibrating Motor)	0.75	0.90
Feedback and Clicker Module Activation	0.25	0.35

Table 7

The difference here is that the MicroController workflow is slightly altered from that of the 555 Timer circuit. Instead of having an alternate input for the vibrating motor, the vibrating motor becomes part of the workflow when a user activates the treat dispenser. Thus, a servomotor activation also includes the activation of the vibrating motor. Therefore, there are only three possibilities for operating this device. Utilizing the same parameters for daily usage as before, the following active times are established for each of these power draw possibilities.

Circuit Load	Device Usage Profile Times
Idle Load (No activation)	18 hours
Servo Motor Activation (Includes Vibrating Motor)	100 seconds
Feedback and Clicker Module Activation	100 seconds

Table 7

$$Average\ Power\ Draw = \frac{[(0.25 * 18 * 60 * 60) + (0.90 * 100) + (0.35 * 100)]}{18 * 60 * 60}$$

$$= 0.252\ Watts = 0.0210\ Amps\ at\ 12\ VDC$$

Again, it is good to be conservative. Estimating the Average Power Draw at 0.05 Amps at 12 VDC will be used to provide plenty of overhead. According to the specifications in Appendix A, the runtime of the battery can be found by dividing 2.8 Ah by the Average Power Draw of 0.05 Amps.

$$Estimated\ Run\ Time = \frac{2.8\ Amp - hours}{0.05\ Amps} = 56\ hours$$

Thus, the MicroController design solution should last almost twice as long as the 555 timer solution. It seems the Raspberry Pi better handles an idle current when inactive verses the 555 timer circuit. This is slightly surprising in that the original calculations showed that the Raspberry Pi could potentially draw much more power than the 555 timer circuits.

System Integration Analysis

After building the housing, it was necessary to then integrate all the circuitry, including the servomotor, to the treat dispenser. The overall construction of the housing with all 555 timer circuitry installed is shown in Figure 30 below.

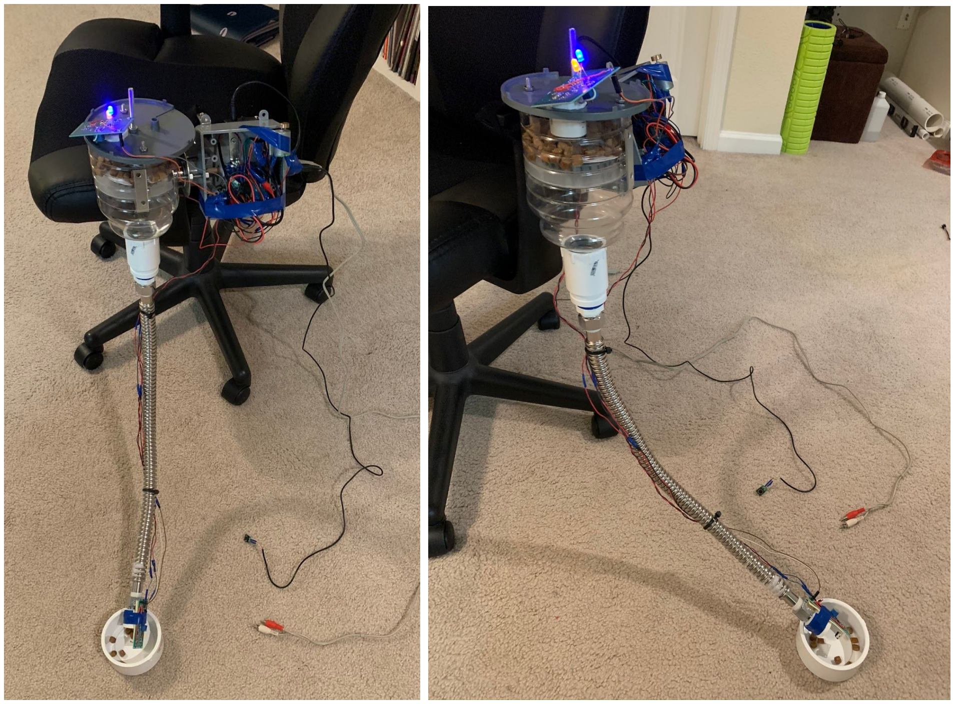


Figure 30: Prototype Treat Dispenser Housing with 555 Timer Circuitry Integrated

A few things can be seen immediately from these images that stray from the original housing design. One is that the treat storage area is not installed on top. Another is that there is an abundance of cables and there is no cover on the electronics compartment. Lastly, the IR circuits for both the treat level sensor and the feedback sensor to activate the click module are mounted external to the electronics compartment. Due to unforeseen issues, the final PCB design was not obtained in time for the project. This final design would have implemented all circuitry on one board and would then allow the placing of IR sensors and LEDs remotely on the unit with small wiring. This would provide a much sleeker look to the device than seen above. It will also allow the device to be more modular as planned.

Since there was no wheelchair to use for this testing, the higher mounting point that the device was designed for was not able to be achieved. Thus, the treat storage area was left off the top to keep the device from becoming too top heavy during testing. If mounted to a wheelchair, the storage area would have mounting brackets to help keep it upright. Therefore, the treat level sensor was just placed on top of the device and the IR sensors fitted into the treat ingress opening on the top cap. This was enough to show how the device would function as designed.

Figure 31: Prototype Treat Level Sensor

The next piece to integrate was the electronics compartment to the treat staging area, and also the control gear and servo motor dowel, which is the most complex part of the device mechanically. As seen in Figure 32 below, the planned design of the bearings with clamps provided great results. The control axis remained perpendicular to the dispensing disk axis during all of testing.

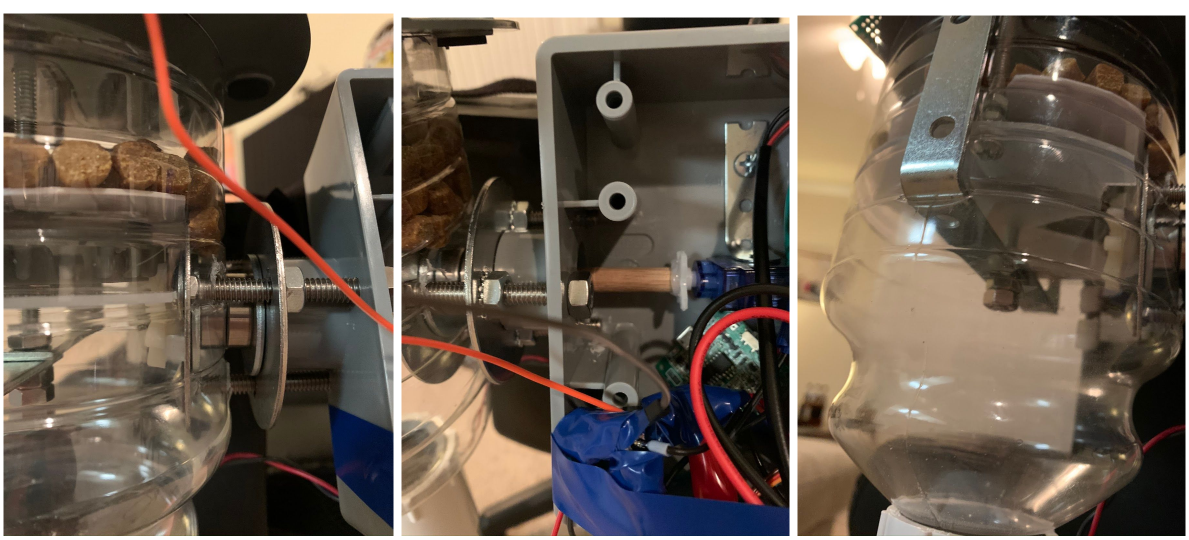


Figure 32: Prototype Control Axis and Attachment of Electronics Compartment

As can be seen in the figure above, middle, the bolts that are used to clamp around the bearings and provide stiffness to the control axis are also long enough to reach the edge of the electronics housing compartment. Thus, by drilling a small hole in the compartment and using a nut, the two pieces mount together nicely and solidly. The image on the left in the figure above shows a good angle on the bearings and glimpse of the control gear (white) inside the clear plastic housing. The image on the right in the figure above gives a view of the bottom plate where the treats will be dispensed from. When the dispensing disk turns, the treats will line up over the triangular slot, and fall to the bottom of the staging area and start towards the treat dispensing area.

Again, the electronics housing compartment is a little over crowded and messy in this prototype due to the lack of final PCB and access to SMD components. As can be seen in Figure XX below, the compartment has enough space to house all the components, but there is too much cable to mount anything nicely. With the final PCB design, this would be a neat compartment with one circuit board and a speaker.

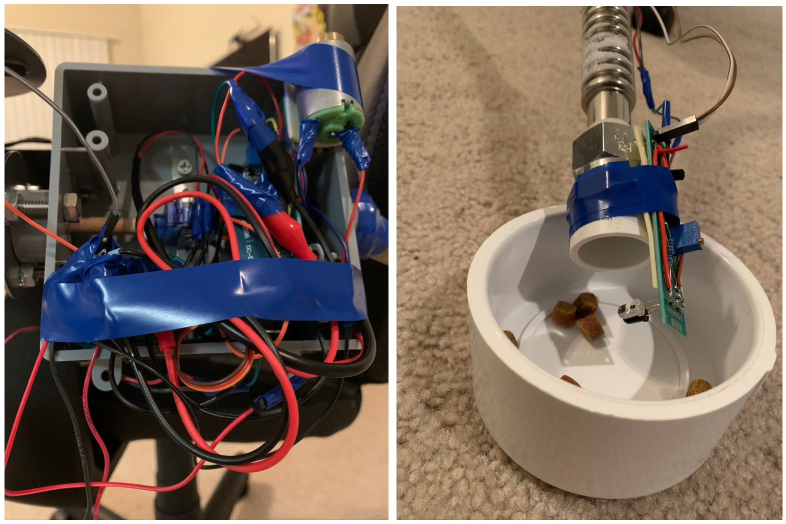


Figure 33: Prototype Electronics Housing Compartment and Dispensing Area

The IR circuit used to provide feedback confirming that a treat has been dispensed successfully is shown at the treat dispensing area in the right image in Figure 33 above. Again, this circuit would be in the electronics housing in the final design (integrated onto the single circuit board) and the only electronic pieces that would be installed here are the IR sensors. The emitter and receiver would be installed in small holes in the PVC at the end of the tube and siliconed in place with wires run along the dispensing tube discreetly up to the electronics housing area.

As shown in Figure 34 below, there is plenty of space at the top of the treat staging area to fill the device with at least a cup of treats. Thus, the treat storage area extended above may not be necessary, however, the top plate that these treats are sitting on should be funneled towards the opening that will load the dispensing disk to ensure the treats do not just rest on top. Overall, the design seems to operate as expected and with few jams ever occurring. With the few modifications as listed in this section, the device could be working at a production level. Ideally, a plastic mold of the housing could be created where all the pieces would click into place easily.

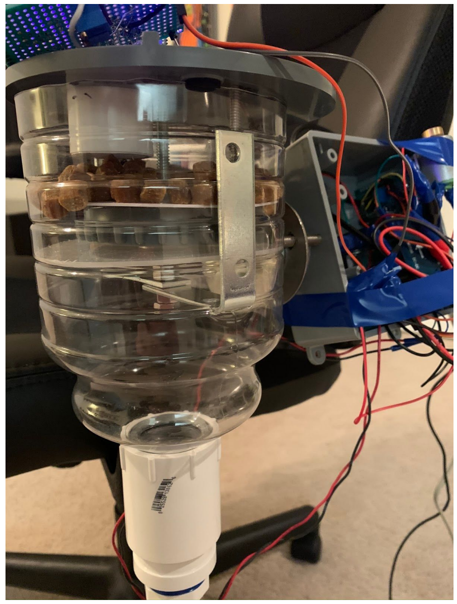


Figure 34: Prototype Treat Storage / Staging and Electronics Compartment

In order to test the effectiveness of this treat dispenser housing, the device was tested throughout a day (25 uses). The results of this test are shown in the table below. As suspected from earlier testing and analysis, this testing confirms that the device as built is a suitable solution for SDVA.

Activation	# of Treats Dispensed	Jammed?	Click Sound Activated?
1	1	No	No
2	2	No	Yes
3	4	No	Yes
4	5	No	Yes
5	5	No	Yes
6	7	No	Yes
7	3	No	Yes
8	4	No	Yes
9	3	No	Yes
10	3	No	Yes
11	0	Yes	No
12	0	No	No

13	4	No	Yes
14	5	No	Yes
15	5	No	Yes
16	4	No	Yes
17	3	No	Yes
18	3	No	Yes
19	3	No	Yes
20	2	Yes	Yes
21	3	No	Yes
22	4	No	Yes
23	2	Yes	No
24	4	No	Yes
25	5	No	Yes

Table 8: Functionality Test

As can be seen from the above test, there were only a few times where the treats were not successfully submitted. This was due to treats getting jammed, which were unjammed using the vibrating motor. At the beginning of the test, only one treat was dispensed because the dispensing disk was not fully loaded before beginning the test. It takes one or two activations before the device starts working normally after filling with treats. It can also be seen that the click module did not activate when treats were dispensed twice, but never when a treat was not dispensed, which meets the system requirements. Lastly, the treats do seem to dispense between 2-5 for the most part. This could be adjusted by modifying the dispensing disk plate. Based on this test and needing the device to dispense between 2-5 each time, the device was 84% successful as this happened 21/25 times.

The overall dimensions on the device are 36” from top to bottom, 12” at the widest width, and 6” at the deepest depth. The unit was ~3.5 lbs making it perfect for mounting onto a wheelchair without causing issue to the user.

IR Sensor Analysis

The sensitivity range of the IR emitter and receiver determines the sensor's accuracy in detecting the position and presence of the dog treats. The 5mm Gikfun emitters rays used in this project ranged from 700-940nm. These longer wavelengths mean that the infrared radiation is less scattered and offers better transmission through different materials. IR sensors were key components in both the Feedback and Treat Level Indicator Circuits.

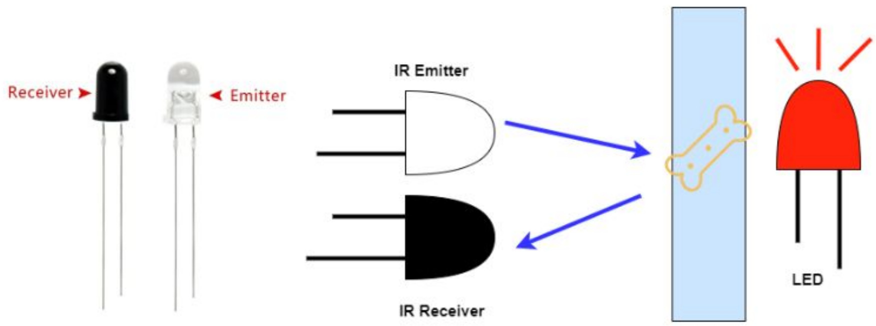


Figure 35 : Working Principle Of IR Sensors

Both circuits also included an LM358 op-amp that functioned as a voltage comparator and 10k ohm potentiometers that were used to calibrate the distance range at which the treats were detected. Since both circuits would be placed in a dark enclosure, a series of experiments were performed in a dark room.

Figure 36 : IR Sensors in Dark Room

The goal was to determine the sensitivity detection range of the IR sensors that would aid in choosing proper resistance values for the circuits. This was done by changing the value of the

potentiometer and measuring the voltage and current values of the emitter as well as the distance between the sensors and the object. After these experiments were conducted the resistance values that were required to set the sensors to detect an object at a specific distance were chosen.
The results from this experiment are shown in the Table 4 below.

Resistance (Ω)	Current(A)	Voltage(V)	Distance(cm)
500	0.185	5.96	17.8
550	0.183	5.92	17.2
600	0.176	5.9	16.5
660	0.177	5.86	16.2
700	0.099	5.86	15.65
750	0.081	5.84	15.25
800	0.08	5.76	14.35
850	0.062	5.78	14.12
900	0.062	5.43	13.75
950	0.055	5.36	12.35
1000	0.052	5.33	10.3
2000	0.027	5.27	8.6
3000	0.023	4.82	7.75
4000	0.02	4.73	6.25
5000	0.02	4.56	5.15
6000	0.02	4.52	4.75
7000	0.017	4.36	2.25
8000	0.009	4.39	1.5
9000	0.009	4.12	0
10000	0.009	3.92	0

Table 9 : IR Sensor Sensitivity Data

The graph below in Figure 37 shows the relationship between the resistance at pin 2 of the op-amp and the current. This shows that the current decreases as the resistance increases.

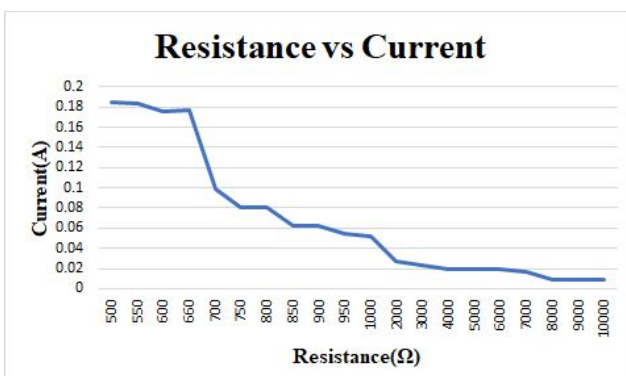


Figure 37 : Resistance vs Current Graph

The graph shown in Figure 37 demonstrates the relationship between the resistance of the potentiometer and the voltage of the emitter.

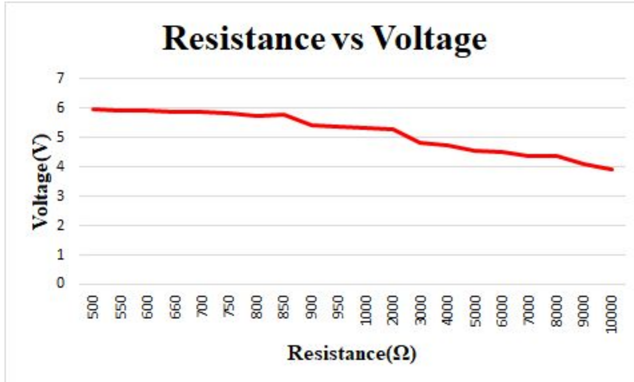


Figure 38 : Resistance vs Voltage Graph

The graph shown in Figure 39 demonstrates the relationship between the resistance of the potentiometer and the distance between the object and the sensors. This data was utilized to select and set the values of the potentiometer in both the Feedback and Treat Level Indicator circuits.

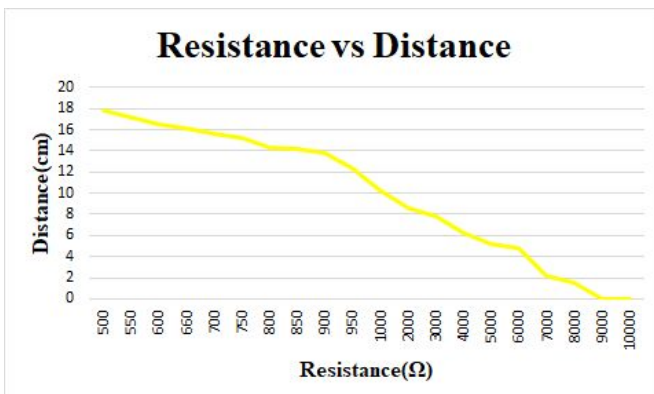


Figure 39 : Resistance vs Distance between Object and Sensor Graph

The 780 Ohm potentiometer shown in Figure 40 was used to ensure that a treat was sensed when it was about 15cm away from the sensors. It was also observed that accurate sensing was obtained when the emitter and receiver were placed as close as possible to each other which was around 1-2mm.

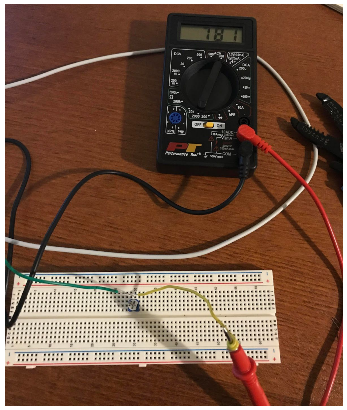


Figure 40 :780 Ohm Measurement

Ⅳ Project Administration

Analysis of Success

For the project team to properly assess the effectiveness of the design several use cases will be consisting of interactions with the dispenser. They should also anticipate how dogs will react before and after the dispenser operates. The project group also must ensure that the dispenser can vary how many treats it disposes of the dog to ensure that the owner's interaction with the service dog is reflected properly. Per Dr. Neuber's information this is important that the original training the owners received can be done with this dispenser without much fault.

Experimental Plan #1 objective will be to have the device dispense any number of treats from the container that holds the treats to the dog bowl mounted onto the wheelchair. The components of this testing case will be a stopwatch, measuring device, and dog treats. Time is important in this first experiment as it tests how long it takes for user input to be relayed and how the service animal reacts to the outputted dog treat. Time from this experiment will be logged for each service animal tested with to ensure that the response received from these animals is not unique. There will be a heavy focus on ensuring that the device is able to dispense a single treat before proceeding into follow up experiments. Both time and observed behavior will determine whether or not the base design would need to go under refactor or not. One thing to note is that jamming in the dispense step may cause the device to malfunction and third party will be ready to provide treats to the dogs in the event the device fails. A scatter plot chart will be used to compare the time observed for a treat to drop and a bar graph will be used to measure the success and failure of the device. Success will be evaluated if consistency across multiple service dogs is reached and the customer who is leveraging the device believes that it was easy to use.

Our second experiment will then focus on variable user input. Our goal with this design is to ensure that a service animal owner can control how many treats the device can output per run. The project team will leverage a measuring device, a stopwatch and dog treat like in experiment one. The testing aspect will be the variable inputs that the owner will perform. The data that the group will collect is whether the device outputs the correct number of treats, how long did it take to drop the right amount, and whether the dog had responded as it normally would when given that amount. There will be a heavy focus on ensuring that the time between input and output is kept as low as possible while ensuring the proper number of treats matches what the user had requested for. Time will be evaluated on each run to ensure that there are no unique cases based on the service animal or the operator. The device that is being used to input these treats will be independent of the device that is dispensing it as the input device will have the same input connector that is standard for those with mechanical disabilities. A scatter plot chart will be used to compare the time it took for the treat to dispense depending on what the user has inputted. Each input value will have its time compared appropriately while a companion bar graph will demonstrate the successes and failures of the trial runs. If it is determined that the device is constantly outputting the incorrect amount of treats the design team will need to refactor the method of dispensing the treats. Success will be determined when variance on dropped treats reaches zero and the service animal owner's user input is properly matching what is being sent to the dispensing device.

Cost Analysis

MCU Cost Analysis

ITEM	LINK	COST ($)
1x A2D Converter	Amazon	4.5
RaspBerry Pi Zero W	Microcenter	9.99
Raspberry Pi GPIO Header	DigiKey	1.99
Servo Motor	RobotGear	11.95
Vibrating Motor	Amazon	8.99
Hall Effect Sensor	Amazon	6.99
Magnet	Amazon	6.99
Gumball Machine	Amazon	27.43
1k ohm Resistor	Amazon	1.00
MPS2222a Transistor	Amazon	1.00
Mono Jack Input	Amazon	8.45
IN4148 Diode	Amazon	1.00
IR Sensor PCB + Components	(See PCB Below)	28.58
Buck Converter	Amazon	2.00
Micro SD Card	Amazon	6.19
12V Power Supply	Amazon	23.96
MAX98357 Amplifier	AdaFruit	5.59
	Total Cost:	156.60

Table 10: Cost of MCU

Analysis of MCU Variant

For the senior design project the group was tasked to create two variants of the same solution with one implementation based on a microcontroller. To ensure that behavior between the two solutions was mirrored properly the design group created a high level workflow diagram of how both solutions would behave in the overall circuit. The RPi has plenty of sample code snippets available on vendor websites and GitHub repositories to allow us to integrate with the Raspberry Pi.

PCB Cost Analysis

OSH Park is a community printed circuit board (PCB) manufacturer that produces high quality, lead-free boards which are manufactured in the United States and shipped for free to anywhere in the world. All of the PCB files for the Treat Dispenser can be found here http://treatdispenser.onmason.com/pcbs/.

Printed Circuit Boards		
Item	Quantity	Price
Servo Control PCB	3	$4.75
Feedback PCB	3	$6.35
Sound Module PCB	1	$11.49
Treat Level Indicator PCB	3	$12.70
	Total Cost ($)	**$35.29**

Table 11 : PCB Manufacturing Cost

PCB Components Cost Analysis:

Servo Control PCB Components		
Item	Quantity	Price
Servo Motor	1	$2.00
NE555 IC	1	$0.95
BC547 NPN Transistor	1	$0.50
220 Ohm Resistor	1	$0.35
1k Ohm Resistor	2	$1.18
10k Ohm Resistor	1	$0.18
47k Ohm Resistor	1	$0.30
0.01u Farad Capacitor	1	$0.31
1u Farad Capacitor	1	$0.48
100u Farad Electrolytic Capacitor	1	$0.91
Mono Jack Input (Female Port)	1	$0.20
	Total Cost ($)	**$7.36**
	Total Cost with PCB ($)	**$12.11**

Table 12 : Servo Control Module Components Cost per Board

Feedback PCB Components		
Item	Quantity	Price
IR Emitter and Receiver Pair	1	$0.60
50k Ohm Potentiometers	1	$0.44
220 Ohm Resistor	2	$0.35
10k Ohm Resistor	1	$0.18
BC547 NPN Transistor	1	$0.50
LM358 IC	2	$0.72
Icstation Recordable Sound Module	1	$11.49
Vibrating Motor	1	$7.99
	Total Cost ($)	**$22.23**
	Total Cost with PCB ($)	**$28.58**

Table 13 : Feedback Module Components Cost per Board

Treat Level Indicator PCB Components		
Item	Quantity	Price
IR Emitter and Receiver Pair	2	$1.20
10k Ohm Potentiometers	2	$0.90
LM358 IC	2	$0.72
NE555 IC	1	$0.95
BC547 NPN Transistor	1	$0.50
5mm LEDs	2	$0.18
220 Ohm Resistors	5	$0.88
10k Ohm Resistors	3	$0.54
47k Ohm Resistors	1	$0.30
100u Farad Electrolytic Capacitor	1	$0.91
0.01u Farad Capacitor	1 ni	$0.31
	Total Cost ($)	**$7.39**
	Total Cost with PCB ($)	**$20.80**

Table 14 : Treat Level Indicator Module Components Cost per Board

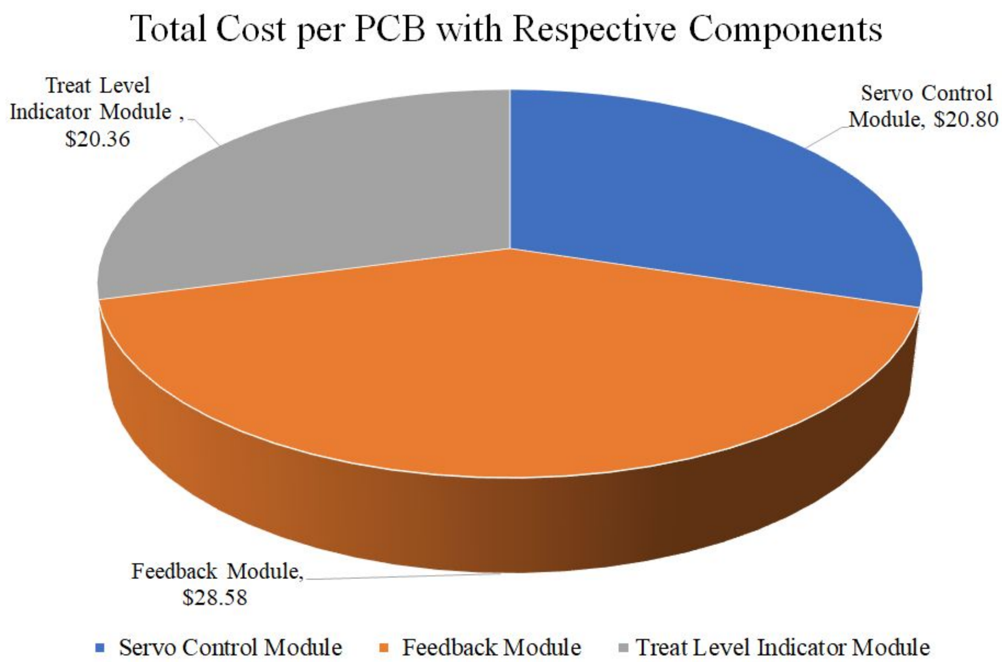


Figure 41 : Total Cost per PCB with Respective Components

Figure 41 shows the cost of each PCB with its respective components. All of the PCBs were sized to be as small as possible to reduce costs and to reduce the amount of space the PCBs took up in the dispenser. All of the PCBs were designed by the team with the exception of the Icstation Recordable Sound Module which was purchased on Amazon [13].

Total Cost of the Treat Dispenser Housing:

Item	Cost
Clear Plastic Container (Popcorn)	2.49
SS Corrugated Pipe	14.98
gumball machine	20.00
3/4" male adapter	0.45
3/4" pvc	1.46
3" x 1.5" pvc funnel	3.48
1.5" pvc female adapter	1.18
1.5" PVC Pipe	3.56
3/4" 45 Degree Elbow	1.14
3/4" adapter	1.04
Clear Plastic Storage Container	5.48
6" all thread	0.98
3" All Thread	0.43
SS L-Brackets	1.29
SS Ball Bearings and Clamp Brackets	10.00
4" x 4" PVC Box w/ 3/4" in/egress	6.00
Velcro Straps	2.00
3" PVC End Cap	2.59
Misc. Hardware	5.00
Total	**83.55**

Table 15: Treat Dispenser Cost

Man Hours Spent

Adam Dost:

Servo Research and setup: 10
Servo Timing: 2
A2D Converter: 20
Weekly Meetings: 40
Group Working Sessions: 24
Feedback Integration: 15
Technical Manual Documentation: 30
Total: 141

Gage Moore:

System Design: 20
System Integration: 15
Software: 35
Testing: 7
Circuit Study/Design: 5
Sensor Study: 7
Breadboarding: 5
Weekly Meetings: 40
Group Working Sessions: 24
Total: 158

Jachan Shrestha:

555 Timers Study: 5 hrs
Sensors Study: 5 hrs
Circuits Study: 20 hrs
Circuit Simulations: 15 hrs

Breadboard Circuit Analysis: 25 hrs
PCB Designs: 40 hrs
Weekly Meetings: 40
Group Working Sessions: 24
Prototype boards soldering: 6
Total: 180

Robert Wignall:

System Design: 10
System Integration: 10
Testing: 10
Circuit Study/Design: 20
Soldering: 10
Manual Documentation: 20
Housing Construction/Testing: 40
Weekly Meetings: 40
Group Working Sessions: 24
Total: 184

Zainab Abdullahi:

555 Timers Study: 3 hrs
Sensors Study: 10 hrs
Circuit Simulations 10 hr
Circuits Study: 18 hrs
Breadboard Circuit Analysis: 20 hrs
PCB Designs: 30 hrs
Weekly Meetings: 40
Group Working Sessions: 24
Total: 155

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Appendix A : Proposal Document

Executive Summary

Currently, 15% of the world's population suffers from some sort of disability. Of that 15%, 4% suffer from an advanced disability such as cerebral palsy and multiple sclerosis [1]. Many of the people who suffer from such diseases are wheelchair bound and use a service dog in order to assist them in their daily lives.

While their service dogs are fully trained upon reception, the dogs must go through yearly tests in order for them to keep their certifications up to date [2]. To keep the dogs well trained, they must be constantly exposed to the training conditions to help them remember their "tricks." Due to the high cost involved with training the service dogs, most owners would prefer to train the dogs themselves, which normally involves some sort of reward for the dog (e.g. a treat). This presents a problem for people suffering from disabilities; they are not able to complete certain tasks easily such as rewarding their dog because of their disability.

This project intends to correct this problem by developing a treat dispenser that will work with a variety of wheelchairs and will comprise of a universal input for plethora of input devices to activate the treat dispenser, such as a switch or a button. The treat dispenser will also be small enough so the wheelchair in which it is mounted on can fit through doors and will not impede the functionality of the wheelchair. A highlight of this project will be the ability to recreate the dog treat dispenser from relatively household items. This will allow the treat dispenser to be cheap and will be able to serve a multitude of people in ne

Problem Statement

The wheelchair is one of the most commonly used assistive devices for increasing and enhancing personal mobility, which is a necessity for being an independent and productive member of society. There are many conditions and afflictions which may result in the need of a wheelchair such as multiple sclerosis, cerebral palsy and muscular dystrophies. Disabled individuals who are wheelchair bound and accompanied by service dogs account for .9 percent of the U.S. population [1]. These highly trained canines can provide independence to their owners and significantly enhance their quality of life. These dogs can complete a wide range of tasks from opening doors, retrieving dropped items and pushing their partners up ramps. These dogs are an integral part of these individuals' lives and must go through extensive training to earn this role [3]. In order to achieve maximum performance from these dogs, frequent rewards in the form of verbal affirmations and treats are required. Rewarding the dog is essential. It not only increases the emotional relationship between the dog and the owner but most importantly, provides the dog with much needed positive reinforcement.

This project was undertaken at the request of The Service Dogs of Virginia, a non-profit organization that raises, trains, and places dogs to assist people with disabilities due to the failure of several designs that have attempted to ameliorate the burden to create an effective standard of assistance. The main challenge users who have limited or no hand mobility at all is giving the dog a treat. There have been several great ideas and attempts to create an adaptive treat dispenser that could be integrated seamlessly to a wheelchair, but there are none that are commercially available as of today nor patented for this use. Despite the numerous attempts made to make this merchandise commercially accessible to the public it has failed repeatedly due to design limitations such as; the dispenser being too large to be seamlessly embed into a wheelchair as well as there being malfunctions with getting the dispenser to release the desired number of treats appropriately. While there have been few designs that have overcome these setbacks, they too have proven to be futile as a result of the dispenser bowl being too small, and fiscal challenges due to the expenses of printing and dipping into a food safe coating.

Need for Redesign/Prior Art Analysis

Currently, there is a need for an improved dog treat dispenser. The available prior art is limited by several factors such as being bulky, cumbersome, mechanical, non-food safe, and not adaptable to a wheelchair. Many handicapped people suffering from advanced disabilities do not have the dexterity as people without disabilities do. This leads to a need for a new design in order to meet their needs.

For example, one of the closest designs currently available is a 3D printed wheelchair treat dispenser [4]. This design is based off a mechanical design in which the user will move a lever in order to activate the dispensing of a treat. As previously mentioned, while this design would be suitable for a person that can actuate a lever, many who suffer from advanced disabilities such as cerebral palsy is unable to do this. The need for an electronic button would be more suitable for such a person who may only be able to move their head in a certain direction or lacks the coordination of their appendages.

Another example would be an “Animal and Food Treat Dispenser” [5]. This design lacks the ability to adapt to a wheelchair as it is cumbersome, has a very small rotational wheel in order to dispense a treat, and can only use a rectangular style treat. There exists a plurality of problems with this design that would not be suitable for a person with an advanced disability. Furthermore, “Treat Dispenser,” “Dog food Dispenser,” “Automatic Feeding Device,” “Pet Feeder for a Handicapped Pet Owner,” and “Dispensing Machine” all share the common characteristic of being too large to fit on a wheelchair, as well as having the inability to dispense a treat electronically [6-10].

The need for a generic switch to activate the dispensing of a treat is clearly needed for people with advance disabilities as they will be able to use a switch, button, or other form of activator that they already utilize in everyday life to complete tasks. In addition to the proposed design to have a generic switch input, it will also be electronically controlled to remove the need for a mechanical input to dispense a treat. This will allow people with advanced disabilities to train their dog in order to comply with the testing requirements to keep their dog "in service."

Upon reading the available prior art, there is no indication that our proposed design will infringe on any of the prior art. While there exist a few key elements such as a rotational food compartment, a tray portion, and a button, none of the elements in combination with our design would infringe on existing patents [11-13]. As all the designs lack the use of a circuit and/or microcontroller to activate the dispensing of a treat coupled with an adaptable size food storage area that is mountable to a wheelchair. Thus, based on our review there exists novelty within our design.

<u>Approach</u>

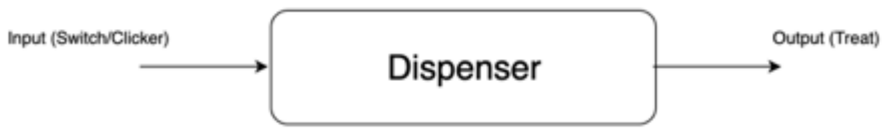


Figure 1: Basic Design with Input and Output

Problem Analysis

The customer has demonstrated earlier versions of the automatic treat dispenser and discussed the flaws of those previous designs. In an attempt to overcome all these issues with previous designs, the following will be considered.

A. Design being too big

Almost all the doors in households or public places in the U.S. pass the bare minimum requirement for Americans with Disabilities Acts (ADA) which means wheelchairs narrowly manage to pass by. With the previous design being too big, the mobility of the wheelchairs was limited, which dissuaded the users to install the dispenser.

Customer suggested design to be mounted on the side or back of the wheelchair with long enough tubes to allow the treats to be dispensed where needed. This will allow the width of the wheelchair to not be modified.

B. Hard to reproduce

Customer requested the design to be easy to reproduce, which means finding the parts and assembling the device must be easy to ordinary person with very few to no engineering skills. All the previous designs used microcontrollers (especially Arduinos) for controlling the dispenser, which required a certain degree of programming skills to reproduce the design. Some of the designs also relied on the use of 3D printed material for custom parts, but this was found to be too expensive, time consuming, and not to be food safe.

Customer requested the design to be easily reproducible (i.e., people with no programming skills would be able to build the dispenser following simple instructions). The parts for the design should be easily found in the market and food safe for all portions of the design. Faculty Supervisor suggested the use of 555 timer as an alternate to the use of microcontrollers. This would allow the circuitry to be implemented on a simple printed circuit board (PCB) with slots labeled for required components, providing a Lego-type build.

C. Difficulty in getting right number of treats to dispense

Customer stated the problem in dispensing a consistent number of treats every time in some of the preliminary designs. The dispenser should never dispense more than 3 treats at a time as this could lead to over-treating the service dog and causing negative behavior from the service dog in time [3].

D. Must work for people with disabilities

Our target users of this device are wheelchair bound people who have limited mobility of their body parts such as head, hands, legs or fingers. The design should be simple enough to dispense the treat at the click of a button or flip of a switch of the user's liking. This will require a universal mono-jack input to the device.

E. Durability

The dispenser should be durable and weatherproof. Since a wheelchair provides mobility, the dispenser must handle the vibrations from travel, as well as work in inclement weather. The dispenser should be strong enough to handle knocks from service dogs, people, and getting bumped while the user navigates through narrow areas, which requires strong mounting.

F. Material Selection

Customer requested to use food safe materials for the dispenser to avoid any health-related hazard. As mentioned earlier, most of the previous models used 3D printed parts which possess health risks to the service dogs as bacteria can build up in crevices between printed layers. A smooth surface should be used.

G. Jamming problem

Customer noted jamming problem with some of the earlier designs. The treats are jammed in the dispenser or the parts of the machine are stuck.

Approach

The automatic treat dispenser will need to consider all the design flaws from previous dispensers in order to provide a working solution to the customer.

A. Body

The body of the dispenser shall be compact so as not to obstruct the mobility of the wheelchair. It will be fitted with a universal wheelchair mount to accommodate different sizes of wheelchair. It will be designed to activate as normal in all kinds of weather and shall be sturdy enough to handle the wheelchair vibrations, and bumps. Readily available material will be used for the main body of the unit. The parts that come in contact with the treats will be food friendly (e.g., stainless steel).

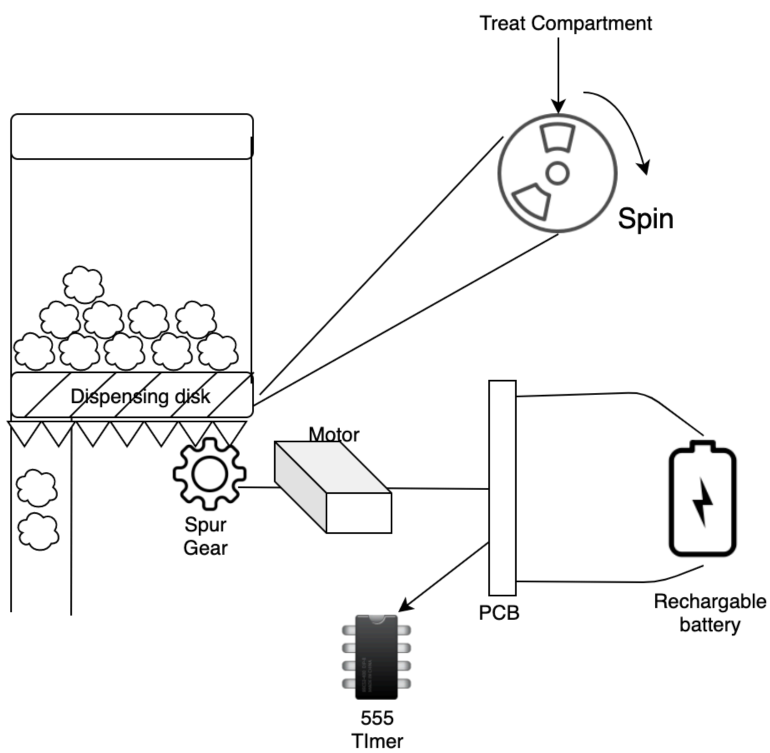
B. Input

The input to the dispenser will be a physical touch button with a mono signal. The team shall primarily focus to design a dispenser that dispenses the consistent number of treat every time on a single click on the button. It shall be designed with self unjamming mechanism to avoid treats getting stuck by using some type of vibrator. The team shall also work on different input/activation method for the dispenser like RC signals, accelerometer.

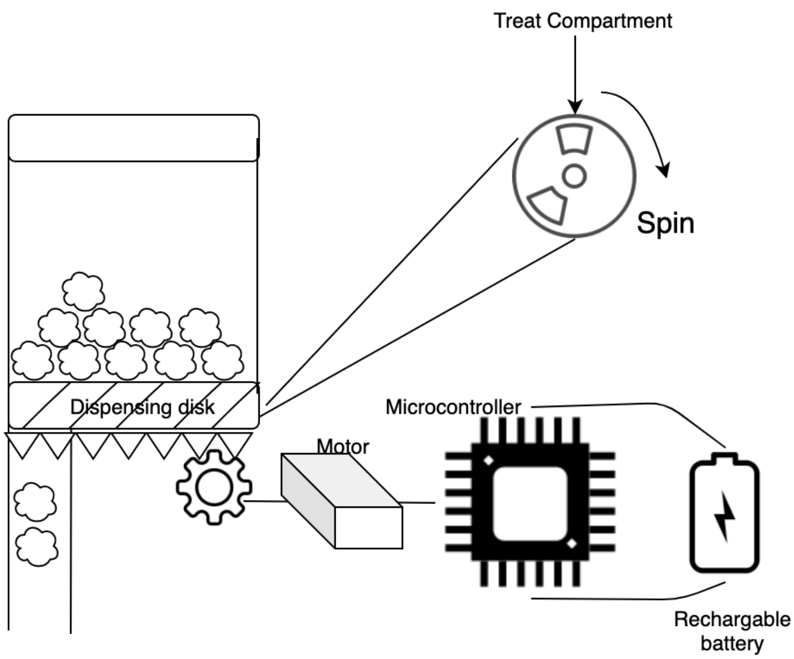
C. Output

The dispenser should output the click sound used for service dog training as well as the dispensed treats to the holding tray mounted on the wheelchair. The reason for adding the click sound is to attract the service dog and ensure that they can use the device appropriately. It also provides a verbal cue to the user that the dispenser activated correctly.

Dispensing Mechanism Design 1A (Conceptual Team Model)

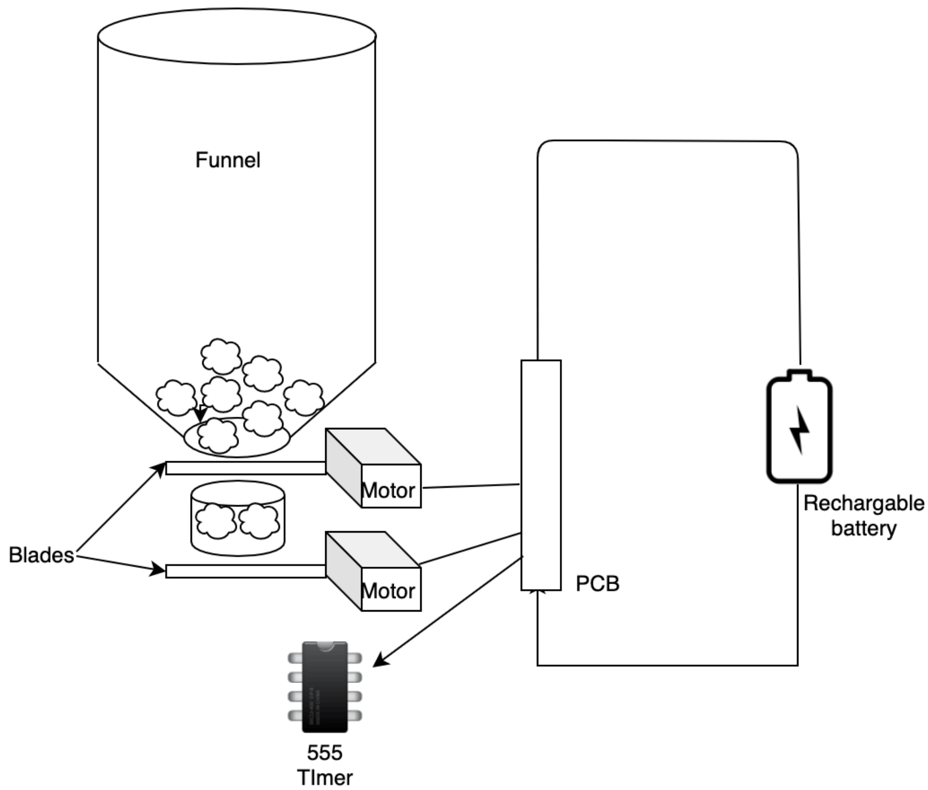


Dispensing Mechanism Design 2A (Conceptual Team Model)

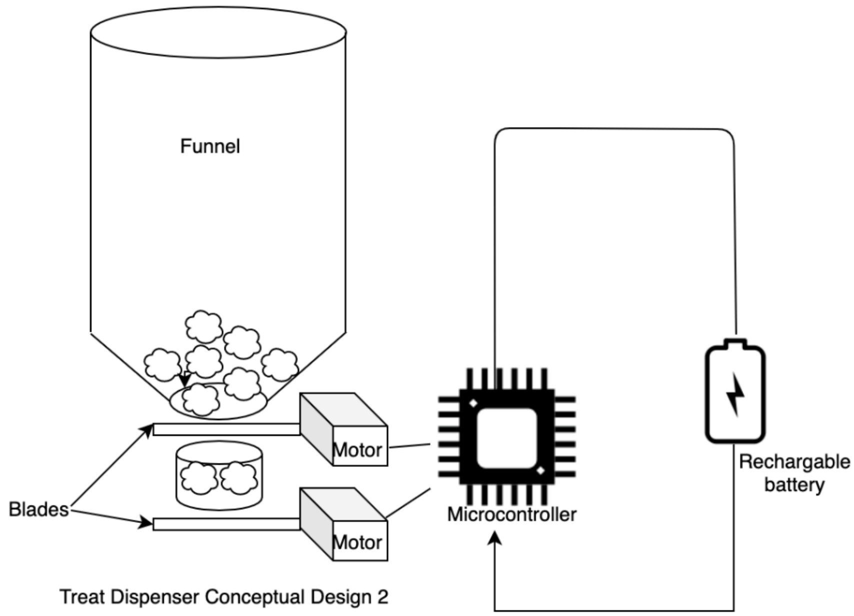


This design has a dispensing disk fitted at the end of a pipe. The dispensing disk is designed with gear teeth on the edges for the rotation of the disk. The rotation of the disk is controlled by the spur gear fitted right next to the disk. One rotation of the spur gear dispenses 2-3 treats at a time. Spur gear is powered by either a dc motor or a servo.

Dispensing Mechanism Design 1B (Conceptual Team Model)



Dispensing Mechanism Design 2B (Conceptual Team Model)



In our alternate design, the dispenser has a funnel that holds the treats to be dispensed. Dispensing will be controlled by two blades fitted right beneath the funnel and the treat measurement pipe. The motors that move the blades are fetched instructions from PCB board which takes input from the user and is powered by a rechargeable battery.

Introduction to background knowledge/phenomenology supporting the project

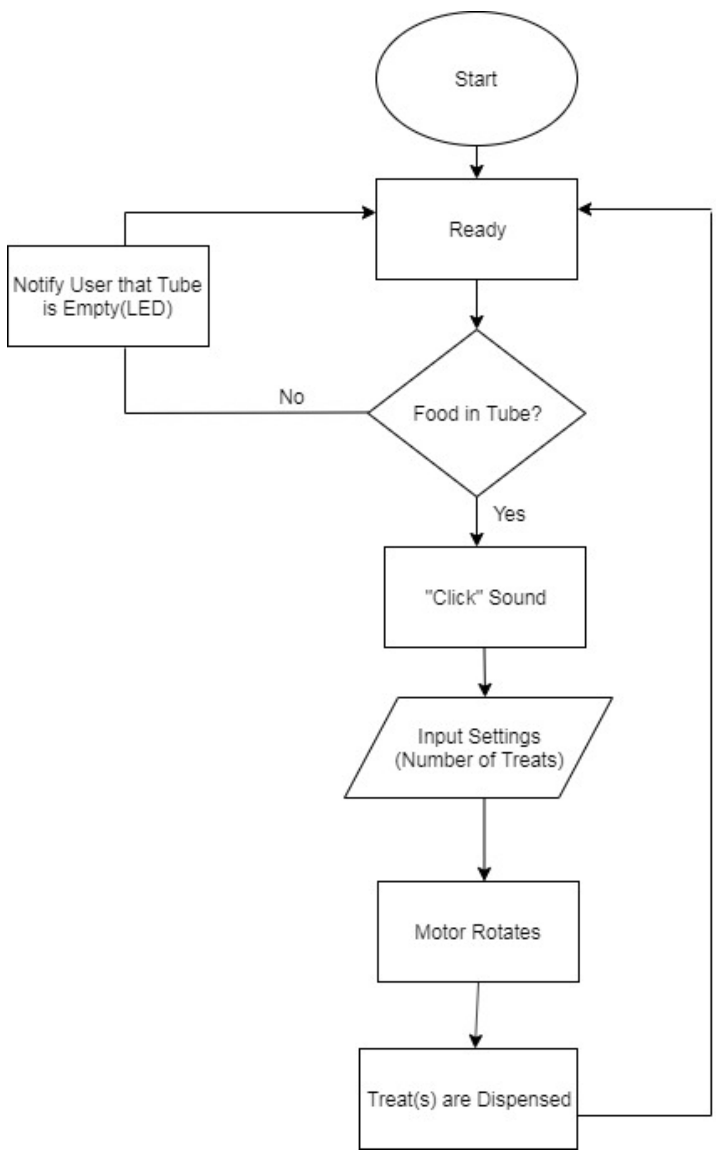
This project will require a considerable amount of time and effort from all the members of the team. Our team has created the conceptual designs that will satisfy all the requirements of the project. Next step is researching on the parts that will be used together for building the design. Our goal is to find the parts that can be easily found on the market and bring it together to build the design. Moving on, the project will require the circuit building skills of the team. Our team will work closely in building the circuit and designing PCB for the project. To keep the simplicity in the design, our team shall restrict the use of microcontroller and use 555 timer or other forms of controllers. After the PCB is manufactured and the parts are decided, the project group will work on housing the parts and finally mounting the device to the wheelchair.

Product Testing

Once two of the most promising designs are complete, the treat dispensers will be tested thoroughly in a lab to ensure that it works as needed. Once confidence is put into the designs, they will be tested by multiple wheelchair bound individuals and their service dogs to measure the devices' performance, quality and safety standards. The device will be tested to verify the requirements of the specifications. The device shall be tested to determine if it solves the current problems faced by the customer. The device will also be tested to identify any potential cost savings for the production. The team will then work on to troubleshoot any problems encountered or modify the designs if required. The team shall keep its eyes on how the device is performing functionally for consistent dispensing.

Microcontroller Design

The motors and switches of the dispenser require some means of control. The controls for Design B will be done through software written for a Raspberry Pi controller, the exact version will be decided on later. The Raspberry Pi will control the user interface, the motors, the number of treats dispensed and accurate dispensing through a distance sensor. An embedded system, such as the Raspberry Pi will allow greater variation in the setup and usage of the input/output mechanisms and the changes the user makes to the standard operation. The programming "pseudocode" of the Pi can be broken down into a flowchart. The system accepts the users input through a click of a button or movement of the head. The system will then check if there are treats to be dispensed in the funnel. If the funnel is empty the system will alert the user by the blink of an LED (preferably red). If there are treats, the system will output a “click” sound and the treats will be dispensed. Additionally, the user will have the option to choose the number of treats dispensed. MC1 below demonstrates how the Microcontroller is expected to behave in the dispenser.



MC 1

Treat Dispenser Project Requirements

Mission Requirements:

The device shall assist people with disabilities in wheelchairs by providing them a method to treat their service dogs.

Functional Requirements:

1. The device will hold up to at least a cup of treats at a time to provide rewards for the service animal throughout a day's time.

2. The device shall use an accelerometer-based control input so that someone with limited physical abilities will still be able to operate the dispenser.

Operational Requirements:

1. The device will operate while mounted on a wheelchair.

2. The device shall be vertically fitted onto the wheelchair to ensure that the device can operate properly, and the owner of the wheelchair can still fit through the same spaces.

3. The device will dispense varying number of treats depending on the operators input.

4. The device shall have a self-healing method of unjamming itself to ensure that it can dispense food without much assistance from the owner or other party.

6. The device must be easy to clean

Input / Output Requirements

1. The device will accept input from the operator. The physical input device will vary, however, the interface with the primary device will be consistent no matter what.

2. The device will accept dog treats into a storage container inside the device.

3. The device will output dog treats through a pipe system that will deliver the food to a food tray.

Technology:

1. Shall use some electrical timers

2. Shall use some form of pipe to move food from storage to destination.

3. Shall use some form of circuit coating or hardening to ensure durability.

Preliminary Design

The automatic dog treat dispenser must implement a design that is robust while being sleek and lightweight. Since the treat dispenser is installed on a wheelchair, it cannot interfere with the normal operations of the wheelchair, nor limit locations that the user can go in the wheelchair. It must be low profile and able to mount anywhere with adjustable tubes to accommodate a low or a high mounting of the device. The device will need to be rechargeable battery powered to work autonomously from the rest of the wheelchair. It cannot be responsible for draining the wheelchair's power as there are more important functions of a wheelchair than a dog treat dispenser.

The dog treat dispenser should integrate seamlessly with the end user's switches/buttons using a 3.5mm mono-jack as connection. This connection will simply need to close a circuit to trigger the dispenser when activated and remain open otherwise. The project will also include the creation of a switch using accelerometers or some other method (perhaps using fiber and detecting vibrations due to movement). This portion is still to be discussed and can be further investigated once the main treat dispenser has been completed.

There are four main areas for the automatic treat dispenser: the dog treat storage compartment, the treat staging and dispensing area, the circuitry and mechanism to activate the treat dispenser, and the treat deployment tube.

Treat Staging and Dispensing Area:

The treat staging and dispensing area influences what the mechanism to activate the treat dispenser should be, as well as the dog treat storage compartment. The dog treat storage compartment feeds directly into the dog treat staging and dispensing area, and the circuit has to work for whatever mechanism is established, so the design must start here. There are three styles of dispensers to be evaluated: gumball machine style, Ferris-wheel style, and stopper style.

1) The gumball machine style consists of a horizontal, circular plate that spins on the axis perpendicular to its center with cut outs to drop the treats through a hole when they are to be dispensed. This plate would have three to four openings around the outside that are just large enough to hold two to three treats side-by-side.

   This spinning plate would then sit on top of another plate that has only one hole in it the same shape as the openings in the spinning plate. This plate would be static and should be able to line up with one of the openings in the spinning plate at a time. There would then be one more plate above the spinning plate with an opening that is large enough to let treats filter into one or two of the openings on the spinning plate at a time. The opening would have to be offset from the opening of the bottom plate and towards the start of the rotation after the bottom opening.

   These three circular plates would be at the bottom of the dog treat storage compartment so that all the treats sit on top of them and can be filtered in as the spinning plate is activated.

   The spinning plate should turn 1/3 or 1/4 of a full spin at a time (depending on how many openings) and have an opening line up with the opening in the bottom plate each turn.

   Thus, the treats are loaded into the spinning plate one or two openings at a time and then dispensed one opening at a time for each activation. The number of openings will have to be tested to determine what works the best and provides the most consistent results.

2) The Ferris-wheel style consists of a design similar to the gumball machine style, but the mechanism spins vertically instead of horizontally. With this design, only one plate is required. Around the outside perimeter should be pockets/compartments large enough to hold the two to three treats needed at a time. These compartments would have openings that face outward from the center axis of this spinning wheel.

The wheel with compartments around the perimeter would sit inside a round cover that is just large enough to allow the wheel to turn within it. This cover is to keep the treats inside the compartments as the wheel turns. The cover would have one opening at the top and the bottom that are the same size and would line up with the compartments on the wheel.

Again, this wheel would sit below the dog treat storage compartment and treats would filter in one compartment at a time. As the wheel turns, treats are dispensed at the bottom of the wheel one compartment at a time.

This wheel would have four compartments around it so that at any time, one compartment is being loaded with treats, one is loaded with treats and waiting to be dispensed, one is being dispensed, and the other is empty. This way, the wheel only has to make quarter turns each time. Half turns could require too much effort and shorten the life of the electronic mechanisms to be used.

3) The stopper style dispenser employs two stoppers: one to help stage the treats, and one to dispense the treats. The dog treat dispenser should dispense quickly, so the treats should be ready to go when activated. Thus, with this style, there should be one activation when first used where the dispenser is loaded, and no treats are dispensed.

There would be a space between the two stoppers that is enough to store and stage the two to three treats that need to be dispensed. To keep the dispenser's size as small as possible, it makes sense to have the treats staged vertically between the two stoppers. Thus, there should be a tube between the two stoppers slightly larger than the diameter of a dog treat.

When the automatic dog treat dispenser is activated, the bottom stopper is removed from the tube first, allowing the treats that are staged to drop and be dispensed. This should open long enough to allow up to three treats to drop and then close shortly after that. Once the bottom stopper is back in place in the tube, the top stopper is removed and treats from the dog treat storage compartment are able to fall into the staging area. This should be removed long enough for three treats to fall in, and then close.

There is a potential hazard with this design in that the top stopper will not be able to go back in place in the tube if a treat falls in the place it should be in. Thus, this top stopper should have a blade on it and be strong enough that it could cut through a treat or break apart a blockage.

The stoppers and tube must all be in an enclosure so that dog treat crumbs do not fall out of the dispenser as the user is wheeling around. There will also be a gasket around the edge of the stoppers to create a seal when in the tubes for the same reason. Unintentionally dispensed crumbs or treats could lead to negative behavior in the service dogs

All of these designs are susceptible to jamming, and dog treats can sometimes get sticky in humid areas, so preventative measures must be taken. These measures can be taken within the dog treat storage compartment.

Dog Treat Storage Compartment:

The storage area for the dog treats needs to work with whichever dispensing method above is chosen. Each will require a slightly different storage compartment to sit above the dispensing mechanism so that treats are fed into the staging area correctly. Each will require the same construction, however.

The storage compartment will have smooth, easy to clean surfaces, and to be detachable for cleaning. The material used will need to be food safe. It should also be transparent or translucent enough for the user to see the amount of dog treats still available at any time. The bulk of the storage compartment can be made of food safe plastic or Tupperware type container. The compartment will be slim and wide to hold at least a cup of dog treats at a time and ensure the wheelchair's profile is minimally impacted.

All storage compartments should have a funnel type bottom to feed the staging area of each dispensing mechanism with dog treats. Though each style would be slightly different, the overall design is the same. The funnel will have sharp enough slopes, so the treats do not get stuck.

The dog treat storage compartment will also have an internal vibrator that activates when the automatic treat dispenser is activated. This is to help ensure that the treats feed into the staging area and jams are broken free. The vibrator can be attached to the outside of the storage compartment.

There will also be a hinged lid on top of the storage compartment with an easy to use latch/clasp for simple refills. The lid will have a seal to make sure the dog treats do not spill out the top of the compartment.

The dog treat storage compartment will be the largest part of the dispenser so it will also have a flat face with some mounting tabs to make it easy to mount anywhere on a wheelchair. The storage compartment will need to be tightly secured to the dispensing mechanism and the rest of the treat dispenser so that no other mounting points will be needed.

Below is a summary of the materials that were evaluated to act as the storage container for the dog treats. One of the key requirements for this storage container was that it must be safe to store food in and below are the results of our findings.

Materials Report

Materials	Properties	Use in project
3D printed	Cheap depending upon the type of material, color, tolerance and quality used [14]. Strong and can be printed as desired. Used widely in casing and parts. Materials like PLA and ABS are cheap and ranges from $15-$20 per kg, while Nylon and Soft PLA are much more expensive.	Could be used to case the final design of the project. CAD 3D designs can be easily modified before the production.
Plastic	While Plastic casing might sound like 3D printing, there are many companies that produce plastic enclosures for electronic enclosures [15]. Enclosures are cheap ($1-$10) and can be cut or modified to fit the casing needs [16]. Tough and weatherproof.	Could be used to case the final design of the project.

Wood /Homemade	Commonly used plywood is easily available in the nearest home depots and can be cut into desired shape and size even by people with no skill.	Could be used to case the final design of the project. MDF are cheap and will keep the cost down. PINE could be used to add quality to the project.
Metal (aluminum)	Enclosures are readily found in the market. Ductile, soft and malleable.	Could be used to case the final design of the project.

Motors	Properties	Use in project
Servos	Precise movement, cheap, easily available, different sizes available. Can easily be paired and controlled with Raspberry Pi or MSP430. Operating voltage 4-10v, excellent torque at high speed (130RPM) [17].	Controlling mechanical movement
Brushed/ Brushless DC motor	Less noisy, easily available with various power options, smooth motion, simple to control.	Controlling mechanical movement
Stepper motor	Slow and precise movement, good torque at low speed, noise, low efficiency [18].	Controlling mechanical movement

Casing needs to be strong and rigid. While plastic and metal are mostly weatherproof, wood can also be coated to make it waterproof [19]. Readily available plastic and metal enclosures are preferred; however, wood is also a good option to enhance decorations or add quality.

Circuitry and Activation Mechanism:

The circuitry in all three design styles will require the use of a timer circuit. This timer circuit will need to activate a motor for long enough to spin the mechanisms in the first two cases and also work out the timing between the two stoppers in the third case.

The circuitry in the first two cases will require a motor to spin the plate/wheel far enough to dispense the treats. The motor speed will be used to time how long it takes for it to spin the plate/wheel to the correct position and the timer circuit will have to be built accordingly to keep the motor activated for that amount of time [20].

Another method would be to use limit switches that are bypassed when the device is activated and then activated right after so that the device stops when a limit is reached. These can be user adjustable for troubleshooting purposes [21].

In the third case, there will be two motors that need to be timed the same from opening to closing [22]. There will also need to be a timer between the two stoppers so that adequate time is allowed between the treats dispensing and the next set of treats being staged. The timing required between will need to be at least two times the amount of time the bottom stopper takes to operate in order to allow the staged treats to drop before the next treats are staged.

The circuitry will be installed within a sealed container to protect the components from damage. The PCB will be designed so components can be easily replaced and will be mounted on rubber mounts to protect the circuit from vibration damage [23]. All connections will be solid enough for a long life under normal use.

The circuit will have a 3.5mm mono-jack input to activate the circuit (in place of the shown input switch) and will be rechargeable battery operated for autonomous operation. The 3.5 mm mono-jack will be the connection point for the switch of user's choice. The circuit itself will look at this portion as a simple switch that closes the circuit when the switch is activated. The lower right circuit depicts the activation circuit. When a button/switch is pressed, it will keep the circuit on for a specified period of time (via the time constant of the 1000uF capacitor) and will turn off the circuit when the capacitor is discharged.

The upper right circuit is the circuit that controls the motor speed. As previously mentioned, it will use a 555-timer chip to create a Pulse Width Modulation signal to drive the motor [24], [25], [26], [27]. This will spin the motor/servo in a direction (e.g. clockwise or counterclockwise) in order to actuate the dispensing mechanism.

An accelerometer type switch will also be investigated as a method of activating the treat dispenser. This device would be wireless for easy use and help those individuals that lack any kind of dexterity. A simple nod could be enough to trigger the accelerometer and activate the treat dispenser

The circuit might also include a small speaker that emits the dog training clicker sounded to pique the interest of the service dog.

Dispensing Tube:

The Dispensing Tube would be the simplest part of the dog treat dispenser. It will consist of a tube that allows the dog treats to easily slide through, and a tray attached at the bottom that will catch the treats and provide a constant location for the service dog to go to for the treats. The tray will be constructed of stainless steel or some hard plastic that will last with constant use by the service dog. It will be big enough for a large service dog's nose to fit in so that it accommodates as many service dogs as possible. The tray will also have provisions for mounting it to a wheelchair, though these mounts will not be responsible for any of the device's weight. It will simply help to hold the tray in place and ensure the treats are dispensed to the tray.

The dispensing tube will be tightly attached to the bottom of the dispensing mechanism and should be only slightly larger than the opening the treats will be dispensed through. The tube will be flexible so that the storage compartment and dispenser portion can be mounted in a variety of locations and still allow the use of the same tube.

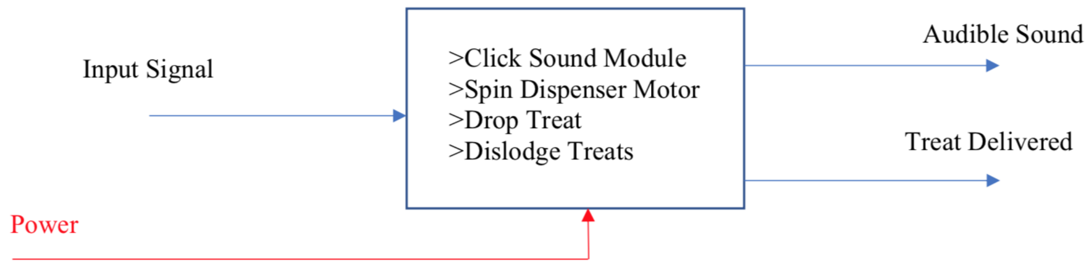
Overall Design:

The overall design consists of a treat storage area connected to the treat staging and dispensing mechanism along with PCB that can be mounted anywhere on the wheelchair, though the higher it can be mounted, the better it should work. There is then a flexible dispensing tube connected to the dispensing mechanism that allows the user to dispense the treats to any position on the wheelchair.

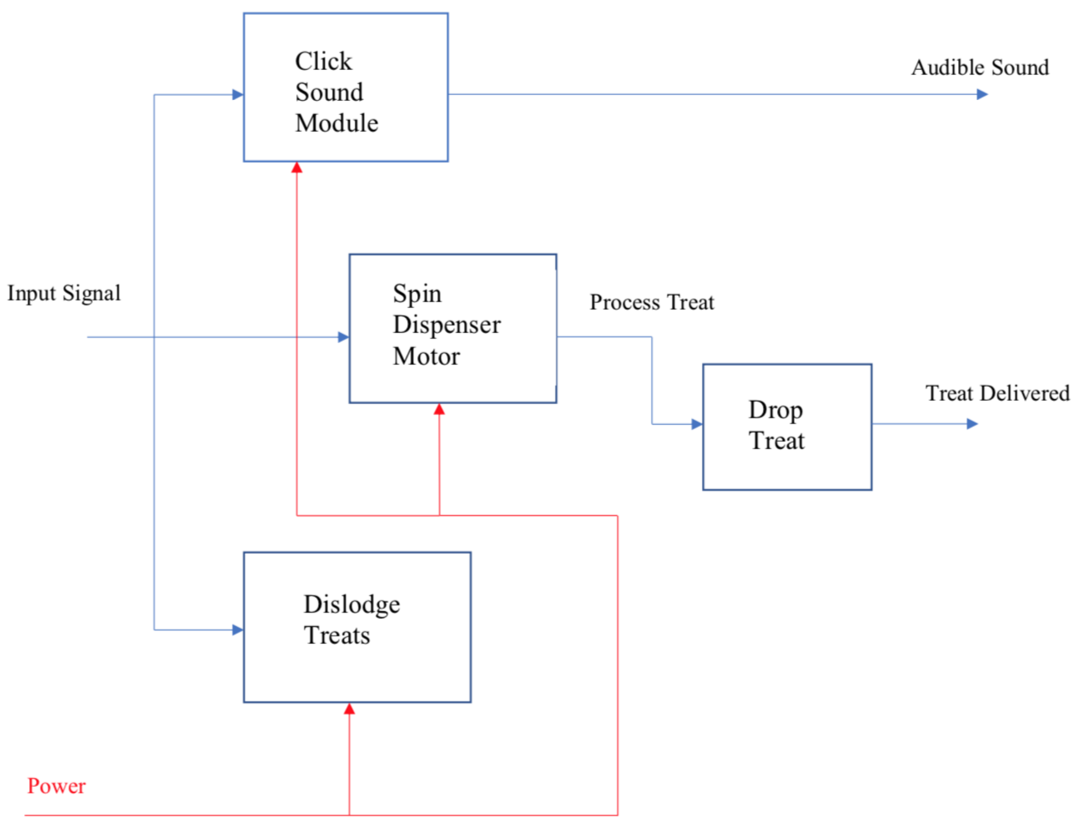
This allows the bulk of the unit to be mounted on the back of the wheelchair where it can be out of sight and not interfere with the user's ability to get through doors or other tight places. This design should provide the most flexibility and use across many wheelchair types.

Functional Architecture

Level 0:

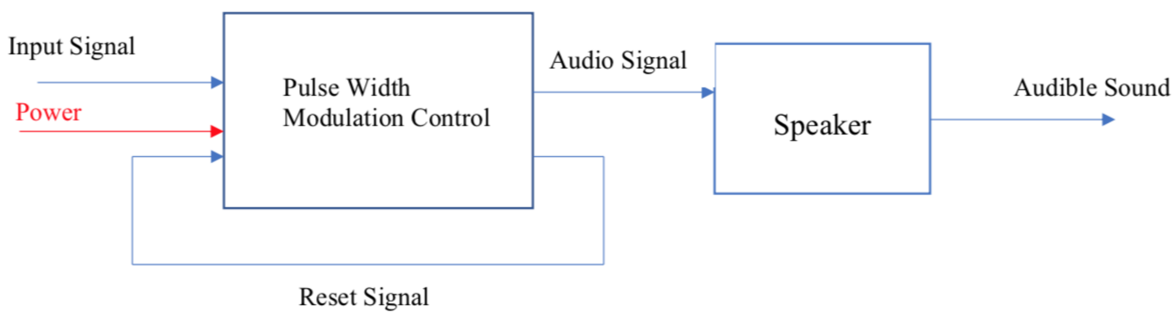


Level 1:

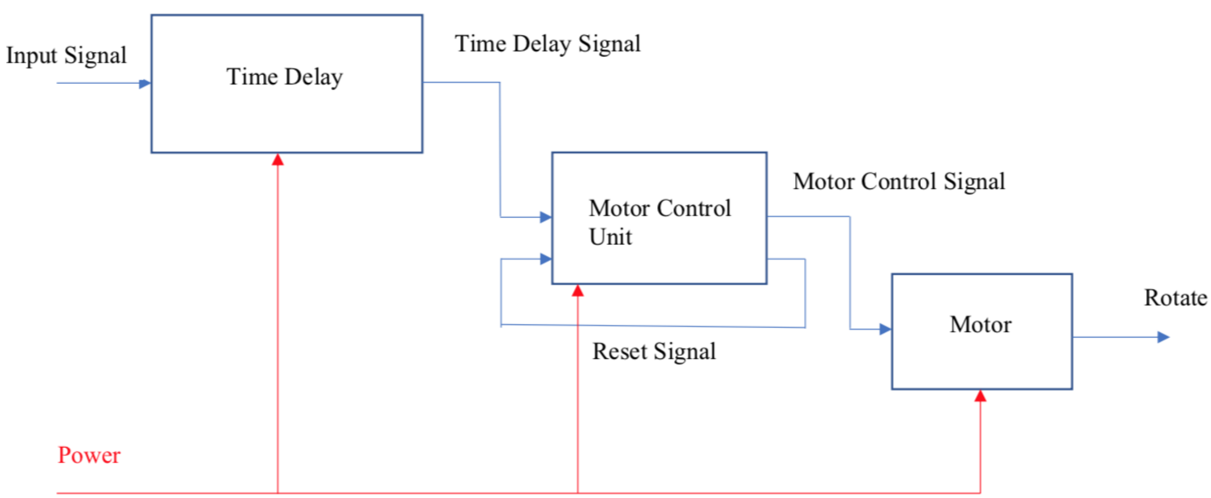


Level 2:

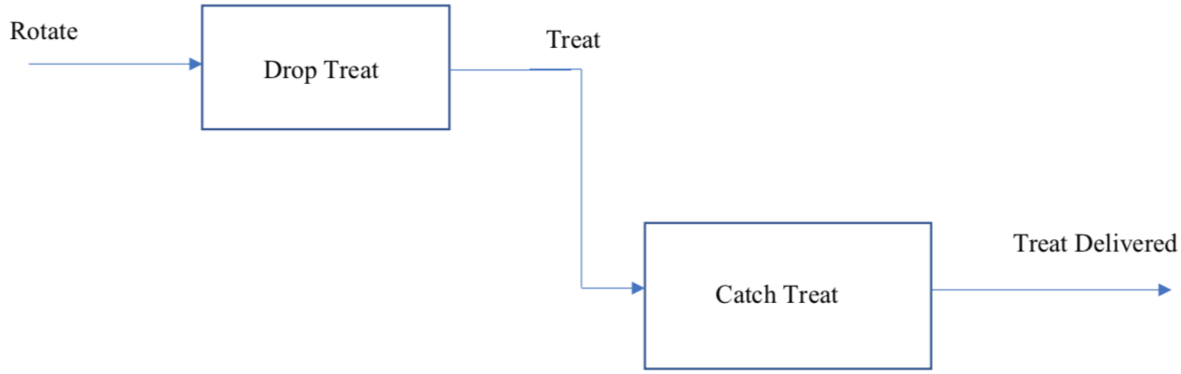
Function: Click Sound



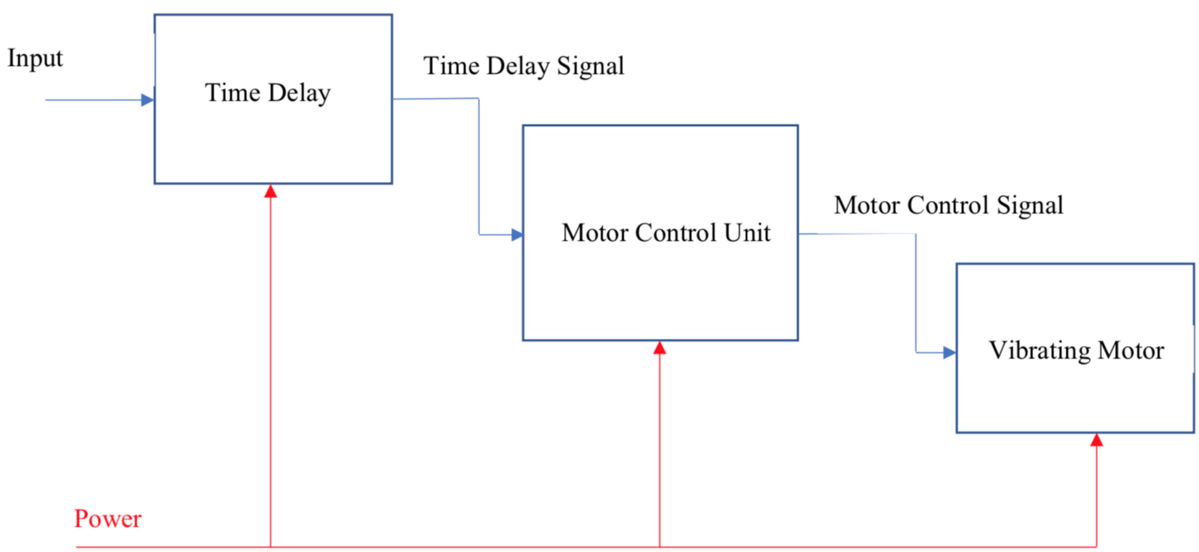
Function: Spin Dispenser Motor



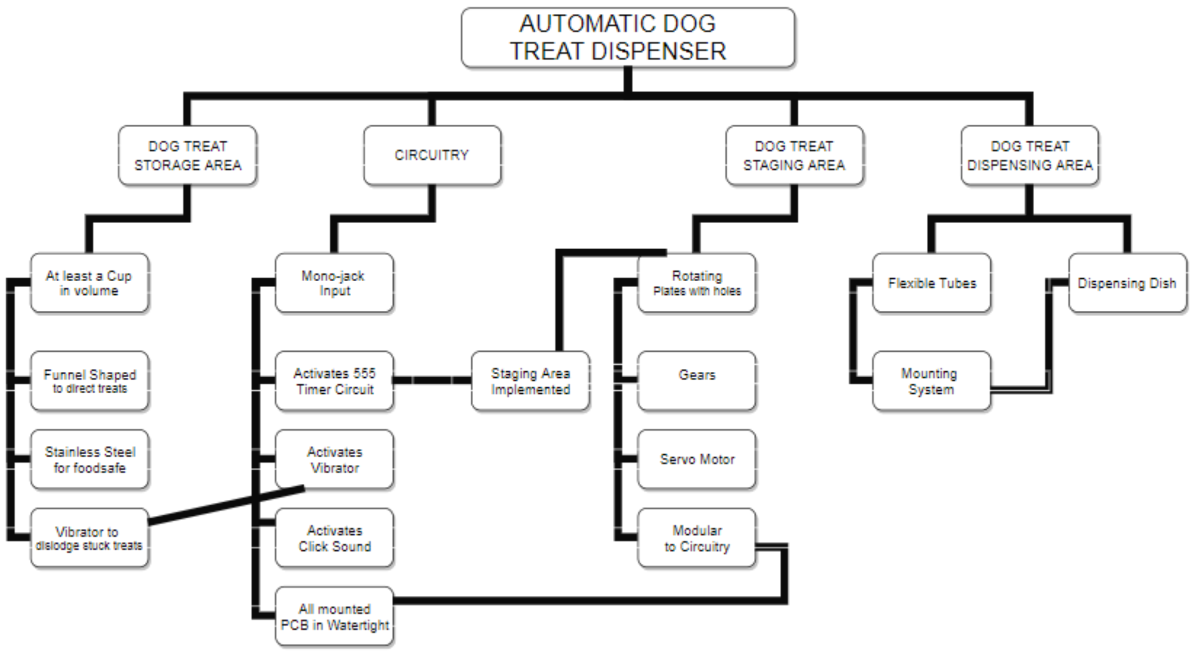
Function: Drop Treat



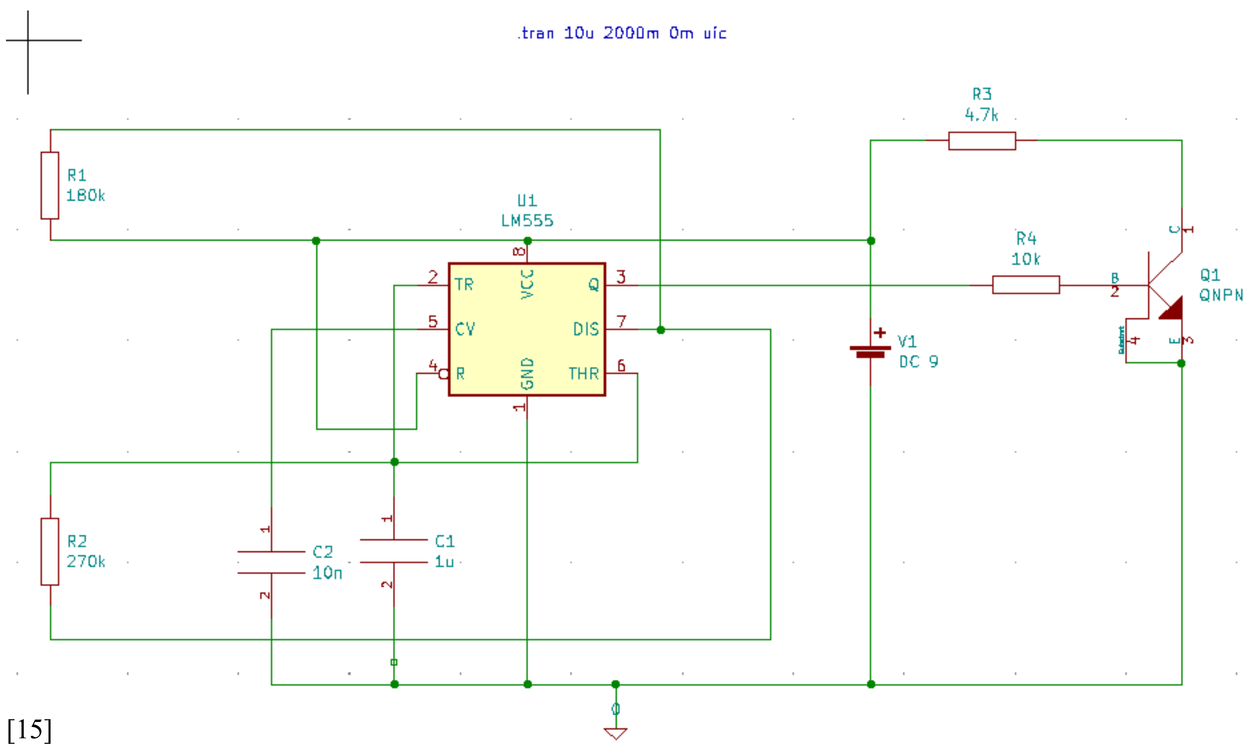
Function: Dislodge Treats



<u>System Architecture</u>



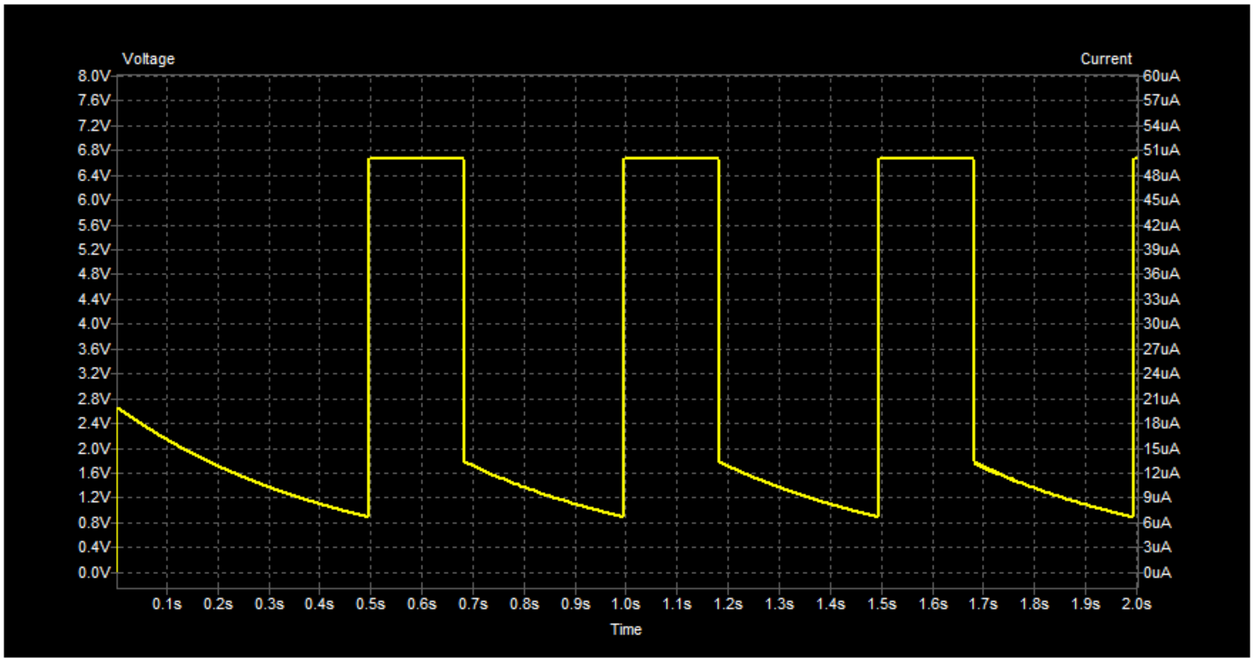
<u>Circuit Design</u>



[15]

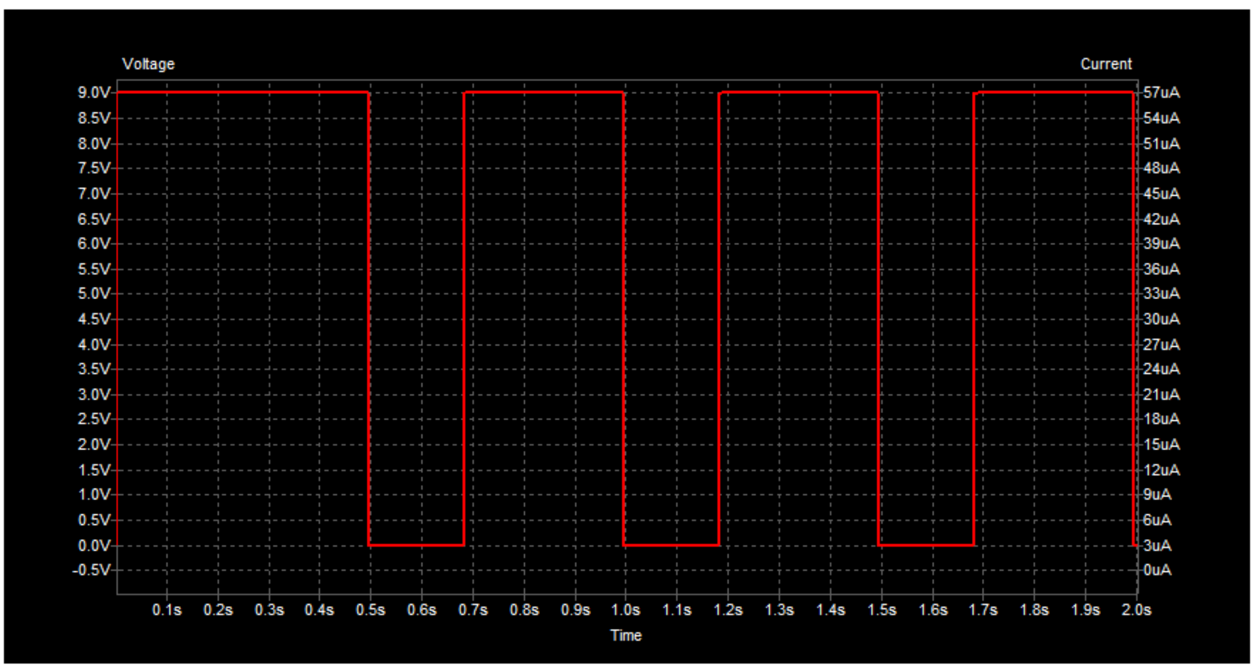
Circuit Waveform

This is the current that our circuit will be pulling from our 9V supply. Around 50uA * 9V will have us around .5mW



CW 1

This is the direct output from the 555 circuit. Half second pulse to the motor in the circuit which have estimated to be long enough for a half rotation per second.



CW 2

Power Requirements

For design 1 the circuit waveform CW1 was calculated to draw .5mW based off the 9V power supply and the 50uA waveform. The motor will leverage is a FS90R which will draw 4W per activation of the motor [28]. It has a maximum stall current of 650mA at 6V which will be at around 4W. The final estimate of each sensor will add around 5W and the clicker activation will also draw around 5W as well. The final estimation of the total power consumption will range from 20-30W total.

For design 2 Raspberry Pi Zero W requires a 1.2A/5V Input which will draw 6W of power for the microcontroller [29]. The team will also leverage additional LEDs and sensors each estimating to be around 5W per addition. The final estimation of the total power consumption will range from 26-36W total.

Preliminary Experimentation Plan

For the project team to properly assess the effectiveness of our design several use cases will be consisting of interactions with the dispenser. They should also anticipate how dogs will react before and after the dispenser operates. The project group also must ensure that the dispenser can vary how many treats it disposes to the dog to ensure that the owner's interaction with the service dog is reflected properly. Per Dr. Neuber's information this is important that the original training the owners received can be done with this dispenser without much fault.

Experimental Plan #1 objective will be to have the device dispense any number of treats from the container that holds the treats to the dog bowl mounted onto the wheelchair. The components of this testing case will be a stopwatch, measuring device, and dog treats. Time is important in this first experiment as it tests how long it takes for user input to be relayed and how the service animal reacts to the outputted dog treat. Time from this experiment will be logged for each service animal tested with to ensure that the response received from these animals is not unique. There will be a heavy focus on ensuring that the device is able to dispense a single treat before proceeding into follow up experiments. Both time and observed behavior will determine whether or not the base design would need to go under refactor or not. One thing to note is that jamming in the dispense step may cause the device to malfunction and third party will be ready to provide treats to the dogs in the event the device fails. A scatter plot chart will be used to compare the time observed for a treat to drop and a bar graph will be used to measure the success and failure of the device. Success will be evaluated if consistency across multiple service dogs is reached and the customer who is leveraging the device believes that it was easy to use.

Our second experiment will then focus on variable user input. Our goal with this design is to ensure that a service animal owner can control how many treats the device can output per run. The project team will leverage a measuring device, a stopwatch and dog treat like in experiment one. The testing aspect will be the variable inputs that the owner will perform. The data that the group will collect is whether the device output the correct number of treats, how long did it take to drop the right amount, and whether the dog had responded as it normally would when given that amount. There will be a heavy focus on ensuring that the time between input and output is kept as low as possible while ensuring the proper number of treats matches what the user had requested for. Time will be evaluated on each run to ensure that there are no unique cases based on the service animal or the operator. The device that is being used to input these treats will be independent of the device that is dispensing it as the input device will have the same input connector that is standard for those with mechanical disabilities. A scatter plot chart will be used to compare the time it took for the treat to dispense depending on what the user has inputted. Each input value will have its time compared appropriately while a companion bar graph will demonstrate the successes and failures of the trial runs. If it is determined that the device is constantly outputting the incorrect amount of treats the design team will need to refactor the method of dispensing the treats. Success will be determined when variance on dropped treats reaches zero and the service animal owners user input is properly matching what is being sent to the dispensing device.

Preliminary Project Plan

List of Major Tasks

- Hardware procurement (1 Week)
  - 555 Timers
  - Rotary Device
  - Switches

- Hardware development (3 Weeks)
  - PCB Design
  - PCB Assembly
  - Microcontroller evaluation
  - Power evaluation
  - Storage Container

- System Integration (3 Weeks)
  - System rotary design
  - Variable output functionality
  - Accelerometer functionality

- Wheelchair Integration (1 Week)
  - Placement verification

- Testing (2 Week)
  - Experiment #1
  - Experiment #2

- Data Analysis and Refactor (1 Week)
  - Feedback review and data review

- Reporting (2 Weeks)
  - Initial Progress Report
  - Mid-Flight Report
  - Final Report

- User Acceptance Testing (2 Week)
  - Experiment #1
  - Experiment #2

- Faculty Demos (Part of reporting)
    - Demo #1
    - Demo #2
    - Demo #3

- Customer Demo (Part of reporting phase)
    - Demo #1

Proposed Schedule:

Treat Dispenser

Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

PERIODS 1–32

ACTIVITY	PLAN START	PLAN DURATI	ACTUAL START	ACTUAL DURATI	PERCENT COMPLETE
Hardware Procurement	1	1	0	0	0%
Hardware development	1	3	0	0	0%
System Integration	4	4	0	0	0%
Wheelchair Integration	5	2	0	0	0%
User Acceptance Testing	8	3	0	0	0%
Data Analysis and Refactor	11	1	0	0	0%
User Acceptance Testing #2	12	2	0	0	0%
Reportings	11	1	0	0	0%
Faculty Demos	13	1	0	0	0%
Customer Demo	0	5	0	0	0%

Team Members will meet twice a week with project manager Adam Dost to ensure that the tasks assigned to them will fit inside their weekly schedule and ensure that the team members are able to both succeed in their academics and in their design project. Gage Moore will begin the procurement process and circuit design that the group will use. Zainab Abdullahi, Jachan and Adam Dost will begin researching materials that can act as storage for the dog treats. The entire project group will work together to ensure that the dispenser's parts are all functional and safe to operate. Robert Wignall will work on the integration piece between the wheel chair and the main dispenser to ensure that the location of dispenser is placed in an area that will ensure the treats that are provided will not impact the person in the wheel chair.

Potential Problems

Since the automatic dog treat dispenser is mostly a mechanical device and is responsible for moving hard dog treats, failures are almost guaranteed. The simple fact that the device is trying to feed treats that are not necessarily uniform through a dispenser that should work consistently is grounds for discussing methods of overcoming issues like jamming or coming apart. As different design types are being discussed, it is apparent that each design will have its own set of problems that will need to be overcome individually as well.

Since the dog treats have the potential of jamming in the dispenser, the dispensing mechanism will need to be solid and able to push through a blockage up to a certain pressure. There is also a potential to add a vibrating motor to the device to rattle the treats loose in the storage compartment and ensure they feed into the dispensing area correctly. This vibrator could be in the center of the dog treat storage compartment to break up any sticky treats as well. The storage compartment will also need to be watertight as the wheelchair may be used in rain. If the treats get wet, they will not feed through the dispenser correctly and can cause other problems down the road, potentially shortening the life of the dispenser.

A major potential problem is that the service dog will not react to the dog treat dispenser. Since the treat is not coming directly from their owner, there needs to be a means to make the device interest the service dog. One potential solution to this would be to add the clicker sound to the treat dispenser that is emitted any time the device is activated. This clicker sound would be the same sound used to train the service dogs so there should be an immediate response. The dispensing/treat dish at the bottom of the device will also need to have some method to draw the dog's attention to it. The device does not perform its job correctly if the dog is unable to locate the treats easily. This dish should also be in the view of the wheelchair user so that they can confirm the treats were dispensed and that their service dog was able to retrieve the treats.

Another potential problem is to have the device easily wheelchair mountable. The device will need to be small to add flexibility of mounting locations and extendable, flexible tubes will need to be used so the dish can be mounted wherever on the wheelchair independent of the main device location. The device will also need to be robust and shock resistant so it does not fall apart while driving around in the wheelchair, which can have jerk-like movements.

As mentioned before, the entire dog treat track must be food safe. There are multiple sections to the device, so the introduction of connections between parts and having gaps can create unsafe areas for germs and bacteria to grow and develop. Thus, the device needs to be able to come apart fully for complete cleaning. It is a bonus if the dog treat track can be removed from the electronics and made dishwasher safe.

With the treat dispenser mounted to the wheelchair, and being rechargeable battery powered, there is a potential for the device to lose power and stop working throughout the user's day. The device should either have indications of rechargeable battery level that can be checked prior to each day's use, and/or have a rechargeable battery. There could also be a warning sound that emits when the rechargeable battery is getting low and replacement or recharging is recommended. This is so the user does not falsely assume they will be able to start working on a new task with their service dog thinking they will be able to treat their dog all along the way. If they start and the device stops working partway through, there could be negative consequences of the training.

In the stopper-style design, a blade is introduced to help prevent jams and too many treats being dispensed. This also introduces a safety hazard if the blade comes loose. The blade will need to be firmly attached and easily removable so it is not flung on accident and can be cleaned.

The gumball and Ferris-wheel style designs both introduce spinning wheels/discs, which can easily be jammed if the axis gets filled with gunk or food particles start to build up along the outside of the discs causing them to scrape against their enclosure. The user will need to be able to open up this section and clean out any jams.

Since there may be some complexities to the design and pieces should come apart for cleaning, there is a potential that the user will not be able to put the dispenser back together. For this reason, the device should be somewhat modular with clear indications on what connects to where. An assembly diagram can also be provided and stuck to the device somewhere for easy reference.

The treat dispenser needs to help strengthen the bond between the disabled person in the wheelchair and the service dog and any problems that might get in the way of that need to be overcome. The device should be as simple to use as possible to make the user's life easier at the end of the day, not complicate anything.

Weekly Meetings

This form must be completed by the PM during each team meeting. Filled forms must be kept by the PM and submitted to the FS/CC upon request.

Project Title: Treat Dispenser for Service Dogs of Virginia **Meeting Date: 09/13**

Team members present: Adam Dost, Gage Moore, Jachan Shrestha, Robert Wignall, Zainab Abdullahi

Team members absent: n/a

Task progress report for the last week effort:

Line#	Task description	Team member assigned	Progress)%-100%	Delivery proof
1	Meet with stakeholder Dr. Neuber and discuss previous attempts to solve current problem	All	100%	Stakeholder Dr.Neuber

Task allocation for the next week:

Line#	Task description	Team member assigned
1	(Proposal) Executive Summary creation	Gage M.
2	(Proposal) Problem statements	Zainab A.
3	(Proposal) Approach – Including a problem	Jachan S.
4	(Proposal) Prelim list	Adam D.
5	(Proposal) Preliminary Design	Robert W.

PM name: Adam Dost

ECE-492 Weekly Task Allocation/Delivery

This form must be completed by the PM during each team meeting. Filled forms must be kept by the PM and submitted to the FS/CC upon request.

Project Title: **Treat Dispenser** **Meeting Date: 09-19**

Team members present: Robby, Adam, Zainab, Jachan, Gage

Team members absent: NA

Task progress report for the last week effort:

Line#	Task description	Team member assigned	Progress)%-100%	Delivery proof
1	(Proposal) Executive Summary creation	Gage M.	100%	Submitted via Slack
2	(Proposal) Problem statements	Zainab A.	70%	Verified via Slack
3	(Proposal) Approach	Jachan S.	70%	Verified in person
4	(Proposal) Prelim list	Adam D	100%	Uploaded to slack
5	(Proposal) Preliminary Design	Robert W.	70%	WIP, Verified in Person

Line#	Task description	Team member assigned
1	Problem statements (cont)	Zainab A.
2	Approach (cont)	Jachan S.
3	Preliminary Design (cont)	Robert W.
4	Proposal – Master Document Creation	Adam D.
5	Functional Diagram	Gage Moore

PM name: Adam Dost

ECE-492 Weekly Task Allocation/Delivery

This form must be completed by the PM during each team meeting. Filled forms must be kept by the PM and submitted to the FS/CC upon request.

Project Title: **Treat Dispenser** **Meeting Date: 10-03**

Team members present: Robby, Adam, Zainab, Jachan, Gage

Team members absent: NA

Task progress report for the last week effort:

Line#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Problem statements (cont)	Zainab A.	100%	Uploaded to Slack
2	Approach (cont)	Jachan S.	80%	Uploaded to Slack
3	Preliminary Design (cont)	Robert W.	80%	Uploaded to Slack
4	Proposal – Master Document Creation	Adam D.	100%	Google Doc created
5	Functional Diagram	Gage Moore	100%	Functional Diagram

Line#	Task description	Team member assigned
1	Approach (cont)	Jachan S., Zainabi
2	Preliminary Design (cont)	Robert W.
3	Expected Roles	Adam D.
4	Circuit Design	Gage Moore

PM name: Adam Dost

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Appendix B : Design Document

Problem Statement

The wheelchair is one of the most commonly used assistive devices for increasing and enhancing personal mobility, which is a necessity for being an independent and productive member of society. There are many conditions and afflictions which may result in the need of a wheelchair such as multiple sclerosis, cerebral palsy and muscular dystrophies. People who are wheel-chair bound accompanied by service dogs account for .9 percent of the U.S. population[1]. These highly trained canines can provide independence to their owners and significantly enhance their quality of life. These dogs are capable of completing a wide range of tasks from opening doors, retrieving dropped items and pushing their partners up ramps. These dogs are an integral part of these individuals lives and must go through extensive training to earn this role[2]. In order to achieve maximum performance from these dogs, frequent rewards in the form of verbal affirmations and treats are required. Rewarding the dog is essential. It not only increases the emotional relationship between the dog and the owner but most importantly, provides the dog with much needed positive reinforcement.

This project was undertaken at the request of The Service Dogs of Virginia, a non-profit organization that raises, trains, and places dogs to assist people with disabilities due to the failure of several designs that have attempted to ameliorate the burden to create an effective standard of assistance. The main challenge users who have limited or no hand mobility at all is giving the dog a treat. There have been several great ideas and attempts to create an adaptive treat dispenser that could be integrated seamlessly to a wheelchair, but there are none that are commercially available as of today. Despite the numerous attempts made to make this merchandise commercially accessible to the public it has failed repeatedly due to design limitations such as; the dispenser being too large to be seamlessly embedded into a wheelchair as well as there being malfunctions with getting the dispenser to release the desired number of treats appropriately.

While there have been few designs that have overcome these setbacks, they too have proven to be futile as a result of the dispenser bowl being too small, and fiscal challenges due to the expenses of printing and dipping into a food safe coating.

Previous Designs and Patents

Previous attempts at this project have been done over the course of several semesters. To validate and ensure the design would succeed where other projects failed the design group evaluated each previous design and took note of each fault's that were found so that the current design iteration would solve any and all problems that the previous designs failed on so that this design would be successful. Examining the current design shown in Figure 1 below carried issues with not storing the treats in a safe food storage container and was prone to jam quite easily upon use and no way of actually unjamming the device without human manual intervention. One of the key early design evaluations done was to ensure that the material that is used for food storage is not only safe material but won't leave a pungent smell and can easily be washed when needed. A materials report was created to address this specific problem to ensure that the current design won't fall victim to this.

Figure 1: Previous Design 1

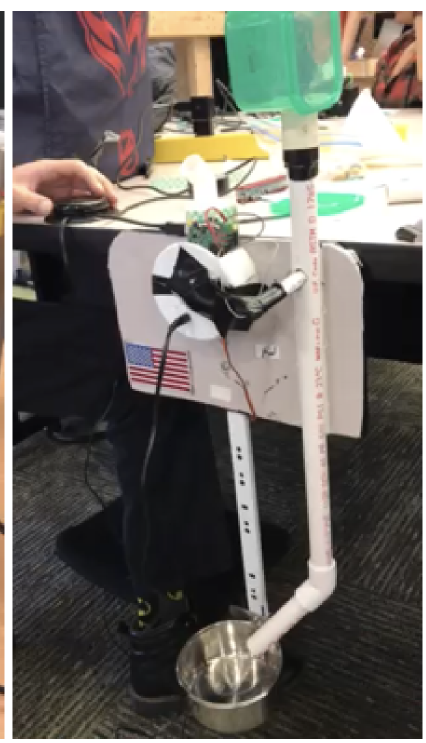


Figure 2: Previous Design 2

The second design shown in Figure 2 above was praised as being one that had easily procured parts that could be sourced locally in a single store. Procurement and accessible parts is very important in this design as cost is a major factor and per our design cost of parts was evaluated to ensure that an operator could replace and repair broken parts in the event the device. Another key design flaw in this was managing the output of the treats. During Dr. Neuber's briefing of what Service Dogs of Virginia does for training which includes varying the number of treats that the dog will receive depending on the task they complete or what the owner believes that they should be rewarded.

Figure 3: Previous Design 3

A third previous design that was evaluated had the most success of the three is shown in Figure 3 above. Both its placement on the wheel chair and the arduino storage area were successful and the storage device had no issues. One of the key issues the group had ran into was coating the storage for treats and found that the cost of it would have increased the entire cost of the device's creation beyond what was acceptable by the design team. Another key issue was the size of the storage device was far too small for what it was supposed to do in live operation.

During our storage device measurement phase this design storage device flaw will play key in helping understand what this iteration of the device will need for storage size.

Currently, there is a need for an improved dog treat dispenser. The available prior art is limited by several factors such as being bulky, cumbersome, mechanical, non-food safe, and not adaptable to a wheelchair. Many handicapped people suffering from advanced disabilities do not have the dexterity as people without disabilities do. This leads to a need for a new design in order to meet their needs. In researching and examining existing patents, elements that were common with our design and elements that could not be used in our design were found.To meet the ADA(Americans with Disabilities Act) accessibility standards, the width of a door must between 32 inches minimum to 48 inches maximum[3]. Many of the patents were not wheelchair adaptable and could not be mounted onto the side or even the back of a wheel-chair. Our goal was to ensure that the dispenser would not interfere with the user's day to day activities or limit them in any way.

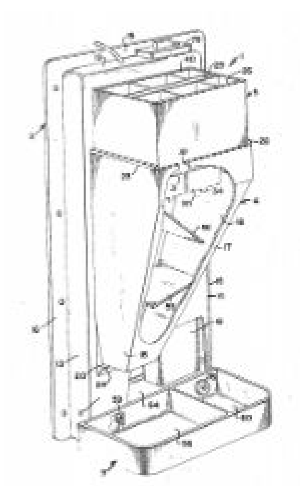


Figure 4: Patent One

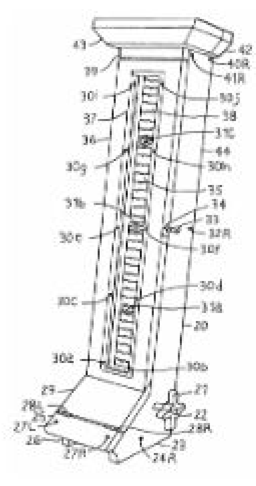


Figure 5: Patent Two

The patents illustrated in Figures 4 and 5 were too large and bulky, in addition to not being able to be mounted onto a wheelchair [4],[5]. Another crucial requirement was for the material used to be food safe and eco-friendly. Figure 6 below shows a patent that could be mounted onto a wheelchair, but was made using 3D printed parts which were not food safe[6].Some elements that shall be used in our design are illustrated in Figures 7,8 and 9 below

[5-7]. These patents used a button for activation and a rotary mechanism which shall be incorporated into our design. The need for a generic switch to activate the dispensing of a treat is clearly needed for people with advanced disabilities as they will be able to use a switch, button, or other form of activator that they already utilize in everyday life to complete tasks.

Figure 6: Patent Three

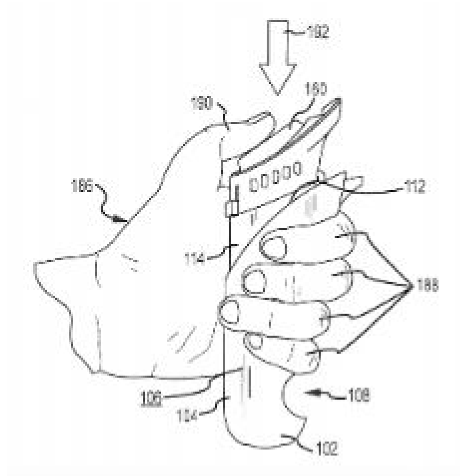


Figure 7: Patent Four

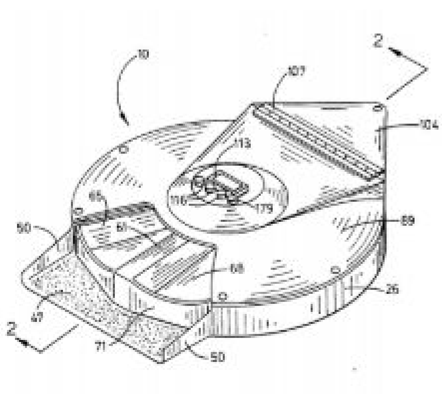


Figure 8: Patent Five

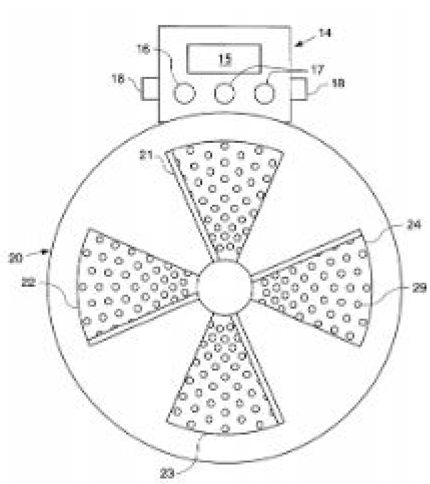


Figure 9: Patent Six

In addition to the proposed design having a generic switch input, it will also be electronically controlled to remove the need for a mechanical input to dispense a treat. This will allow people with advanced disabilities to train their dog in order to comply with the testing requirements to keep their dog “in service.”

Upon reading the available prior art that has been registered, there is no indication that the proposed automatic treat dispenser design discussed in this document will infringe on any of the prior art. While there exist a few key elements such as a rotational food compartment, a tray portion, and a button, none of the elements in combination with our design would infringe on existing patents [4-7]. As all the designs lack the use of a circuit and/or microcontroller to activate the dispensing of a treat coupled with an adaptable size food storage area that is mountable to a wheelchair. Thus, based on our review there exists a novelty within our design, and it is okay to proceed with implementing it as described herein.

Treat Dispenser Project Requirements

Mission Requirement:

The device shall assist people with wheelchair-binding disabilities by providing them a method to reward their service dogs.

Functional Requirements:

1. The device will hold up to at least one cup of treats at a time in order to allow for treats to be provided to the service animal throughout at least one full day.
2. The device shall use timers to control treat dispensing mechanisms
3. The device shall utilize a mono-jack input so the user may use their own control mechanism. If time allows, this project will investigate an accelerometer-based control input.

Operational Requirements:

1. The device will dispense 1-5 treats, depending on initial setup, with a single activation of the user's input device.
2. The device will be integrated seamlessly to a wheelchair without being too bulky.
3. The materials used will be food compatible.
4. The device will be easy to take apart and easy to clean.

Input Requirements:

1. The device will accept input from the operator. Though the physical input device may vary, the interface with the device will stay consistent (mono-jack).
2. The device will accept dog treats into a storage container integral to the device.

Output Requirements:

1. The device will output dog treats through a pipe system leading to a food tray.
2. The device will output a "click" sound to notify the service dog a treat has been dispensed.
3. The device will provide notification if the treat storage compartment is empty and no treats can be dispensed.

Technology:

1. Shall use some Surface Mounted Technology (SMT) 555 Timers or a Microcontroller.
2. Shall use some form of food-safe pipe/tube to move food from storage to dispensing tray.
3. Shall use some form of coating/hardening on the circuit to ensure durability.
4. Shall use food-safe materials for all surfaces that come in contact with dog treats.
5. Shall use rechargeable batteries to keep the economic impact minimal.
6. Shall use a servo motor or solenoid to be activated by the controlling circuit.

System Architecture

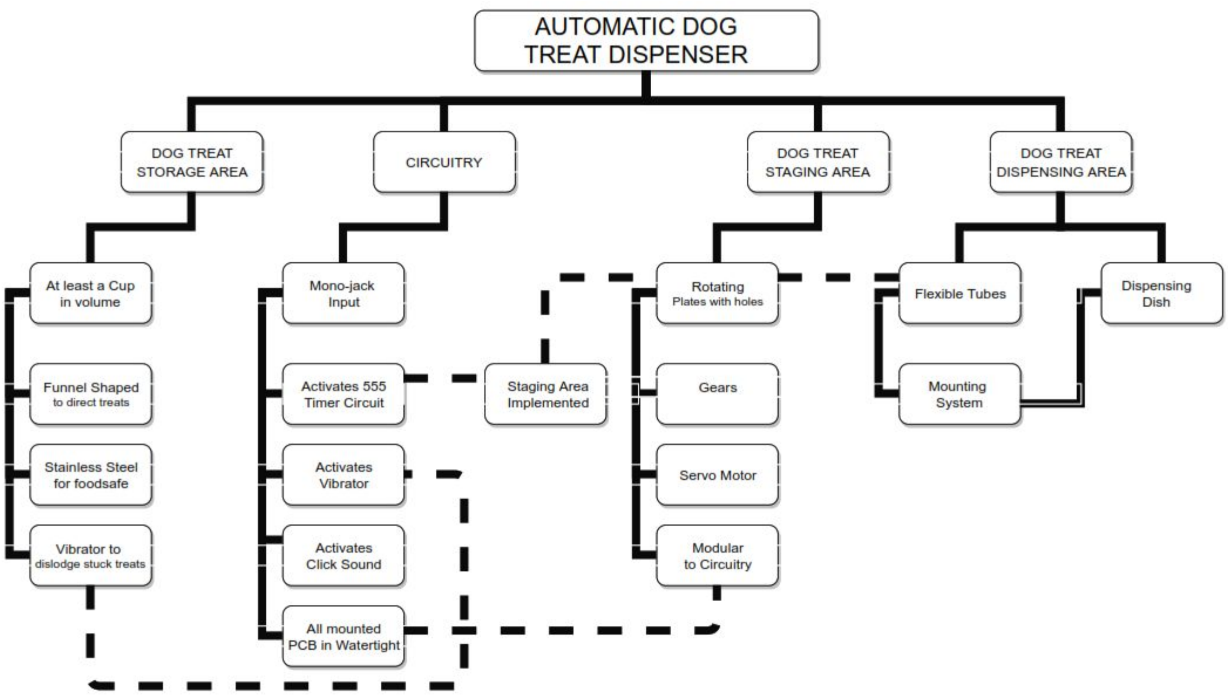


Figure 10: System Architecture

The System Architecture for the automatic treat dispenser is shown in Figure 10 above. The overarching blocks such as “Dog Treat Storage Area,” “Circuitry,” “Dog Treat Staging Area,” and “Dog Treat Dispensing Area” are the four main components utilized in this design. This shows how all components are interconnected and related at a high level to ensure that all required module functionality is achieved. The dashed lines show where the four modules relate to each other. For example, the Circuitry is connected to the Dog Treat Staging Area by the following. When the 555 timer circuit is activated, the treat staging area is implemented, which in turn connects to the rotating plate portion of the Dog Treat Staging Area. Once prototyping begins, this diagram will be used as a reference so no piece is missing. This diagram will be modified throughout the prototyping and testing portion as new and different methods may be implemented to achieve the best results.

Dog Treat Storage Area

As shown in the figure above, the dog treat storage area will hold at least a cup full of dog treats at a time. This will ensure that the service dog will never be without a treat whenever the dog completes a correct task and shall be rewarded. The storage area will also be funnel shaped and made out of stainless steel. This will not only help with jamming problems (along with the vibrating motor), but will also help overcome past design flaws such as using non food safe materials.

Circuitry

At a high level, the circuitry will either utilize a 555 timer circuit or a microcontroller to be used as the control system for the treat dispenser. The type of microcontroller that will be used is the Raspberry Pi Zero W, and a 555 timer circuit utilizing Surface Mount Technology (SMT) will be used for the 555 timer based design in order to keep the printed circuit board (PCB) as small as possible. This will help to keep the treat dispenser's footprint small.

The circuitry comprises the entirety of the controller portion of the design, but will further need to be comprised with a mono-jack input for switch connection. This will allow for any switch with a mono-jack to be plugged into the controller and used in conjunction with the treat dispenser. Since disabilities can vary from only being able to move a finger to only being able to move their head, this simple means for device input connection is necessary so the end user may utilize their custom switches. The circuitry component controls all of the moving parts in the dispenser design, and is the heart of the project. Not only will the circuitry control the spinning of the rotational disk, but it will also control the vibrating motor to help dislodge treats, activate the "click" sound module, and provide any required feedback to the user.

Dog Treat Staging Area

Essentially, the dog treat staging area is the part of the design where a treat will simply wait to be delivered to the service dog. It works in conjunction with the rotational mechanism described later to hold the treats in their respective positions so that, when the rotational disk is spun, the treat will fall into a dispensing hole which will then drop to the service dog.

Dog Treat Dispensing Area

The dog treat dispensing area is a simple but important piece of the design. The dispensing area comprises of a long flexible tube for easy customizability for the end user. This would potentially allow the whole treat dispenser to be mounted on the back of the wheelchair, out of the way of obstacles, and still be able to provide a treat to the service dog at the side of the wheelchair, which should be their ready position and keep the dog from having to walk around the wheelchair. Furthermore, the dog treat dispensing area is comprised with a food dish or bowl in order for the dog to receive a treat without it scattering across the floor. As mentioned above, service dogs are used to consistency when in training, so delivering the treats to the side of the wheelchair will help maintain their training. These four main modules are described more in depth in the Detailed Design section of the report.

Background Knowledge/Phenomenology

Servo Motor

A servo motor utilizes a brushless DC motor technology, which helps keep the motor's efficiency high (no friction and lost energy due to brushes). The efficiency is about 10% higher than for a brushed motor[8]. There are magnets connected to the rotor and electromagnets connected to the stator (the stationary part of the motor). Every time the rotor spins 180 degrees, the polarity of the electromagnets on the stator needs to be flipped (or turned off in some cases) to allow the rotor to keep spinning. Otherwise, the magnets would constantly negate each other and provide a total torque of zero. The system model as shown in *Figure 11* below will be used to analyze the servo motor [9].

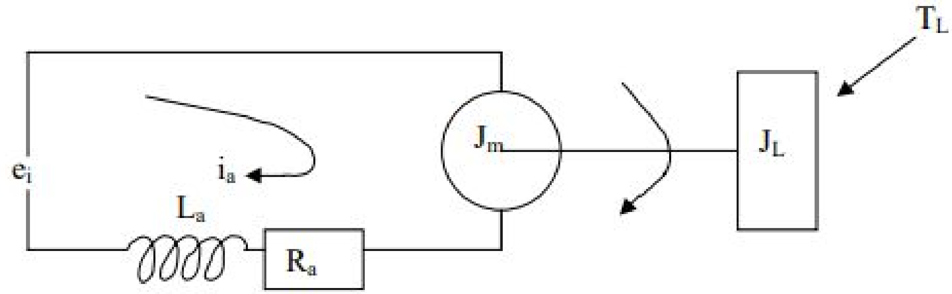


Figure 11: System Model for Servo Motor

When analyzing servo motors there are two important time constants, the electrical time constant and the mechanical time constant. The time constants are usually listed in the data sheets, but are for the motor alone with no load connected to the shaft of the motor. Thus, it is important to know the actual values of the time constants under the actual load conditions. This will need to be determined during prototyping. Once the treat dispensing module is built, tests can be run to measure the torque required for consistent results.

Electrical System

$$e_i = i_a R_a + K_e V_m \quad (Voltage\ Equation)$$

The steady state equation for the electric part of the motor is derived using Kirchhoff's voltage law. Where e_i is the input voltage, which is equal to the sum of the voltage drop across the resistor R_a and inductor (resistance of zero), L_a, as well as the motor when activated using the given electrical time constant, K_e, and angular motor velocity, V_m.

Mechanical System

$$T = Torque = i_a K_T = J\alpha \qquad (Torque\ Equation)$$

Torque is what causes objects to obtain angular acceleration. It is a force that causes an object (the circular plate) to rotate about an axis. The torque, T, of the motor is equal to the torque constant, K_T, times the current, i_a. This is also equal to the total inertia of the motor, J, multiplied by the acceleration of the arm, α. Once the required torque to activate the treat dispenser module is found, the servo motor needs to be utilized at a current that meets or, preferably, exceeds the measured required torque.

555 Timer

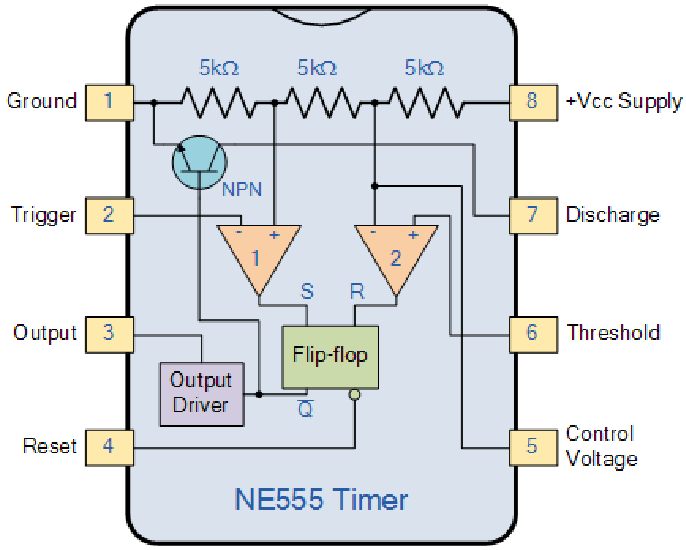


Figure 12: 555 Timer Integrated Circuit

A 555 timer integrated circuit (IC) is made up of two operational amplifiers (op-amps), a flip-flop, output driver, transister, and series of resistors [10]. The timer gets its name from the series of three 5 kΩ resistors between ground at Pin 1 and the positive voltage supply at Pin 8, producing a voltage divider network so that ⅔ of the supply voltage is supplied to the inverting input of op-amp two and ⅓ is supplied to the non-inverting input of op-amp one. The trigger at Pin 2 is connected to the inverting input of op-amp one so that, when the trigger is higher than ⅓ of the supply voltage, the op-amp's output activates the set terminal on the flip-flop. The threshold at Pin 6 is used to override the ⅔ input voltage and reset the flip-flop. The control voltage at Pin 5 can be used to override the RC timing network, but will be ignored in this project and connected to ground with a capacitor to eliminate noise. The flip-flop's output is connected to a driver to amplify the signal some, and then is connected to the output at Pin 3. The reset at Pin 4 is connected directly to the flip-flop's reset. Lastly, there is the discharge at Pin 7, which is used to discharge the timing capacitor to ground when the output is active. There are three main modes of operation for a 555 timer circuit: astable, monostable, and bistable (Schmitt Trigger).

In astable mode, there is no “stable” state; the output is an always oscillating square wave with period and duty cycle determined by the values of resistors and capacitors in the circuit. In monostable mode, the stable mode is when the output is low. When the 555 IC’s connection to the trigger pin goes low, the output goes high for a certain amount of time as determined by the impedance of the circuit. After that timeframe, the output goes low again until a signal is seen at the trigger again. In bistable mode, also known as a Schmitt Trigger, the 555 timer behaves similarly as it does in monostable mode, but the output will remain high until the input to the Reset pin goes low. Thus, the timing aspect of the circuit is essentially bypassed, and two inputs would need to be utilized. Based on the requirements for the automatic treat dispenser, the astable and monostable modes of operation will be the most useful.

Astable Operation

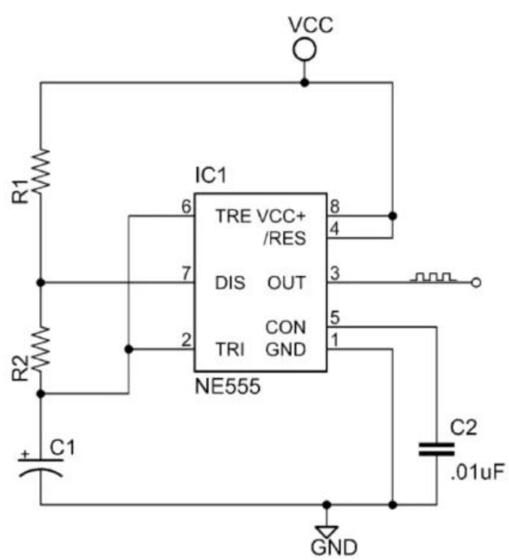


Figure 13: 555 Timer Circuit for Astable Operation [11]

As mentioned previously, this circuit’s output will generate a square wave with controllable frequency and duty cycle [11]. This mode’s output is also known as pulse width modulation (PWM) and may be useful for activating a motor intermittently and dislodging treats by vibrating the treat storage compartment. Here, the period T is given by the sum of the time the output is high and the time the output is low ($T = T_h + T_l$), where:

$$T_h = 0.7 * (R1 + R2) * C1$$
$$T_l = 0.7 * R2 * C1$$

Combining these two equations, we can find the period *T* directly using the following:

$$T = 0.7 * (R1 + 2 * R2) * C1$$

To vibrate a motor well, a small duty cycle is desired. A duty cycle less than or equal to 50% would provide a "sputtering" type effect that can also help to save power.

$$Duty\ Cycle = 100 * \frac{T_h}{T_h + T_l}$$

Monostable Operation

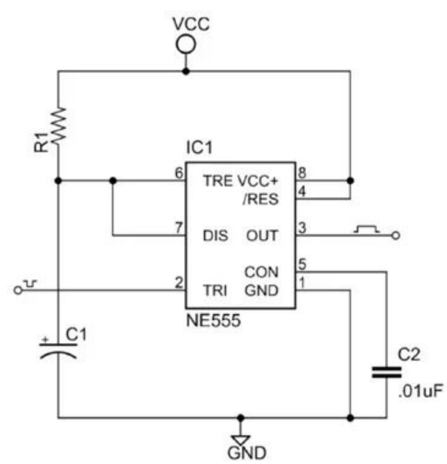


Figure 14: 555 Timer Circuit for Monostable Operation [11]

Under these conditions, the 555 timer's output will remain high for an amount of time based on the external RC system after triggered, and return to a low state until triggered again [11]. It also gives the option of an "override," which will keep the output high while a trigger is applied, providing an option for a "long push." Bringing the reset pin low can also cut the output signal short if needed, which could be required if the treat compartment is empty. This signal can cancel the treat dispenser and also be used to notify the user to refill the treat dispenser.

The amount of time the output goes high after a trigger can be found by:

$$T = 1.1 * R1 * C1$$

To design the circuit, a capacitor is selected first as resistors are much easier to find in different sizes that can fit the required *T*. This output *T* should be equal to the amount of time it takes to turn the motor around one time. In order to determine the required *T*, an analysis of the dispensing module must be made.

Dispensing Analysis

Since the design utilizes a circular dispensing module divided into three equal compartments, the goal is to turn the module ⅓ of the way, or 120°, around so a new compartment lines up with the dispensing hole each activation. Using the equation for circumference *C* of a circle, $C = 2\pi r$, where *r* is the radius of the dispensing module, the size of the motor's gear can be determined using the following logic:

To dispensing module must turn ⅓ of the way around to dispense the treats, so the distance needed to turn is given by:

$$\tfrac{1}{3}\,(2\pi r) = \tfrac{2}{3}\,\pi r$$

Therefore, the gear attached to the servo motor that will turn the dispensing module can be lined up with the outside perimeter and have the circumference given by:

$$Circumference\ of\ Motor\ Gear = C_{motor} = \tfrac{2}{3}\,\pi r$$

Since gears are being used as shown in Figure 23 of the Detailed Design portion below, the outer diameter will be C_{motor} (to the gear tips) while the inner diameter should be large enough for the gear to grip the teeth of the dispensing module turn the module accordingly. Now that the size of the gears are determined, timing requirements can also be established.

Servo Motor Timing Analysis

To figure out the timing needed to keep the Servomotor active long enough to turn our plate 120° as described above, the RPM of the servo motor must be taken into account. The specified RPM for the Servo motor can be used to figure out how long it will take to rotate around one time as:

$$Rotation\_Time = \frac{60}{RPM}$$

This *Rotation_Time* will then be used to design the 555-Timer circuit as well as the code for the microcontroller. The output from both of these designs should stay high for at least one *Rotation_Time* after an activation. Of course, for different functionality, this time may need to be extended (i.e., vibrating to dislodge treats). Thus, from above, the required *T* for monostable operation will be given by $T = Rotation\_Time$. This same time *T* can also be used for the astable operation.

In the case where it is determined that the servo motor provides inconsistent results or an overly complicated circuit, a solenoid with arm will be used in its place. As described later in the prototyping section, this lateral motion can be translated into rotational motion so the rest of the design can remain the same. When a solenoid is used, the time *T* will be given by the amount of time to fully activate the solenoid, extending the arm fully. This will be called *Solenoid_Time* and $T > Solenoid\_Time$.

Raspberry Pi

Raspberry Pis are an inexpensive “off the shelf” solution that provides diverse functionality in a small package. The small form factor (66.0mm x 30.5mm x 5.0mm) will allow this part to be integrated to the treat dispenser without causing any obtrusions[12]. Raspberry Pis offer several configuration options due to the power of the microprocessor. This device can be utilized with a screen and user interface (Human Machine Interface - HMI), or blindly using button commands to make adjustments to programming. No matter how the RaspberryPi is used, the program can be saved and backed up in a separate location so that it can be copied to replacements in the event of damage or a failure. Using the tool PiBakery, the Raspberry Pi can be pre-configured with the design’s required code already ready to operate on each startup. This can drastically reduce any repair time and allow for more tech-savvy users to customize their experience if wanted.

Power Analysis

555 Timer: In order to begin analyzing the power requirements of a 555 Timer Circuit, a simulation or the information from its datasheet can be used. For this project, a basic simulation of the circuit in Astable operation was performed as shown in Figure 15 below. By measuring the current leaving the positive terminal of the power supply, the total current for the circuit can be determined (Shown in Figure 16). Since the total current and supply voltage is known, the total power consumption can then be calculated as well. The output PWM signal shown in Figure 17 coincides with the amount of time needed to spin the servo motor, so this circuit could potentially be used, making the simulated numbers a worthwhile analysis tool.

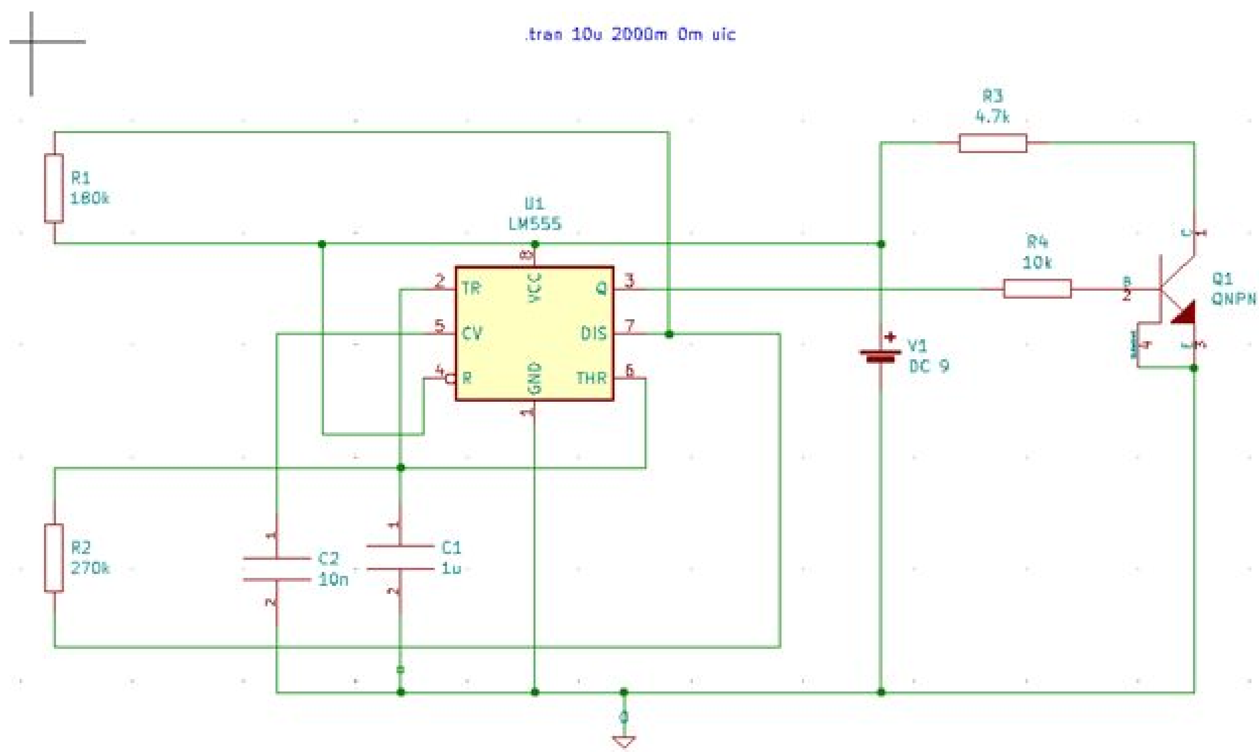


Figure 15: 555 Timer Circuit in Astable Mode for Simulation

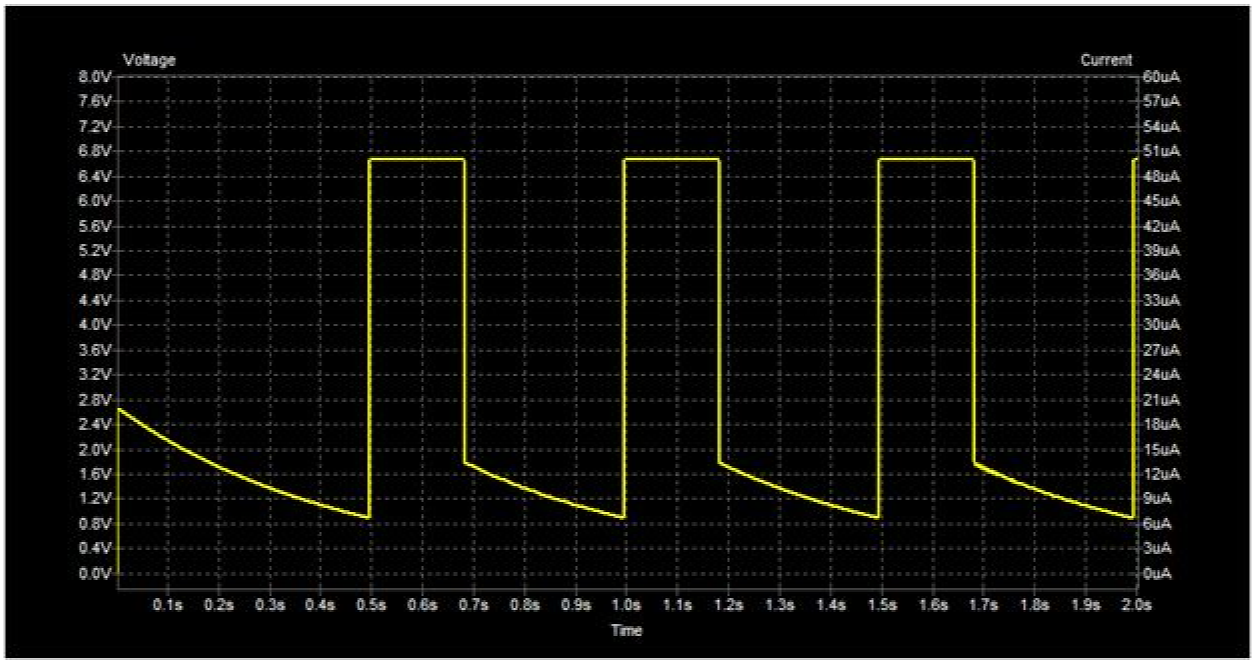


Figure 16: 555 Timer Circuit Current Draw (Right Axis)

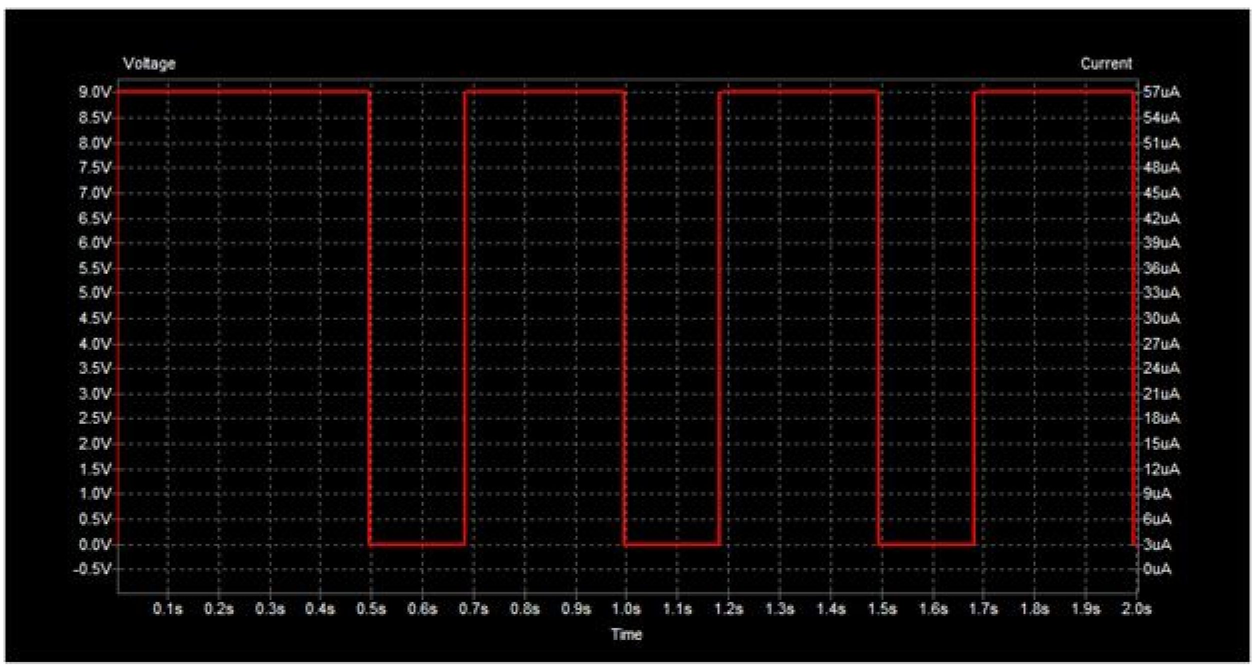


Figure 17: 555 Timer Circuit PWM Output Signal Voltage (Left Axis)

Using the total current waveform from these initial simulations of the 555 Timer circuit in astable conditions, the circuit should draw around 0.5 mW without any load. This is based off the 9V power supply and 50 μA peak shown in the waveform. Next, the motor will need to be considered. The motor the design will leverage is an FS90R, which, based on the datasheet, will draw about 5W per activation [13]. This is determined by the maximum stall current of 650mA at 6V which will be at around 4W and adding in a slight safety factor. To determine if the treat dispensers have treats or not, a sensor, like a photosensor, will need to be used. Also, if an accelerometer activation switch is created, it will need some power to provide activations to the treat dispenser. An estimate of 5 watts will be added by each sensor. Thus, the final estimation for the total power consumption will be around 20-30 W per activation.

Microcontroller: The Raspberry Pi Zero W requires a 1.2A/5V input which gives a total power consumption of 6W max [14]. The team will also leverage additional LEDs and sensors to provide feedback to the user of the device, each at around 5W per sensor. Thus, the total estimated power consumption using this design would be between 26-36 W. This is another number that will need to be verified during prototyping and testing.

Battery Requirements: From the power analysis above, it can be seen that either design will require around 2 amps per activation at 12 Vdc. In order to determine the number and size of batteries needed, the device usage needs to be taken into account. The design requires the ability to store a minimum of one cup of dog treats at any time, which is about 15-30 treats depending on the brand used. Thus, with 2-3 treats being dispensed on average, the device will be used between 8 and 15 times before a refill is required. When a refill is required, the batteries can also be changed out for a freshly charged set, though going 2-3 days between charges may be favorable. Therefore, the worst case scenario will be around 45 activations of the device between battery charging, and each activation should have the circuit draw power for less than 5 seconds (in the case of the 555 timer design since it is comprised of passive components; microcontroller design may have higher power needs).

Therefore, the batteries will need to provide power to the device for around 240 seconds, or 4 minutes, between charges. 4 minutes is the same as 0.0667 hours. A double A (AA) battery has about a 2 Ah capacity at 1.2 Vdc. If ten AA batteries are used in series, a voltage of 12 Vdc can be achieved, which should power the device for about:

$$1/0.0667 = 15\ charges$$

Where the *charges* were determined to be the worst case of 3 days above. Thus, these ten AA batteries would be able to run the device for an estimated 45 days before charging is needed.

The Raspberry Pi Zero W can be powered by USB cable, and there are many USB battery packs available that would be able to power the microcontroller for at least a day at a time. The battery requirements for the microcontroller design would include the constant power to the Raspberry Pi at about 6 W Maximum for the entire day. This can be estimated to be about 2 W on average throughout an entire day (including activations) as the idle power will be much less than when trying to activate modules. At 12 Vdc, this comes out to be about 0.1666 Amps. Multiplying this by a 12 hour day shows that 2 Amp-hours of battery will be required. As determined above, this can be accomplished with ten AA batteries, or with a rechargeable battery pack that will have an even higher capacity. Therefore, no matter which design is utilized by the customer, they will be able to use the automatic dog treat dispenser all day long on a single charge. The general operation of either style design is shown in Figure 18 below.

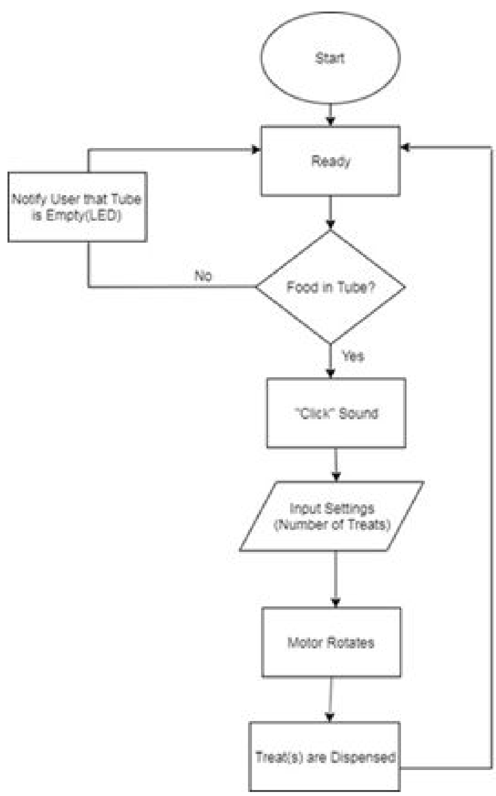


Figure 18: System Model Flowchart

As shown in the flowchart, every device operation should be achievable from a single input. There should be one feedback letting the user know whether or not treats are present in the storage or dispensing area, but everything else is directed towards processing and dispensing treats to a service dog. Once the treats are dispensed, the process starts over and waits for user input.

Detailed Design

Previously in the proposal document, there existed four different designs. This stemmed from two major design components such as a rotational dispenser mechanism, and a dual slot design dispenser mechanism as shown below as Figures 19 and 20, respectively.

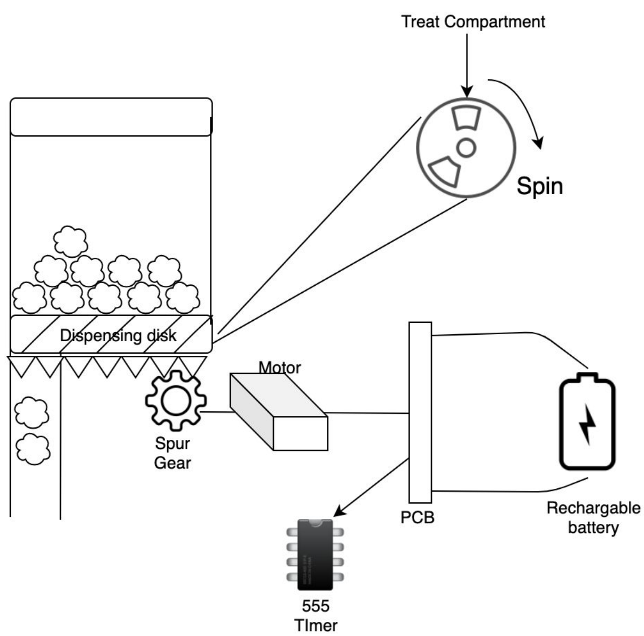


Figure 19: Design with Rotary Dispensing Mechanism

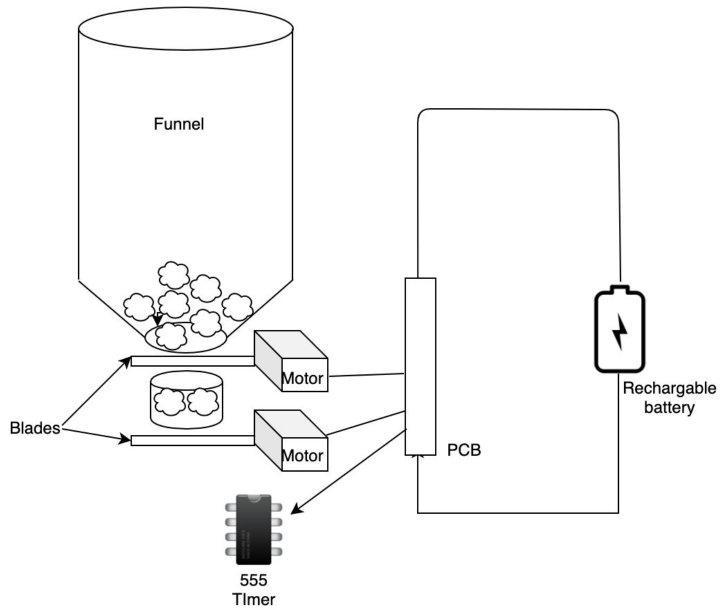


Figure 20:Design with Dual-Slot Dispensing Mechanism

As depicted above, Figure 19 shows a rotational dispensing disk that rotates upon activation of a button to dispense a treat. Figure 20 shows how the dual slot mechanism operates by actuating a first arm in order to drop a treat into the placeholder, and then closes to prevent other treats from dropping in. The second arm would then open in order to allow the treat to drop into a bowl below to allow the dog to receive a treat. These are the two main designs that we previously have chosen to base the dog treat dispenser off of.

However, based on a review of both designs, it has been decided to move forward with the rotational mechanism based dog treat dispenser. Not only will this design require half the servos to dispense a treat, but it will also allow for a more simplistic design that saves money and energy. The major difference in the two designs the team is moving forward with will be what actually controls the system.

The first design will utilize passive components on a printed circuit board (PCB) and 555 timer chips to control the system. The second design will utilize a RaspberryPi Zero W microcontroller in order to control the system.

Using a PCB will allow for an overall lower cost (in components and materials) and allow someone to simply “plug and play” with our design in regards to reproducing it. This “plug and play" action will be suitable for someone with little to no engineering experience to build the automatic treat dispenser design so many people will have access to it. On the other hand, the microcontroller based design (Raspberry Pi Zero W) will require some minimal background in electronics when it comes to programming the system and making sure the General Purpose Input and Output (GPIO) pins are hooked up correctly to allow the dispenser to function properly. With the two major design controllers noted, the decomposition of the designs are as follows.

Overall Design

The automatic dog treat dispenser will implement a design that is robust while being sleek and lightweight. Since the treat dispenser will be installed on a wheelchair, it cannot interfere with the normal operations of the wheelchair, nor limit locations that the user can go in the wheelchair. It will be low profile and able to mount anywhere with adjustable tubes to accommodate a low or a high mounting of the device. The device will be battery powered to work autonomously from the rest of the wheelchair. It will not be responsible for draining the wheelchair's power as there are more important functions of a wheelchair than a dog treat dispenser.

The dog treat dispenser will integrate seamlessly with the end user's switches/buttons using a 3.5mm mono-jack as connection. This connection is simply needed to close a circuit that will trigger the dispenser when activated and remain open otherwise. The project will also explore the creation of a switch using accelerometers or some other method (perhaps using fiber and detecting vibrations due to movement). This portion is still to be discussed and can be further investigated once the main treat dispenser has been completed.

There are four main areas for the automatic treat dispenser: the dog treat storage compartment, the treat staging and dispensing area, the circuitry and mechanism to activate the treat dispenser, and the treat deployment tube.

Treat Staging and Dispensing Mechanism

The treat staging and dispensing area influences what the mechanism to activate the treat dispenser should be, as well as the dog treat storage compartment. The dog treat storage compartment feeds directly into the dog treat staging and dispensing area, and the circuit has to work for whatever mechanism is established, so the design must start here. The style in which the design will be based off of is the gumball machine style (rotational mechanism).

The gumball machine style consists of a horizontal, circular plate that spins on an axis perpendicular to its center with cut outs to drop the treats through a hole when they are to be dispensed (Figure 21). This plate would have three to four openings (dependent on rotational disk) around the outside that are just large enough to hold two to three treats side-by-side[15].

This spinning plate would then sit on top of another plate that has only one hole in it the same shape as the openings in the spinning plate. This plate would be static and should be able to line up with one of the openings in the spinning plate at a time. There would then be one more plate above the spinning plate with an opening that is large enough to let treats filter into one or two of the openings on the spinning plate at a time. The opening would have to be offset from the opening of the bottom plate and towards the start of the rotation after the bottom opening.

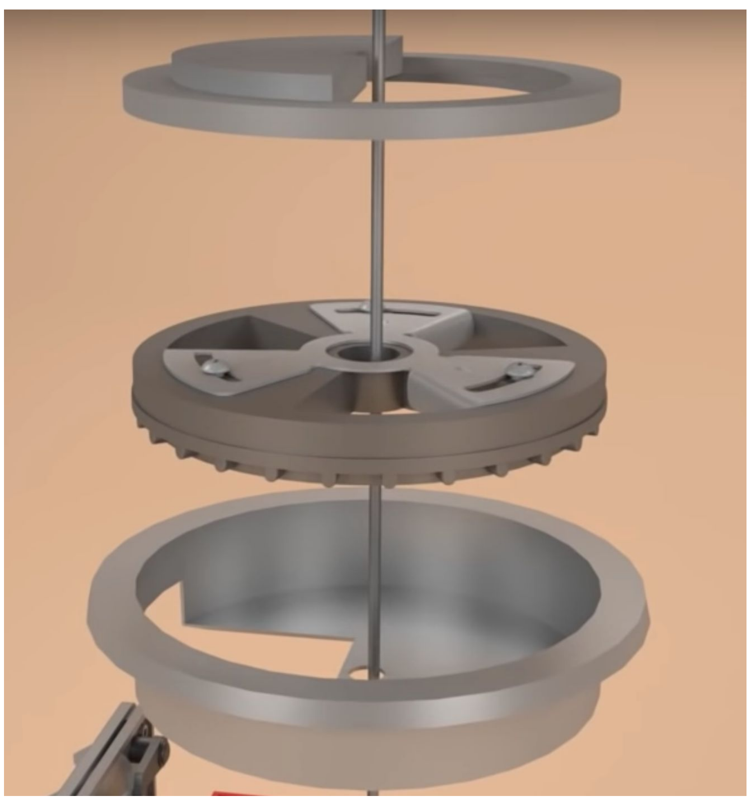


Figure 21: Dispensing Plates

These three circular plates would be at the bottom of the dog treat storage compartment so that all the treats sit on top of them and can be filtered in as the spinning plate is activated. The spinning plate should turn 1/3 of a full spin at a time (due to the 3 evenly sized compartments) and have an opening line up with an opening in the bottom plate each turn.

Thus, the treats are loaded into the spinning plate one or two openings at a time and then dispensed one opening at a time for each activation. The number of openings will have to be tested to determine what works the best and provides the most consistent results.

The great fact to note about this style of dispensing mechanism is that the gumball machine style rotational disk is usually adjustable as shown below as Figure 22.

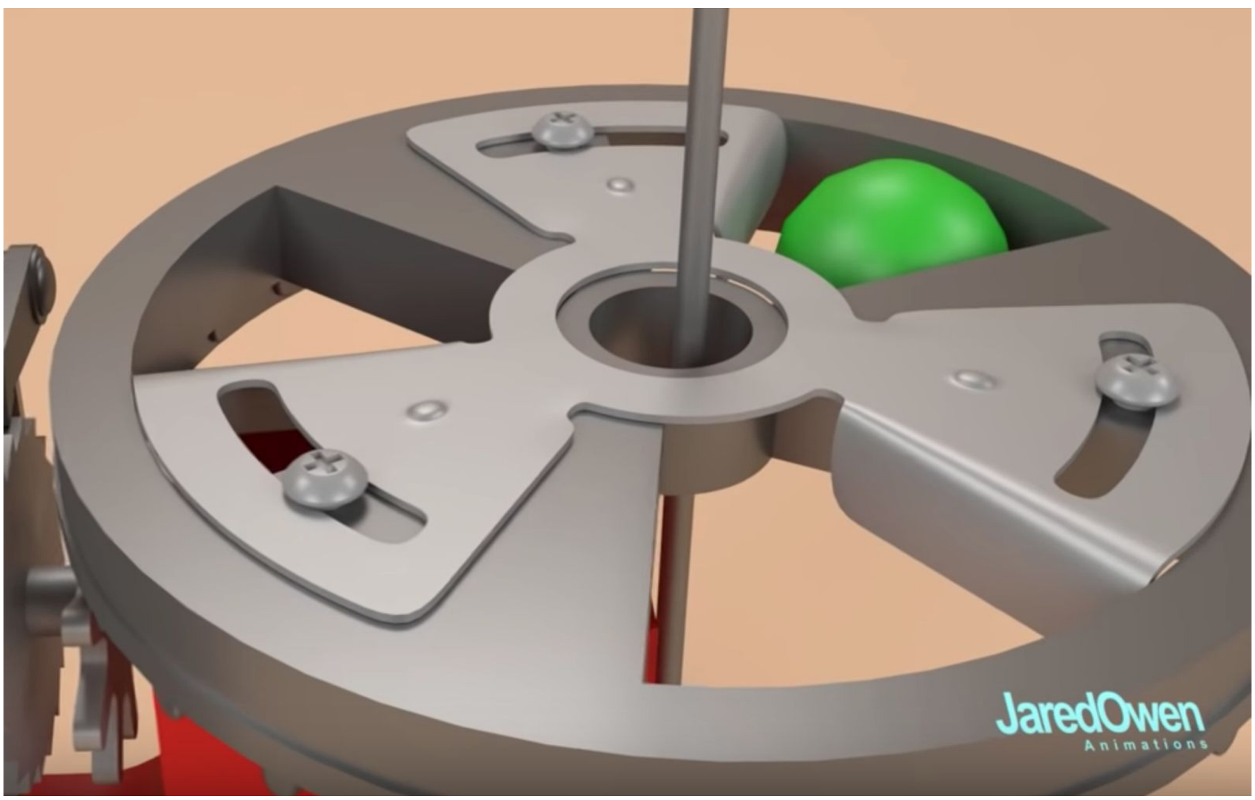


Figure 22: Dispensing Mechanism

The screws on the plate will allow for the user to adjust the spacing in order to let a treat (shown as a gumball above) drop into the space so the user can drop as many treats per activation as they wish.

In order for the disk to rotate, the normal gumball machine handle is normally activated by a user twisting the handle. As shown below as Figure 23, the handle will be replaced by a servo to allow for an electronic activation to spin the disk.

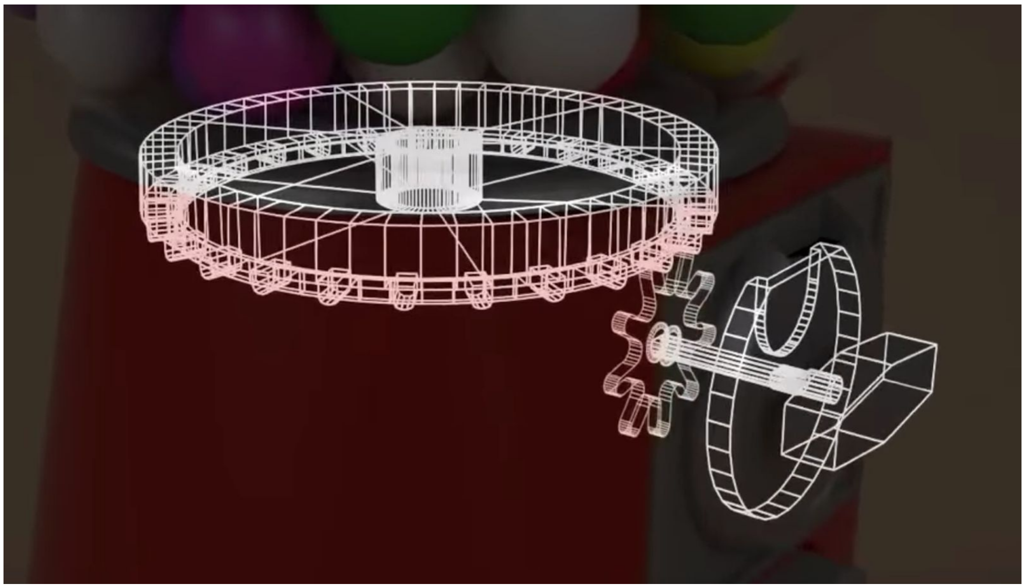


Figure 23: Rotary Mechanism

The servo will be attached to the handle portion of this spur gear in order to drive the larger rotational disk above to allow a treat to be dropped and be provided to the dog.

Although this design will allow for great control over the treats being dispensed, this design may be susceptible to jamming, and dog treats can sometimes get sticky in humid areas, so preventative measures must be taken. These measures can be taken within the dog treat storage compartment.

Dog Treat Storage Compartment

The storage compartment will have smooth, easy to clean surfaces, and be detachable for cleaning. The material used will need to be food safe. It should also be transparent or translucent enough for the user to see the amount of dog treats still available at any time. The bulk of the storage compartment will be of stainless steel which is a food safe material. The compartment will be slim and wide to hold at least a cup of dog treats at a time and ensure the wheelchair's profile is minimally impacted.

The storage compartment will have a funnel type bottom to feed the staging area of each dispensing mechanism with dog treats. The funnel will also have sharp enough slopes so the treats do not get stuck.

The dog treat storage compartment will also have an internal vibrator that activates when the automatic treat dispenser is activated. This is to help ensure that the treats feed into the staging area and jams are broken free. The vibrator can also be attached to the outside of the storage compartment (to avoid stopping treats from falling down within the compartment).

There will also be a hinged lid on top of the storage compartment with an easy to use latch/clasp for simple refills. The lid will have a seal to make sure the dog treats do not spill out the top of the compartment.

The dog treat storage compartment will be the largest part of the dispenser so it will also have a flat face with some mounting tabs to make it easy to mount anywhere on a wheelchair. The storage compartment will be tightly secured to the dispensing mechanism and the rest of the treat dispenser so that no other mounting points will be needed.

Circuitry and Activation Mechanism

The circuitry in the PCB based design style will require the use of a timer circuit. This timer circuit will need to activate a motor for long enough to spin the gumball style dispensing mechanism.

The circuitry both of the designs will require a motor to spin the plate/wheel far enough to dispense the treats. The motor speed will be used to time how long it takes for it to spin the plate/wheel to the correct position and the timer circuit will be built accordingly to keep the motor activated for that amount of time [16].

Another method would be to use limit switches that are bypassed when the device is activated and then activated right after so that the device stops when a limit is reached. These can be user adjustable for troubleshooting purposes [17].

The circuitry will be installed within a sealed container to protect the components from damage. The PCB will be designed so components can be easily replaced and will be mounted on rubber mounts to protect the circuit from vibration damage [18]. All connections will be solid enough for a long life under normal use.

The circuit will have a 3.5mm mono-jack input to activate the circuit (in place of the shown input switch) and will be battery operated for autonomous operation. The 3.5 mm mono-jack will be the connection point for the switch of user's choice. The circuit itself will look at this portion as a simple switch that closes the circuit when the switch is activated. The lower right circuit depicts the activation circuit. When a button/switch is pressed, it will keep the circuit on for a specified period of time (via the time constant of the 1000uF capacitor or time constant of the Raspberry Pi zero w), and will turn off the circuit when the capacitor is discharged (or time constant is reached).

As previously mentioned, the circuit that controls the motor speed will use a 555-timer chip to create a Pulse Width Modulation signal to drive the motor [19], [20], [21], [22]. This will spin the motor/servo in a direction (e.g. clockwise or counterclockwise) in order to actuate the dispensing mechanism.

An accelerometer type switch will also be investigated as a method of activating the treat dispenser. This device will be wireless for easy use and help those individuals that lack any kind of dexterity. A simple nod could be enough to trigger the accelerometer and activate the treat dispenser. This activation switch will be implemented once the treat dispenser is functioning as needed.

The circuit will also include a small speaker that emits the dog training clicker sounded to pique the interest of the service dog.

Dispensing Tube

The Dispensing Tube would be the simplest part of the dog treat dispenser. It will consist of a tube that allows the dog treats to easily slide through, and a tray attached at the bottom that will catch the treats and provide a constant location for the service dog to go to for the treats. The tray will be constructed of stainless steel that will last with constant use by the service dog. It will be big enough for a fairly large service dog's nose to fit in so that it accommodates as many service dogs as possible. The tray will also have provisions for mounting it to a wheelchair, though these mounts will not be responsible for any of the device's weight. It will simply help to hold the tray in place and ensure the treats are dispensed to the tray.

The dispensing tube will be tightly attached to the bottom of the dispensing mechanism and should be only slightly larger than the opening the treats will be dispensed through. The tube will be flexible so that the storage compartment and dispenser portion can be mounted in a variety of locations and still allow the use of the same tube.

Functional Block Diagrams

Level 0:

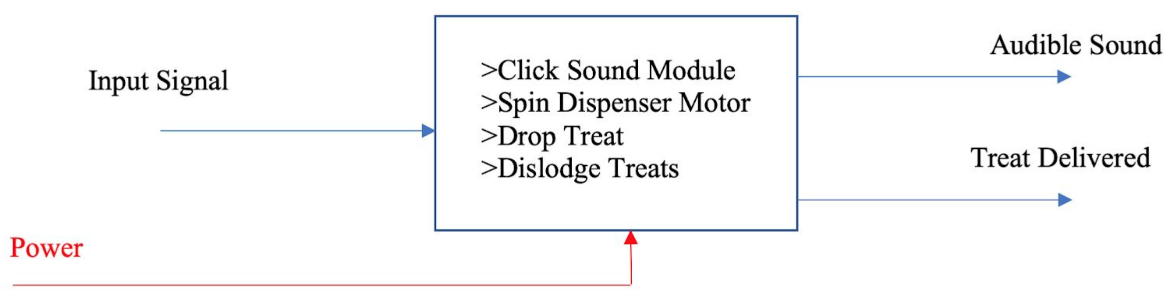


Figure 24: Level 0 Functional Block Diagram

Shown above in Figure 24 is the Level 0 Functional Block Diagram. This is a high level representation of how the treat dispenser will operate via input(s), outputs, and the "black box" in between where all the design functions and dispenser modules operate. The input signal will be the activator for the whole control system. This will control each of the modules contained within the design: the Click Sound, Spin Dispenser Motor, Drop Treat, and Dislodge Treats modules. The outputs of the system are the treats being delivered to the service dog, the audible "click" sound that will entice the dog, and any other notifications needed to be provided to the user based on the status of the treat dispenser (e.g., empty treat storage area).

Level 1:

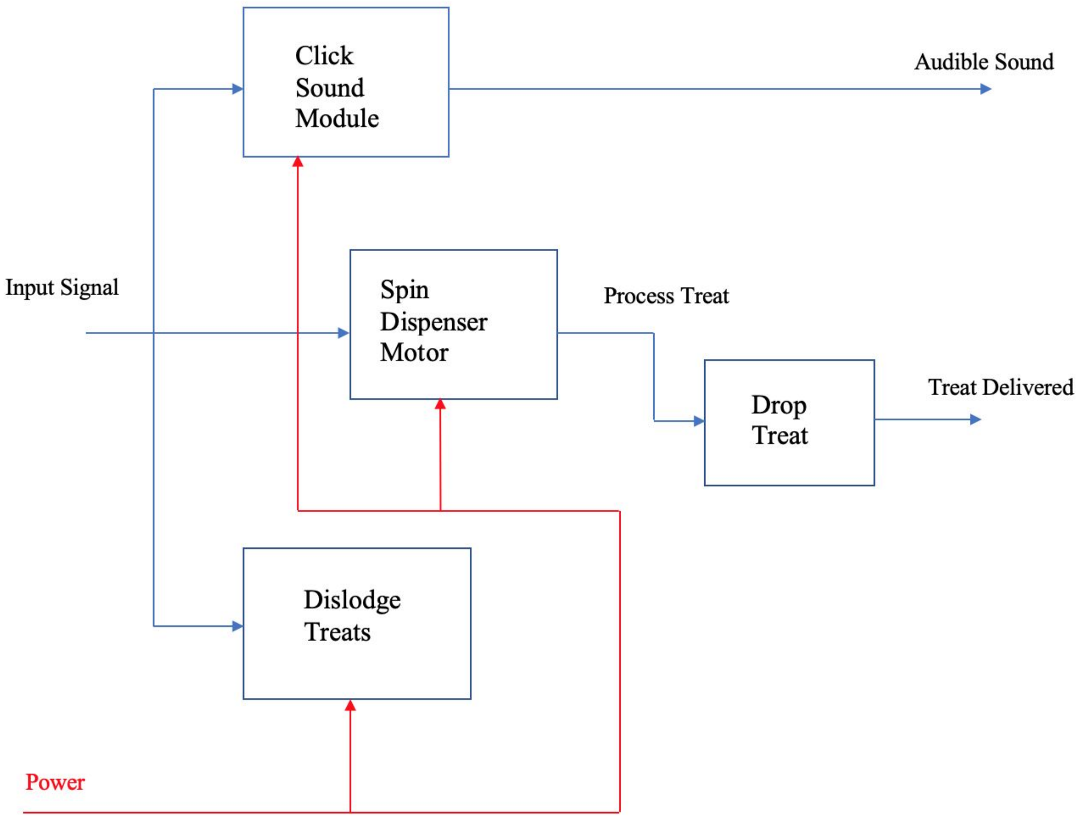


Figure 25: Level 1 Functional Block Diagram

The Level 1 functional block diagram in Figure 25 above depicts how the modules within the "black box" from the Level 0 diagram are connected. The input signal will be routed to the click sound component, spin dispenser motor, and the dislodge treats module. This input signal triggers the treat dispenser and lets it know that a user would like to provide a treat to their service dog. In turn, this trigger will produce the "click" sound, spin the dispenser motor, and dislodge any stuck treats in the mechanism. The spin dispenser motor will then process the treat (move the treat over to the hole to drop a treat) where, finally, the drop treat module will simply provide the treat to the service dog. A more in-depth analysis on each of the components / modules is shown below in Figures 21 through 24, the Level 2 functional block diagrams.

Level 2:

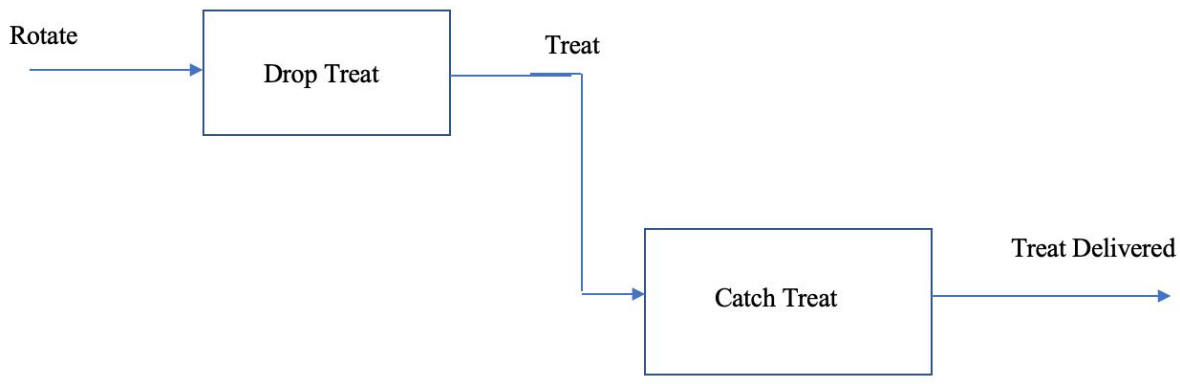


Figure 26: Level 2 Functional Block Diagram for Drop Treat Module

Figure 26 above represents a cascaded system that will serve as the main function of the design. The input signal is now denoted as "Rotate" as the input signal will now make the drop treat module physically rotate the gumball style mechanism to provide a treat to the dog. A servo will act as the component that will create the rotational force to spin the rotating disk. Once the disk is rotated, the treat will then enter the "catch treat" portion so the service dog will be able to receive/obtain the treat. Once the device is in the "Catch Treat" mode of operation, the treat will be simply caught, and the dog will be able to take the treat from a receptacle, which completes the "Treat Delivered" portion of this module.

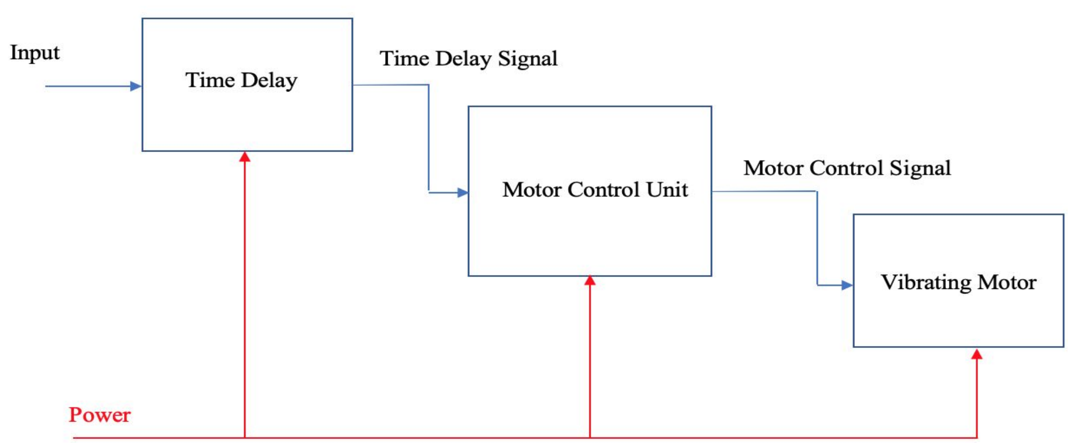


Figure 27: Level 2 Functional Block Diagram for Dislodge Treats Module

The diagram in Figure 27 above shows the dislodge treats function of the treat dispenser. The input signal will activate a time delay circuit that will allow the motor to spin for a specified amount of time. This time delay will primarily come from the use of a large capacitor so when the input signal is received, the circuit will allow the voltage to flow to an input of another timing circuit. This time delay signal is then routed to the motor control unit which will utilize a Pulse Width Modulation control signal (motor control signal) to spin the vibrating motor. This will be provided by either a 555 timer chip, or the raspberry pi depending on which design is in use. Next, this signal will simply drive the vibrating motor so that if there are any treats stuck in the system, they will be dislodged and returned to normal treat storage, ready to be dispensed to a service dog.

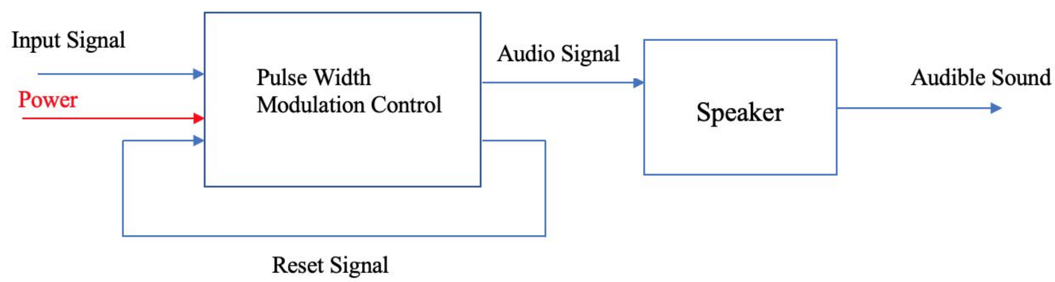


Figure 28: Level 2 Functional Block Diagram for Click Sound Module

The next block to be discussed will be the Click Sound module. This will utilize the input signal from the user's switch (connected to mono-jack port) to control the 555 timer circuit or the RaspberryPi to produce a sound that is audible to the service dog. The Pulse Width Modulation control block comprises of the input signal to initiate a PWM signal that will generate an audible sound signal comparable to the clicker sound used in dog training. In the case of the RaspberryPi microcontroller, a saved waveform depicting the audible sound to be passed through to the speaker as a result of the input trigger. The PWM control block also consists of a reset signal so that further commands for dropping a treat will have a sound ready for the dog to hear indicating a treat has been dropped. This audio signal will then be passed to the speaker so that the dog can actually hear the audible sound produced from the PWM control block.

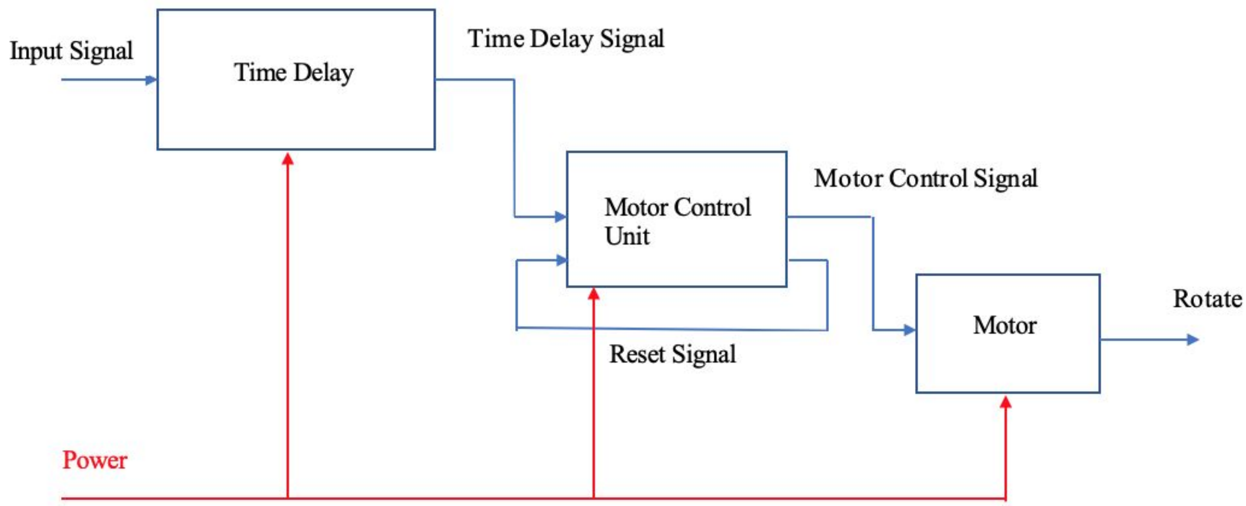


Figure 29: Level 2 Functional Block Diagram for Spin Dispenser Motor Module

The spin dispenser motor will be the last module discussed. This module will receive an input signal from the user based on a button / switch actuation, which will then be routed to a time delay circuit. This time delay circuit will work in the same manner as the dislodge treats module will, although this time delay signal will then control how long the motor will actually be spun to rotate the disk. The motor control unit will then receive the output signal from the time delay circuit and set the time constant for the motor to spin. The motor control unit will also comprise a reset signal to ensure it is ready for further treat dispensing commands from the user. This will be done either through the 555 timer, or the raspberry pi as previously mentioned based on which design is in use. Furthermore, the motor will receive its input signal as a steady pulse for the duration it should be active, which will result in the motor spinning the rotational disk the 120° needed to drop a treat(s).

All of these modules interconnect to create a cohesive design. At each step of the process, the device is in different states, so a state diagram can also be utilized to explain how all the modules come together. This is shown in Figure 30 below. The initial state is to go from an unknown state to “Waiting” in the top left marked with 0. There is only one thing that can happen from this state, which happens when the dispenser is activated. The state of the device then moves to position 1, “Spin Motor” where there are two possible outcomes. The motor either spins for a given amount of time and comes back to this state until a treat can be dispensed. Once a treat is dispensed, the device goes to state 2, “Dislodge Treats.” Here, the user can determine whether or not treats were dispensed. If not, the dislodge treat button is pressed and the device goes back through states 0, 1, and 2. Once the treat is dispensed correctly, the treat is dropped and the device moves to state 3, “Dispensing,” which is the final state of the device. Here the treat is either held and the device remains in state 3, or the treat is retrieved by the service dog, which triggers the device to return to state 0, “Waiting.” This process repeats itself until the treat storage compartment is empty and needs to be refilled, or the batteries need to be recharged. After one of these breaks, the device reinitializes as shown by the arrow at the top left and goes to state 0, “Waiting.”

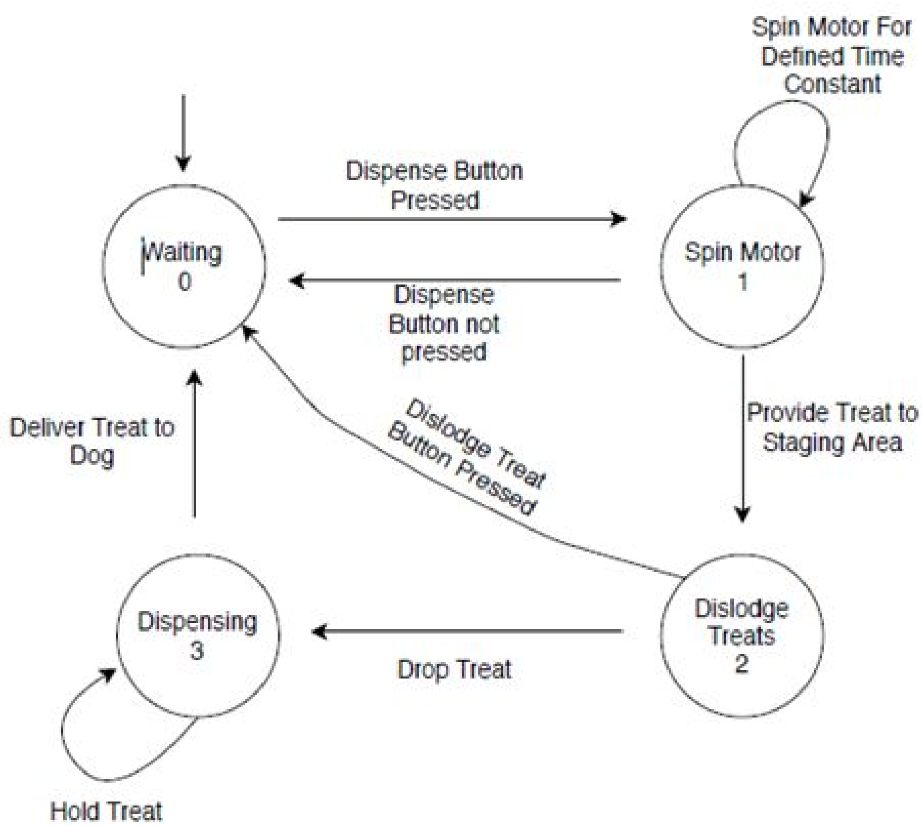


Figure 30: State Diagram of Automatic Dog Treat Dispenser

Software Flowchart

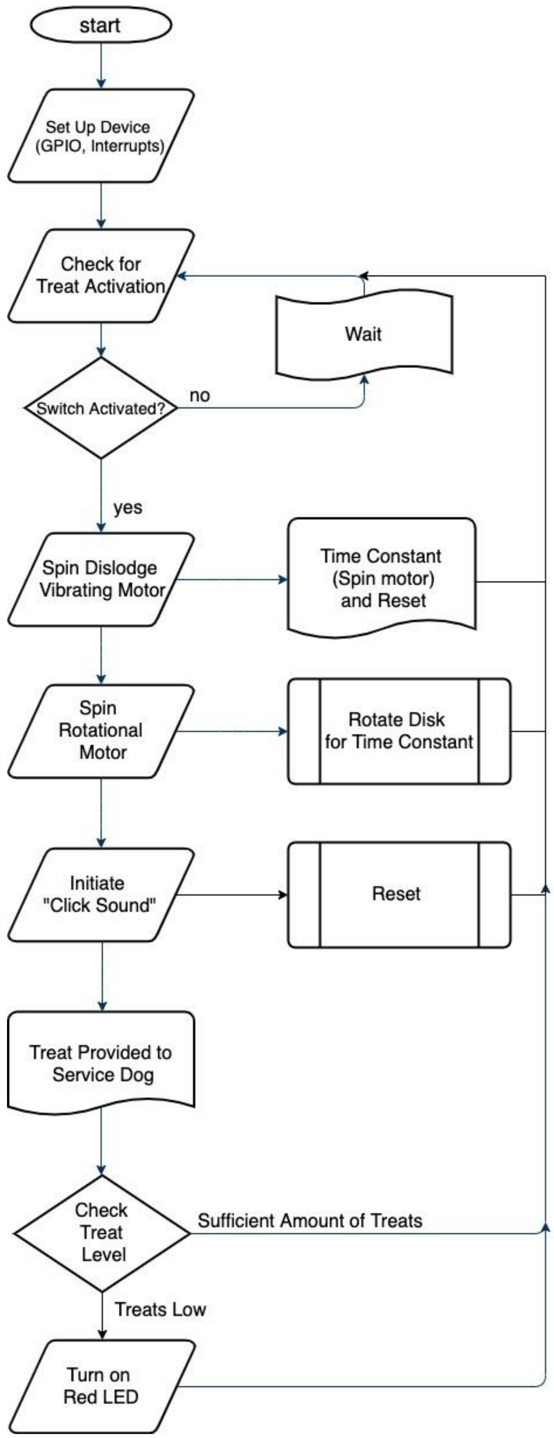


Figure 31: Software Flowchart

Software Explanation

The software flowchart shown above in Figure 31 depicts how the RaspberryPi will operate. First, the RaspberryPi will go through a startup session. During this start up session, the device will set itself up by using RaspberryPi libraries for GPIO ports to designate the pins to their correct functionalities. Not only will the device be set up, but the interrupts will also be set. The interrupts will allow for the RaspberryPi to "wait" for an activation signal that will initiate dispensing a treat without the need for button polling.

Immediately following the startup session, the Raspberry Pi will monitor via interrupts the activation of the switch. If the Raspberry Pi detects a switch activation, this is when dispensing a treat will commence. If the switch has not been activated, it will simply stay in a continually monitoring period, wherein the Raspberry Pi will wait for the activation signal. If the switch has been activated via an interrupt, this will cause the dislodge treat function to start.

The dislodge treat function will activate the spinning of a vibrating motor located on the dog treat container. This will allow for any "stuck" treats to be shaken loose by the force of the vibrating motor. The motor will continue to spin for a time constant before going back into a waiting period to be activated again.

Next, the dog treat will actually begin to be dispensed via the "Spin Rotational Motor" function. This will simply spin the motor to allow a dog treat to be provided to the dog. The rotational motor will also spin for a designated time constant to allow a treat to be moved into place to align with the hole below. Upon finishing spinning for the time constant, the motor will stop spinning, and await for its next activation. Once the treat is dropped into place, the familiar click sound will then be played in order to alert the dog of a treat being dispensed. At this point, the treat will then be provided to the dog.

As a final check, in order to ensure that the dog is never without a treat, the system will check to see if any more treats need to be added. If the treat container has a low amount of treats, the system will send a signal to a red LED to alert the user that they are low on treats. If the container has a sufficient amount of treats left, then the Green LED will turn on. Once the function has completed, the Raspberry Pi will go back into its waiting period and wait for another user input to initiate a treat to be dispensed.

Material and Components

The main components of the automatic treat dispenser design as described so far are the storage compartment and treat staging/dispensing area, the circuitry, the motor, and the power source. To determine the best material and devices for the design, the following decision matrices shown in Tables 1 through 4 were completed. For each of the four categories listed, 3-5 possible contenders were researched and compared based on the listed criteria. The criteria was also ranked from 1 to the number of criteria based on the importance for the intended design.

	Criteria and Weight of Importance for Design						
Servo Motor Model	Power [4]	Speed (rpm) [3]	Torque [5]	Rotation Angle [6]	Weight [1]	Cost [2]	Totals
FS90R	5	5	4	5	5	5	100
NG90	4	4	2	0	4	5	52
STEMKT/AC/D	5	3	3	5	4	4	86
S3003	5	3	2	0	4	2	47

Table 1: Decision Matrix for Servo Motor

Figure 32: FS90R Servo Motor

The first component to be analyzed is the Servo Motor. This piece is integral to the design and the entire dispensing mechanism relies on it. Thus, the most important aspects are for the motor to do its job in being able to turn the required 360°, and to have enough torque to turn the dispensing mechanism and dispense treats to the service dogs. Next most important is the power requirement. In order to keep the cost and size of the device low, the power requirement needs to be low so as few/small batteries as possible are needed. Then, the speed of each motor is compared. This is less important since all the motors have speeds that will dispense the treats in around 1 second. Finally, the least important aspects are cost and weight since these are normally very cheap and light. Thus, these are non-issues for the design. After implementing these requirements, the FS90R Servo Motor was found to be optimal.

Model	Criteria and Weight of Importance for Design					Totals
	Cost [1]	Size [3]	Power [4]	Familiarity [5]	Avail [2]	
RPI 3B	4	3	3	3	5	50
RPI ZERO	5	5	4	5	5	71
RPI 4B	3	3	3	4	5	54
TNKBRD	2	3	3	2	3	39
MSP430	1	5	5	2	1	48

Table 2: Decision Matrix for Mircrocontroller

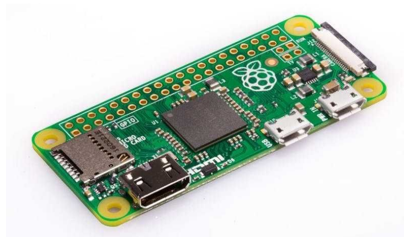


Figure 33: Raspberry Pi Zero W

The next main component to be evaluated is the Microcontroller. The decision on this part selection could be the difference between a successful project and a failed experiment. If the microcontroller is picked that no one on the team is familiar with, there will be a challenge to learn the language and implement the design as needed. Thus, it is crucial to pick a microcontroller that someone on the team is familiar with. Next, the power and size are the most important features to keep battery requirements and bulk down. Finally, the cost and availability are compared against each other and it was found that the Raspberry Pi Zero W is the optimal choice for this design.

Material Type	Criteria and Weight of Importance for Design				Totals
	Cost [2]	Durability [3]	Food Friendliness [4]	Team Preference [1]	
Stainless Steel	3	5	5	5	46
Glass	3	3	5	2	37
Plastic	5	4	3	2	36

Table 3: Decision Matrix for Housing / Food-Safe Material

Figure 34: Stainless Steel

The largest component is the one responsible for keeping the device together as well as protecting it is the material for the storage compartment and circuitry housing. This material should also be used for the dispensing disk as it will be food-safe and easy to clean. The main requirement here is for the material to be food-safe and durable to ensure the device lasts. The winner here is stainless steel, but another metallic alloy like aluminum could also be used.

	Criteria and Weight of Importance for Design						
Battery Type	Voltage [1]	Cost [2]	Availability [4]	Weight [5]	Capacity [3]	Environmental [6]	Totals
Alkaline	1	5	5	5	1	1	65
Nickel-Metal Hydride	5	3	4	4	5	4	86
Nickel Cadmium	3	3	3	2	2	3	55
Lithium Ion	5	4	4	3	4	5	86
Nickel Zinc	4	1	1	4	3	5	69

Table 4: Decision Matrix for Rechargeable Batteries

Figure 35: Nickel-Metal Hydride (Left) and Lithium Ion (Right) Rechargeable Batteries

Probably the most difficult material to compare and decide on is the type of rechargeable battery to use. Here, the most important aspect is the environmental impact. Since the point of new technology is to improve lives, unnecessary waste is not an option. Next, since batteries can be heavy and weigh down the device, the weight is taken into consideration. Availability of batteries can also be a huge issue. There are many unique batteries so it is important to choose those that can be easily attained [23]. Next, we look at capacity, cost, and voltage. Again, the costs of almost every component is very small as compared to some electronics so the cost is not an issue. The capacity, however, is important in ensuring that the device will stay powered for at least a day at a time between battery charging [24]. The least important component is voltage since batteries can be added in series to get to required voltages, though fewer batteries is better.

Based on this criteria, two batteries tied in the decision matrix: Lithium Ion, and Nickel-Metal Hydride. This is actually good since the 555 Timer design and the Microcontroller design have different power requirements. Based on research, the Nickel-Metal Hydride batteries will be better suited for the 555 Timer design since the power requirements are less than that of the microcontroller design [25]. The Lithium Ion batteries make a good fit for the Microcontroller since they can be purchased as a battery pack with 5 Vdc USB outputs (power for Raspberry Pi) and 12 Vdc mono-jack output, providing flexibility and ease of use.

Prototyping Progress Report

Schematic & Simulation Result

After performing some initial prototyping, it was determined that the circuit as simulated at the beginning of the design phase (Figure 15) was not going to be feasible. After some testing, the circuit as shown in Figure 36 below was built and found to operate the circuit as needed at a very basic level. The timing is still not correct and will need to be modified to match the servo motor, but it allows for the treat dispensing area to be designed and tested with the actual driving mechanism. This new circuit was simulated as shown in the right portion of Figure 36.

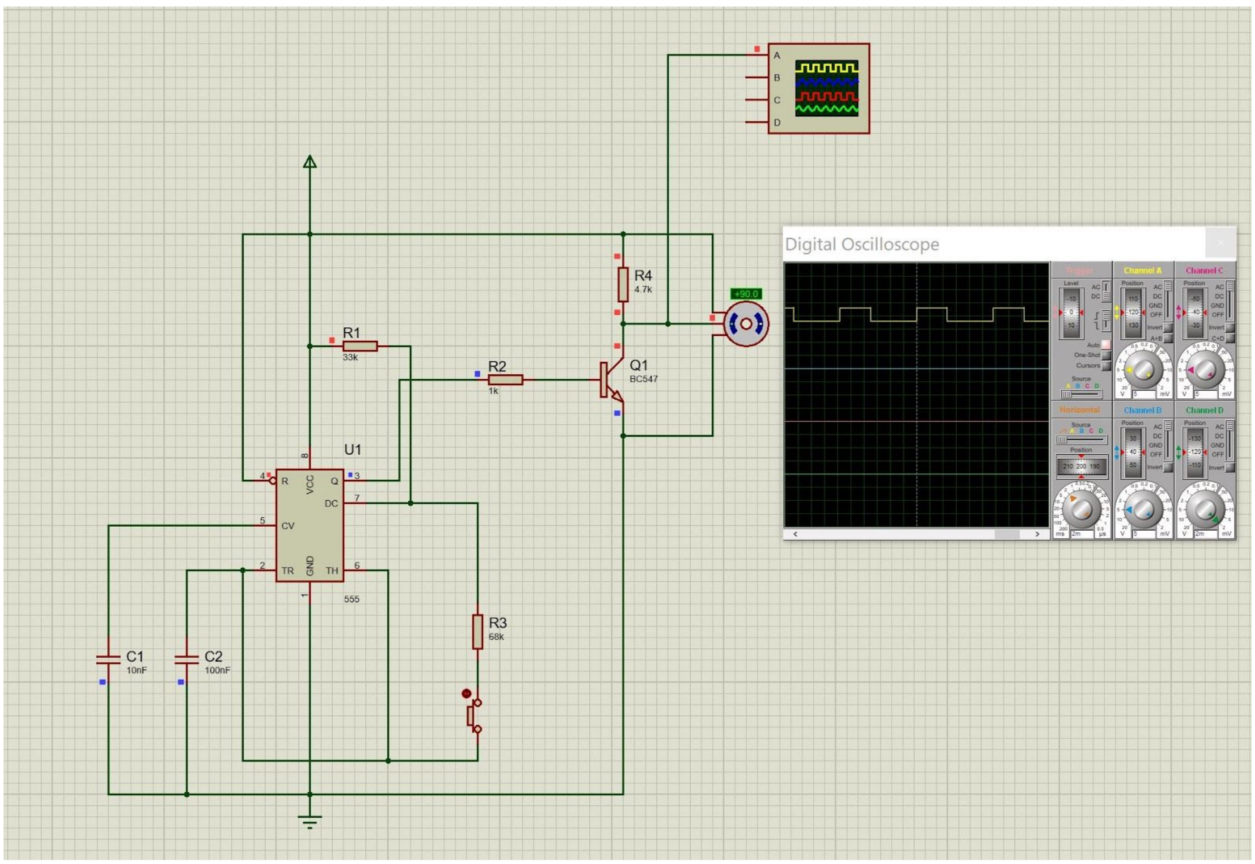


Figure 36: 555 Timer Circuit in Astable Operation

As can be seen in Figure 36's Digital Oscilloscope, the PWM (yellow) signal is successfully generated for driving the servo motor. The servo motor made a rotation of positive 90 degrees during the testing phase.

PCB Board using SMD Components - 3D View

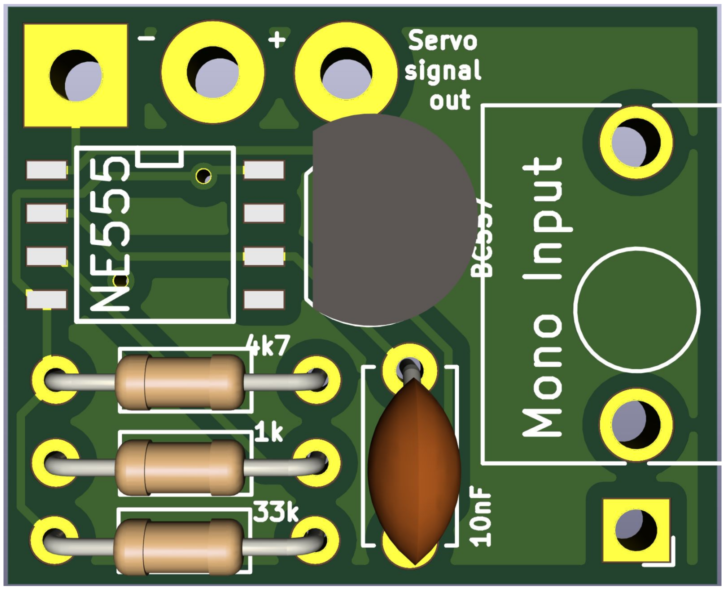


Figure 37: PCB Prototype (Board measurement: ***20*****mm by** ***17*****mm**)

Breadboard Circuit Testing

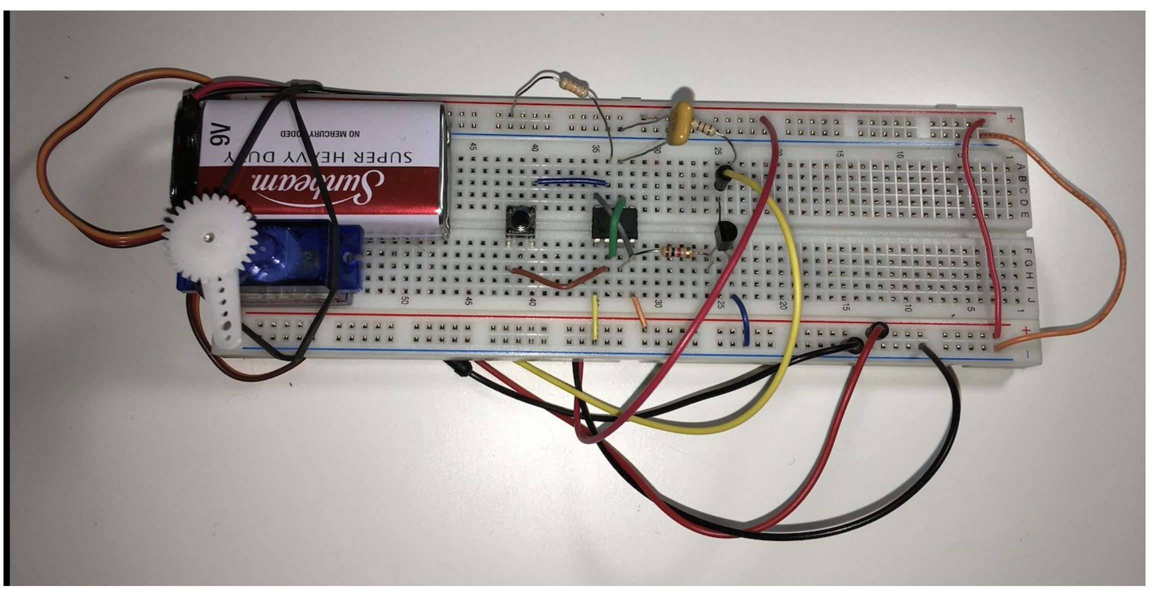


Figure 38: Breadboard Prototype

Comments: Breadboard simulation was carried out to check the functionality of the schematic shown in Figure 36 above. Real time breadboard simulation differed with the computer simulation as slightly different capacitor values were used.

Cardboard Prototyping

Utilizing cardboard, the treat dispensing mechanism was able to be visualized, and functionality tested as shown in Figures 39 through 41 below.

Figure 39: Top View of the Dispensing Disk

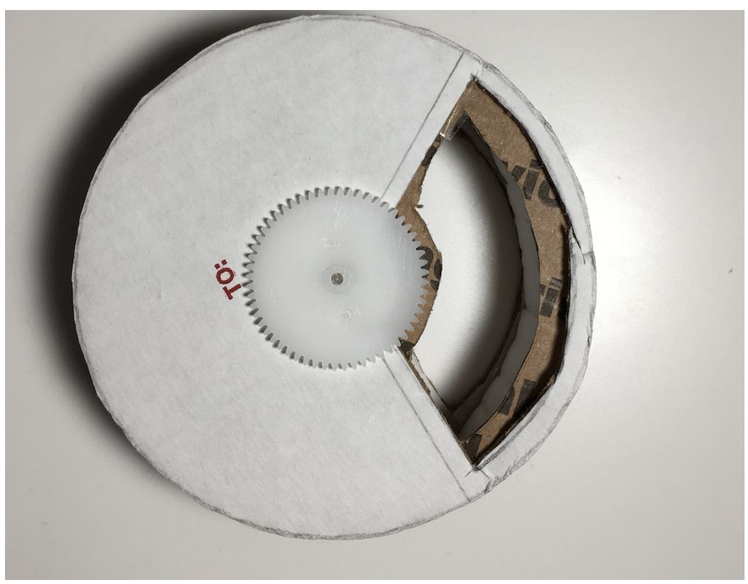


Figure 40: Bottom View of the Dispensing Disk

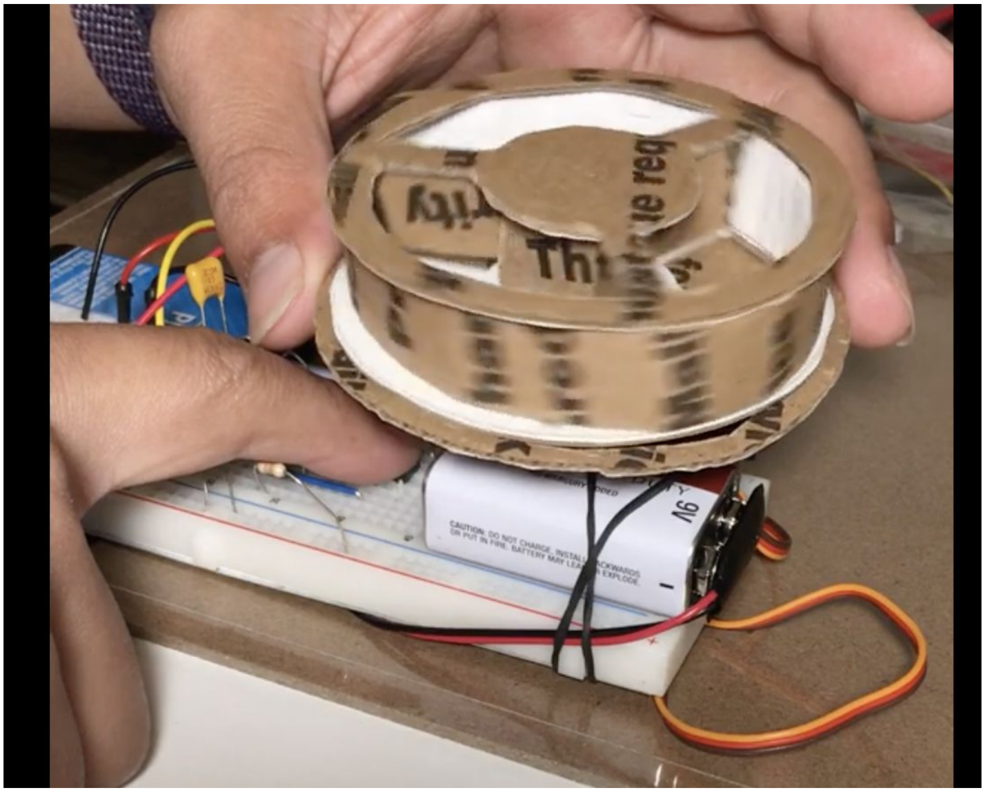


Figure 41: Prototype Testing of the Dispensing Mechanism

Raspberry Pi Prototyping

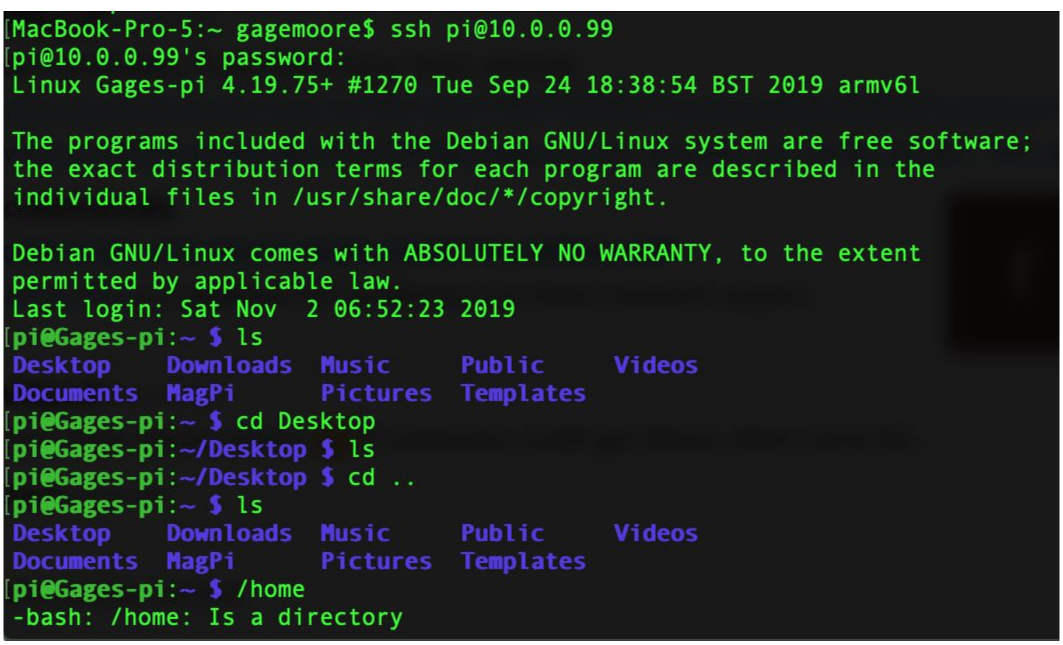


Figure 42: SSH into Raspberry Pi

Shown above in figure 42, the raspberry pi was effectively connected to via Secure Shell (SSH). SSH is secure shell encrypted protocol which allows for secure file transfer between the raspberry pi and a computer to load the files onto the microcontroller. This allows for our python files to be transferred to the raspberry pi itself in which it can run the appropriate code to control the treat dispenser.

Motor_Driver_File.py

```python
#Test Code for Servo Driver
import RPi.GPIO as GPIO     #Utilizing the GPIO Pins
import time
GPIO.setmode(GPIO.BOARD)    #Set the pins
GPIO.setup(7,GPIO.OUT)      #Set Pin 7 as Output
for x in range(0,3):        #Iterate Loop 3x
    GPIO.output(7,True)     #Turn motor on for 1 sec.
    time.sleep(1)
    GPIO.output(7,False)    #Turn motor off for 1 sec.
    time.sleep(1)
GPIO.cleanup()              #Finish Program

```

Figure 43: Servo Driver Code

Shown above is the actual code that is used to control the motor during our prototyping efforts. The code uses a series of import statements to help set up the General Purpose Input and Output ports of the Raspberry Pi. The code simply runs a loop three times that spins the motor clockwise for a second and then turns it off.

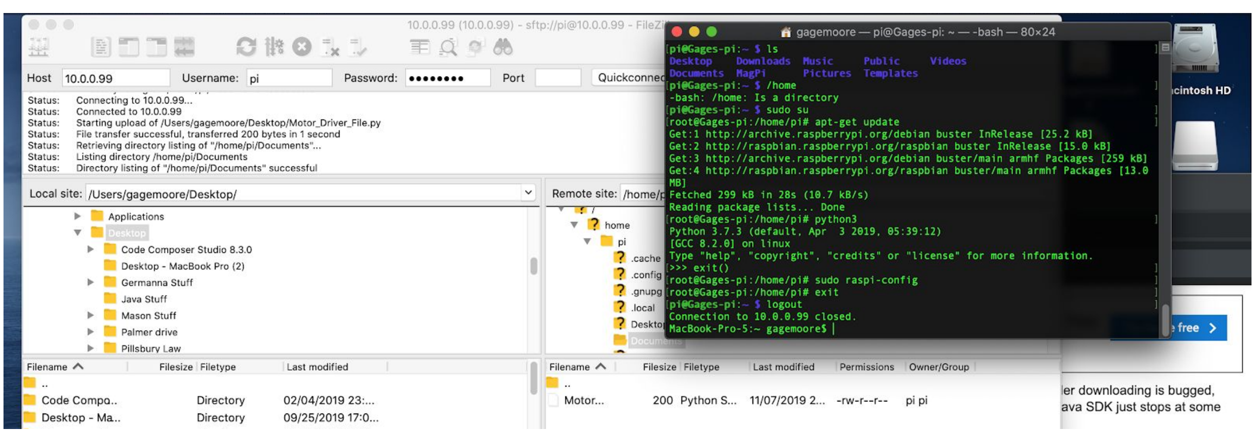
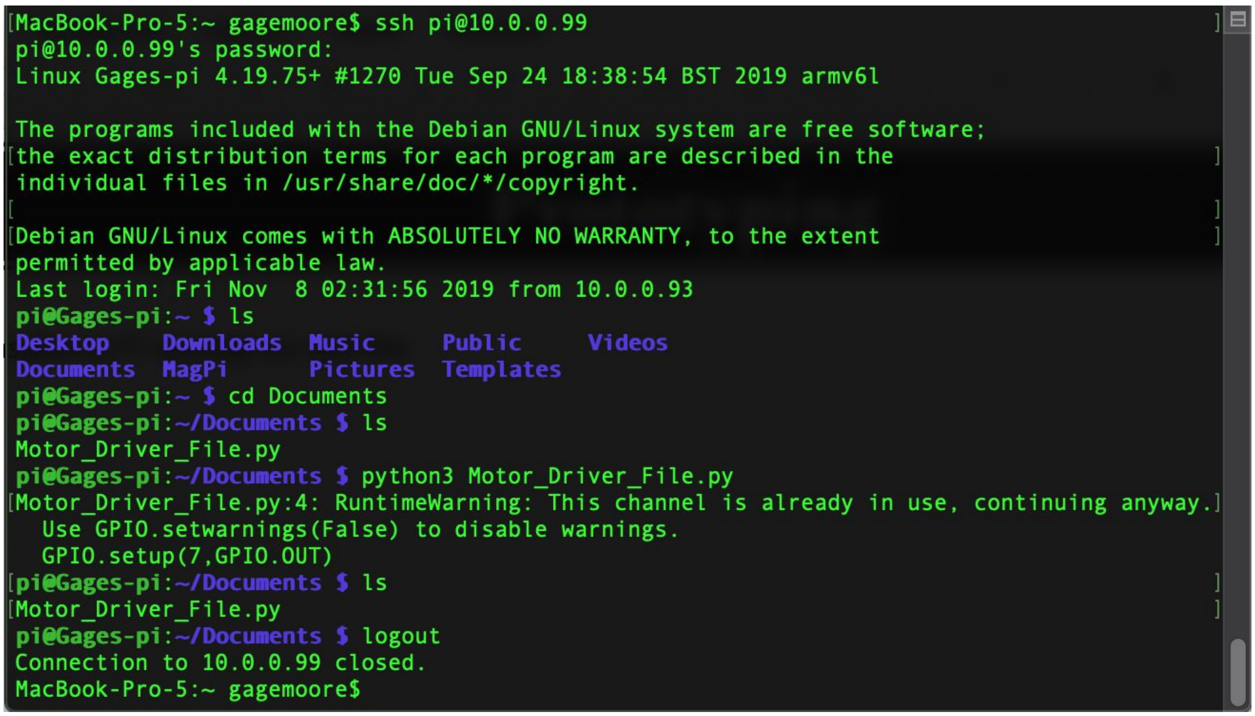


Figure 44: FileZilla SSH Client Usage

Figure 44 above shows how the application FileZilla (an SSH client to help migrate code over to the Raspberry Pi) is used. All that is needed to be known prior to using the tool is the ip address of the Raspberry Pi, along with the login credentials. Once we were able to log into the Raspberry Pi, we were able to successfully migrate the appropriate motor driver code onto the Raspberry Pi.



```
MacBook-Pro-5:~ gagemoore$ ssh pi@10.0.0.99
pi@10.0.0.99's password:
Linux Gages-pi 4.19.75+ #1270 Tue Sep 24 18:38:54 BST 2019 armv6l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Fri Nov  8 02:31:56 2019 from 10.0.0.93
pi@Gages-pi:~ $ ls
Desktop    Downloads  Music     Public     Videos
Documents  MagPi      Pictures  Templates
pi@Gages-pi:~ $ cd Documents
pi@Gages-pi:~/Documents $ ls
Motor_Driver_File.py
pi@Gages-pi:~/Documents $ python3 Motor_Driver_File.py
Motor_Driver_File.py:4: RuntimeWarning: This channel is already in use, continuing anyway.
  Use GPIO.setwarnings(False) to disable warnings.
  GPIO.setup(7,GPIO.OUT)
pi@Gages-pi:~/Documents $ ls
Motor_Driver_File.py
pi@Gages-pi:~/Documents $ logout
Connection to 10.0.0.99 closed.
MacBook-Pro-5:~ gagemoore$
```

Figure 45: Successful Operation of Code

Figure 45 above shows how the motor driver file was successfully run on the Raspberry Pi, and how exactly to do it using the command prompt from the Raspberry Pi. Figure 36 below depicts the microcontroller hooked up to the servo motor in order to control the device. The code successfully ran on the Raspberry Pi indicating that we were able to control the motor through this code as a good prototyping effort.

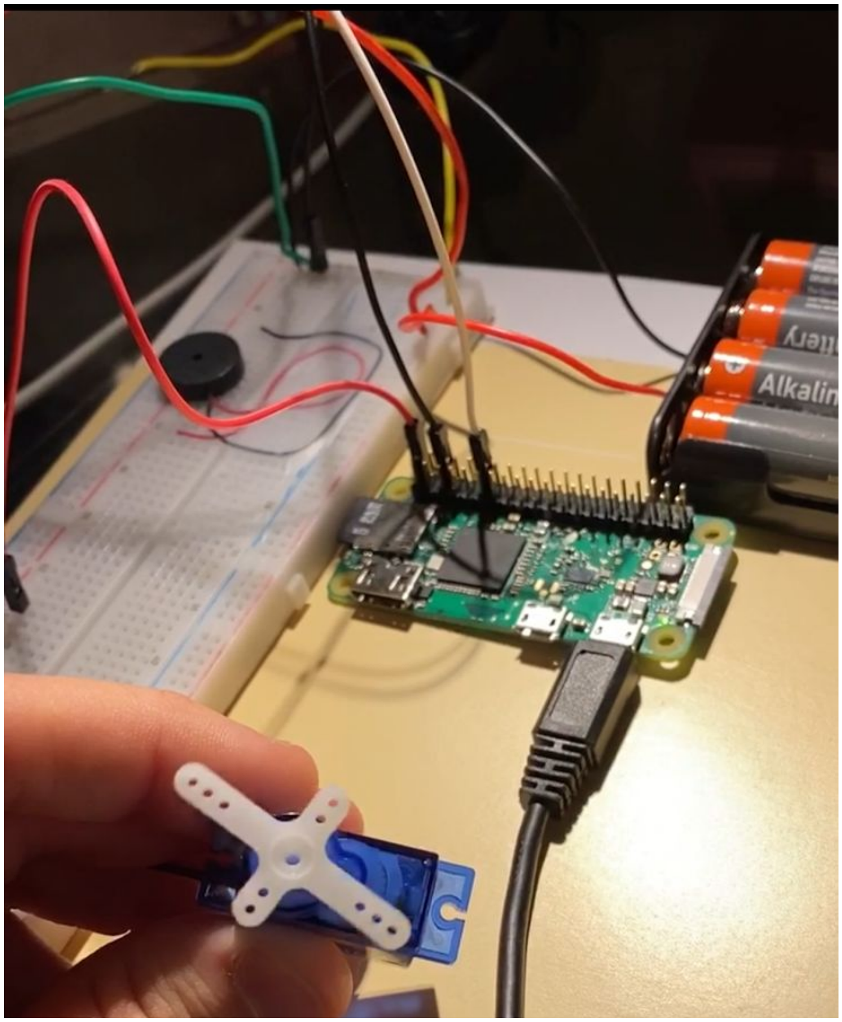


Figure 46: Successful Operation of Driving Motor (Video at treatdispenser.onmason.com)

Options to be Considered (Not Implemented)

Tests were carried out to test the servo motor. However, team has considered using Linear Solenoid Actuator to replace servo motor, should the circuit or the design fail. This actuator can be simply used to create a linear dispensing mechanism or create a similar rotary dispensing mechanism like of servo by converting linear motion to rotary motion.

Solenoid Actuators convert electromagnetic energy into mechanical energy resulting in a push/pull mechanism. It provides excellent force, but requires higher voltage and power (12V or more depending on its size) and is slightly more expensive than a Servo motor. This device could be easily implemented to activate a physical clicker in the device if the customer determines it is needed.

Figure 47: Solenoid Actuator

Solenoid Control Module

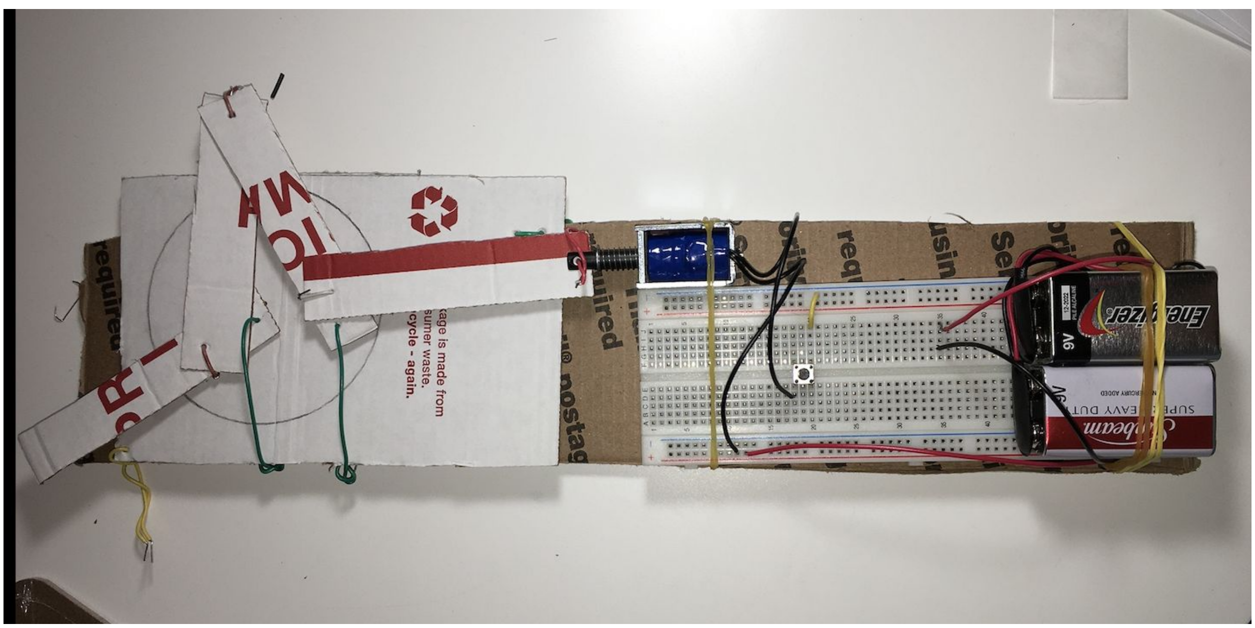


Figure 48: Prototype using a Solenoid Actuator

Comments: Solenoid control module prototype was created using cardboards to visualize the motor and parts movements. Working video of this module can be found on our website treatdispenser.onmason.com under the prototyping tab. The above prototype translates the lateral motion of the solenoid actuator to a rotational motion that can be used to activate the treat dispensing module.

Testing Plan for ECE 493

There are several test cases that the design team will perform in a controlled lab environment before involving service dogs and their owners. In order to start building our test cases we look back into our original functional and operational requirements and begin framing our test cases along those lines to ensure that we meet both the customers expectations and that the scope of the work does not fall victim to scope creep.

Functional Requirements:

1. The device will hold a minimum of a cup of treats at all times to provide rewards for the service animal.
2. The device shall use an accelerometer-based control input so that someone with limited physical mechanics can easily use the dispenser.
3. The device shall use timers to time and control dispensing mechanism.

From these requirements the first basic test cases can be derived. The first test case will be to ensure that the storage mechanism can properly hold a cup of treats, receive input from a switched device, and dispense a treat. This test case can **fail** in the following ways:

1. The storage device fails to hold the minimum amount and tips over and spills food
2. The storage device collapses after multiple dispenses
3. The storage device hole that food goes through regularly gets stuck
4. The device fails to accept accelerometer input
5. The device misinterprets the accelerometer input
6. The timers fail to perform as expected
7. The timer integration with the dispensing mechanism fails to behave as expected

Each function in our design will need to have incremental testing done on it from the simplest operations to the most complex operation. With testing involves using alternative solutions like the solenoid as a replacement incase the current servo motor isn't the most optimal solution.

Preliminary Project Plan

List of Major Tasks

- Hardware procurement (1 Week)
    - 555 Timers
    - Rotary Device
    - Switches

- Hardware development (3 Weeks)
    - PCB Design
    - PCB Assembly
    - Microcontroller evaluation
    - Power evaluation
    - Storage Container

- System Integration (3 Weeks)
    - System rotary design
    - Variable output functionality
    - Accelerometer functionality

- Wheelchair Integration (1 Week)
    - Placement verification

- Testing (2 Weeks)
    - Experiment #1 and #2

- Data Analysis and Refactor (1 Week)
    - Feedback review and data review

- Reporting (2 Weeks)
    - Initial Progress Report
    - Mid-Flight Report
    - Final Report

- User Acceptance Testing (2 Week)
    - Experiment #1 and #2

- Faculty Demos (Part of reporting)
    - Demo #1, 2, 3

- Customer Demo (Part of reporting phase)
    - Demo #1

Gantt Chart for ECE-493

Treat Dispenser

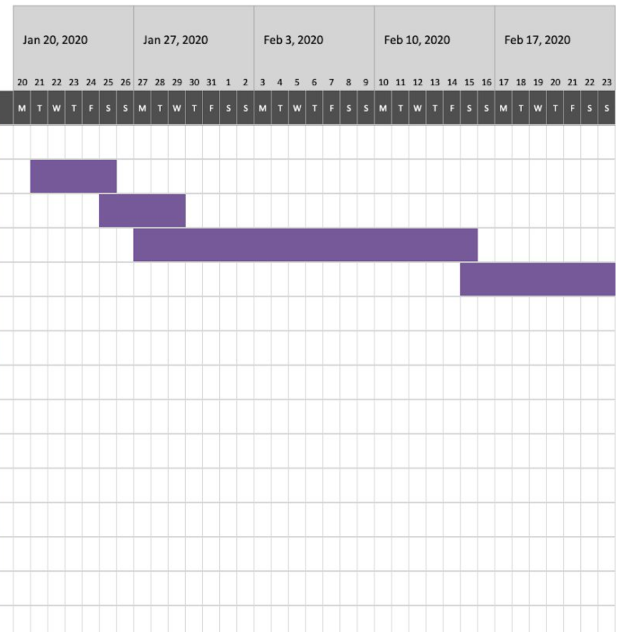
FS: Nathalia Peixoto
PM: Adam Dost

Project Start: Tue, 1/21/2020

Display Week: 1

Members: Jachan Shrest, Zainab Abdullahi, Robert Wignall, Gage Moore

TASK	NOTES	PROGRESS	START	END
Initial integration				
Hardware Procurement		0%	1/21/20	1/25/20
Hardware Development	PCB / MCU	0%	1/25/20	1/29/20
System Integration	DESIGN 1 & DESIGN 2	0%	1/27/20	2/15/20
Wheelchair Integration	DESIGN 1 & DESIGN 2	0%	2/15/20	2/29/20
User Acceptance Testing	DESIGN 1 & DESIGN 2	0%	3/1/20	3/2/20
Anaysis and refactor				
Data Analysis and Refactor			3/3/20	3/15/20
User Acceptance Testing #2			3/16/20	3/17/20
Reportings			3/17/20	3/20/20
Additional Features	MCU Specifc focus		3/20/20	4/20/20
Presentation				
Faculty Demos			TBD	TBD
Customer Demo			TBD	TBD



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Appendix C : Raspberry Pi Code

```
import os
```

```
import time
import sys
import RPi.GPIO as GPIO
import board
import busio
import adafruit_ads1x15.ads1115 as ADS
from adafruit_ads1x15.analog_in import AnalogIn

GPIO.setmode(GPIO.BCM)
GPIO.setup(10, GPIO.OUT)    # set GPIO 4 (pin 7) to servo
GPIO.setup(16, GPIO.OUT)   # set GPIO 14 (pin 37) to vibrating motor
HallPin = 17               # set GPIO 17 (pin 11) to hall swtich
p=GPIO.PWM(10, 50)
q=GPIO.PWM(16, 207)

control=False

q.start(0)
# Create the I2C bus
i2c = busio.I2C(board.SCL, board.SDA)

# Create the ADC object using the I2C bus
ads = ADS.ADS1115(i2c)
# you can specify an I2C adress instead of the default 0x48
# ads = ADS.ADS1115(i2c, address=0x49)

# Create single-ended input on channel 0
chan = AnalogIn(ads, ADS.P0)

def setup():
   GPIO.setup(HallPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)                    # Set BtnPin's mode is input, and
pull up to high level(3.3V)
   GPIO.add_event_detect(HallPin, GPIO.BOTH, callback=detect, bouncetime=50)
   GPIO.setup(23, GPIO.IN, pull_up_down=GPIO.PUD_UP)
   GPIO.add_event_detect(23, GPIO.BOTH, callback=buttonPressed, bouncetime=500)    # set pin 23 to Input switch



def buttonPressed(chn):

   global control
   if (control == False):
      q.ChangeDutyCycle(100)
      time.sleep(1)
      q.ChangeDutyCycle(0)
      print('Stop Vibrating Motor')
      time.sleep(1)
      p.start(7)
      print('Start Servo')
      control=True

def detect(chn):
   global control
   p.stop()
   control = False

def loop():
   while True:
      if(chan.voltage>2):
         os.system('aplay /home/pi/DogClickSound.wav')
```

```
        time.sleep(0.5)
      pass

def destroy():
   GPIO.cleanup()                    # Release resource

if __name__ == '__main__':     # Program start from here
   setup()
   try:
      loop()
   except KeyboardInterrupt:  # When 'Ctrl+C' is pressed, the child program destroy() will be  executed.
      destroy()

#IN BCM MODE Amplifier pinout:
#   5V Raspberry -> Vin
#   GND Raspberry -> GND
#   PIN18 Raspberry -> BCLK
#   PIN19 Raspberry -> LRC
#   PIN21 Raspberry -> DIN

# Note, this code requires set up a set up file to get the audio to play. The set up steps
# for I2S Audio can be found here: http://www.lucadentella.it/en/2017/04/26/raspberry-pi-zero-audio-output-via-i2s/
# Code taken from https://www.raspberrypi.org/forums/viewtopic.php?t=178441

# This will utilize the adafruit MAX98357 audio amplifier, no external power required.
# The power draw is negligible,
https://www.electrokit.com/uploads/productfile/41016/adafruit-max98357-i2s-class-d-mono-amp.pdf
# The link above is also another set up, but provides more information (such as volume control)

# More code adapted from: https://www.sunfounder.com/learn/lesson-17-hall-sensor-sensor-kit-v2-0-for-b-plus.html

# Note, a trick for running all of these devices solely off of Raspberry Pi power is to
# split one of the 5V pins for the Servo Motor and the Amplifier. FOR THIS APPLICATION ONLY: will the servo not
be
# using power when the amplifier needs it. This is made such that an external 5V source is not needed to run
```

Appendix D : Treat Dispenser Manual

Part Requirements

Raspberry Pi MCU

1x Raspberry Pi Zero W (Can be swapped for 3B) (Link)
1x Analog To Digital Converter (Link)
1x Servo Motor FT90r (Link)
1x Breadboard for Development (Link)
1x Adafruit MAX98357 I2S Class D-Mono Amp (Link)
1x Buck Converter (Link)
1x 12V Power Supply (Link)
1x Micro SD card (Link)
2x IR sensors (Link)
1x MPS2222a Transistor (Link)
1x IN4148 Diode (Link)
1x 1k ohm resistor (Link)
1x Vibrating Motor (Link)
1x Switch/Push Button (Link)

Raspberry Pi Setup:

Step 1: MCU Setup

The easiest way to do the initial setup of the Raspberry Pi would be to follow the two links given below. The steps are perfectly laid out and should take roughly 30 minutes to complete with very little background knowledge.
Instructions for Mac: (https://desertbot.io/blog/setup-pi-zero-w-headless-wifi)
Instructions for Windows: (https://desertbot.io/blog/headless-pi-zero-w-wifi-setup-windows)

Step 1b: MCU Setup through PiBakery

For those with a bit of technical background there is a tool called PiBakery that will allow you to essentially "pre-bake" the Raspberry Pi's image along with pulling down anything online from the moment it is booted up. To leverage that tool please click (https://www.pibakery.org)

Step 2: File Transfer, Amplifier Code Setup, Python installation

Before we can hook up components for testing, we will need to place the main driver code file onto the Raspberry Pi, run the script to download the I2C audio output functionality to the Raspberry Pi, and install python onto the Raspberry Pi itself.

First, lets begin with installing python onto the Raspberry Pi. In order to do this, you must be able to ssh into your Raspberry Pi and log into the Raspberry Pi. If you followed instructions in step 1 above, you are already set up for ssh. Please log into your raspberry pi and get ready to run a few commands.

The first command we will want to run while logged into the Raspberry Pi will be:

```
sudo apt-get install python3
```

Once you hit enter after typing that command, it will install python 3 on the Raspberry Pi. Note: you may have to restart your raspberry pi after this.

Next, we will run the script in order to get I2C audio running on your Raspberry Pi. For a complete list of instructions, please visit https://learn.adafruit.com/adafruit-max98357-i2s-class-d-mono-amp/overview to set up the device for I2C audio. Below, I will outline the most important steps for getting it set up on the Raspberry Pi.

First, run the command below:

```
curl -sS
https://raw.githubusercontent.com/adafruit/Raspberry-Pi-Installer-Scripts/master/i2samp.sh | bash
```

Once you have run that command, it will run as a script and all you need to do is sit back and relax as the code will run. It will install every package needed for the audio to work. It will also ask to reboot, and when it does please reboot the device.

Second, we will log back into the Raspberry Pi and re-run the command:

```
curl -sS
https://raw.githubusercontent.com/adafruit/Raspberry-Pi-Installer-Scripts/master/i2samp.sh | bash
```

This will allow you to test the speaker. Since we do not currently have anything connected up, nothing will play. But once we hook up the device with the appropriate connections, please run this command to verify that the speaker works.

Finally, we can go ahead and install the main driver file onto the Raspberry Pi.

To do this, if you are using a Mac, please run the command below:

```
Scp (copy file path here) pi@raspberrypi.local:
```

Once you run the command above, it will prompt you for your Raspberry Pi password. Please enter in your password, and begin the file transfer. Once it is finished, you will now have the file located on your Raspberry Pi. NOTE: the (copy file path here) is the location of where you saved the file to. For example, it would be replaced with /Users/myMac/Desktop/Master.py
A video from https://www.youtube.com/watch?v=vMhu2gk1rW8 may be helpful to look at if you are having trouble.

Once you have installed the main driver file onto the Raspberry Pi, please re-run the command again, but this time, we will want to also place the .wav file containing the “click sound” onto the raspberry pi. Simple copy the path to where the .wav is saved named as “DogClickSound.wav”

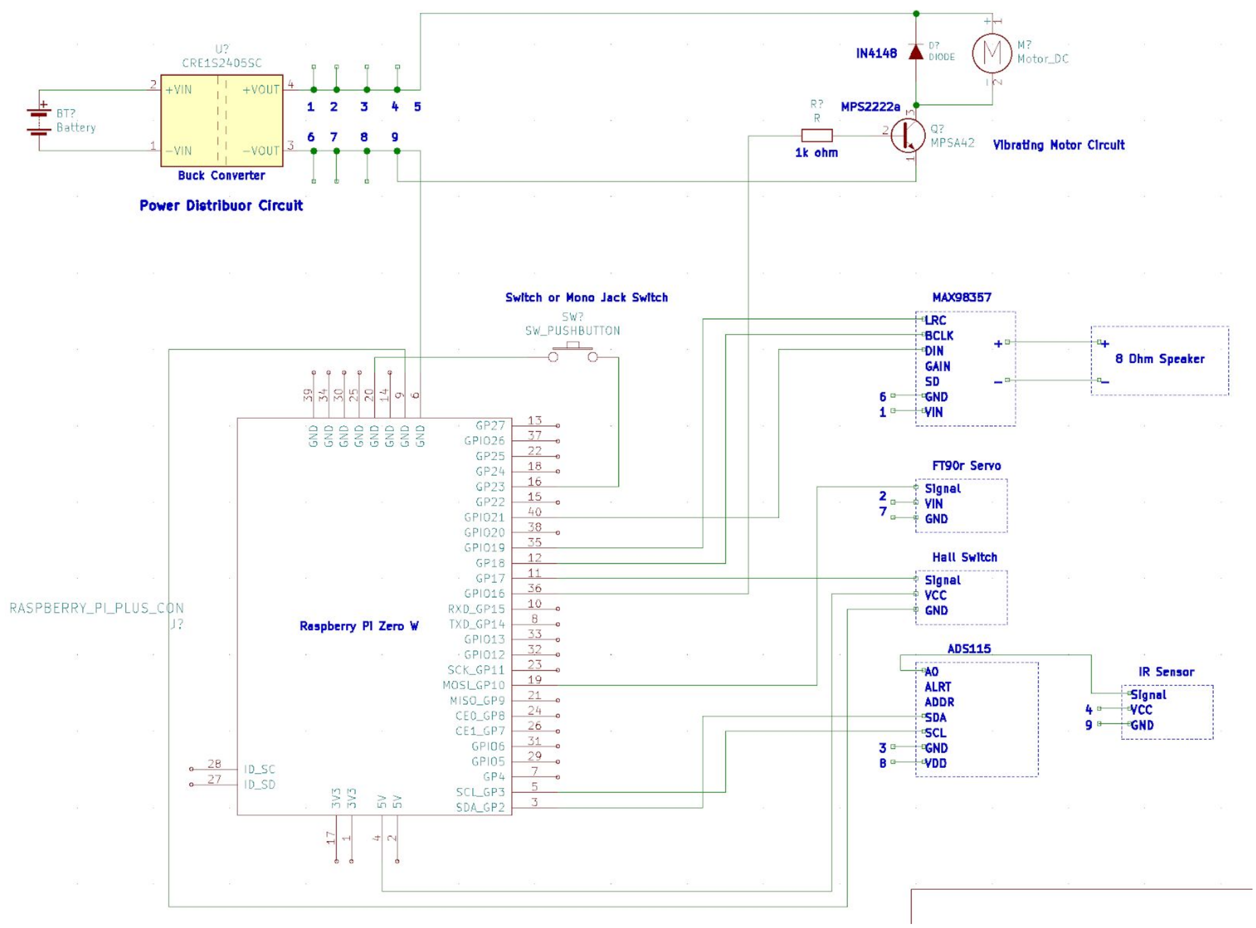
If you are using Windows:

Please follow the instructions from https://www.youtube.com/watch?v=WIOpNuQc068 by using Putty (used for Step 1 Raspberry Pi set up) and install the Main driver file and the DogClickSound.wav file.

Step 3: Making connections

Before we can put the parts in the housing for this project, we will make all the necessary connections in order to test the device's functionality. Let's start with the breadboard before we solder anything together.

Please refer to the schematics below for connections to the breadboard. The whole schematic file is also available in the materials section of the directory.



In an effort to make connections easier, please refer to the connections list below:

Vibrating Motor Circuit:

Raspberry Pi	Circuit
Pin 26 (GPIO 16)	1k Ohm resistor on gate of Transistor
Ground from Buck Converter (9)	Emitter of Transistor
5V Power from Buck Converter (5)	Positive input for Motor

Amplifier:

Raspberry Pi	MAX98357 Chip
Pin 35 (GPIO 19)	LRC
Pin 12 (GPIO 12)	BCLK
Pin 40 (GPIO 21)	DIN
Ground from Buck Converter (6)	GND
5V Power from Buck Converter (1)	VIN

Servo:

Raspberry Pi	FT90r Servo
Pin 19 (GPIO 10)	Signal (Orange color)
5V Power from Buck Converter (2)	VIN (Red color)
Ground from Buck Converter (7)	GND (Brown color)

Speaker:

MAX98357 Amplifier	Speaker

+	+
-	-

Hall Switch:

Raspberry Pi	Hall Switch Chip
Pin 11 (GPIO 17)	Signal
Pin 4 (5V Power)	VCC
Pin 9 (GND)	GND

Switch or Mono Jack Switch

Raspberry Pi	Switch or Mono Jack Switch
Pin 16 (GPIO 23)	+
Pin 20 (Ground)	-

ADS115:

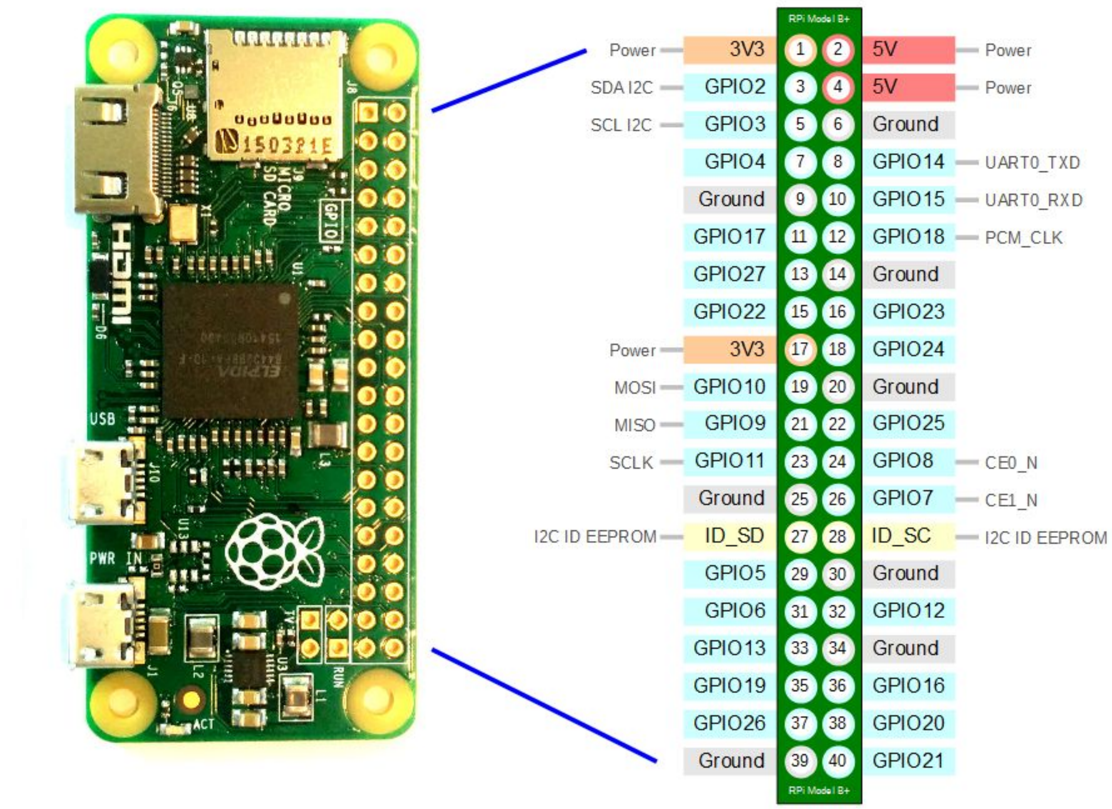
Raspberry Pi	ADS115
Pin 3 (SDA)	SDA
Pin 5 (SCL)	SCL
---	A0
Ground from Buck Converter (3)	GND
5V Power from Buck Converter (8)	VDD

IR Sensor:

ADS 115	IR Sensor
A0	Signal

Buck Converter 4 (5V Power)	VCC
Buck Converter 9 (GND)	GND

Please refer to the image below for a pinout of the Raspberry Pi Zero W:



(https://raspberrypi.stackexchange.com/questions/83610/gpio-pinout-orientation-raspberypi-zero-w)
Once you have made all of the connections above, you can ssh back into the Raspberry Pi, run the script from Step 2 to set up the Amplifier and verify it makes a sound.

Next, we can test the full functionality of the device by running the following command once logged into the Raspberry Pi:

```
Sudo python MasterFile.py
```

Once you run this command, it will open the Master File and begin executing the code. You can press the push button to see if (i) the vibrating motor spins, (ii) the servo arm spins, (iii) the hall effect sensor stops the servo arm from spinning, and (iv) the click sound is played.

Step 4: Configuring the Bootstrap

Once we have tested the individual components for functionality, we can now configure the bootstrap for this device. This will allow for the MasterFile code to run upon startup of the Raspberry Pi. This will be a key factor with respect to the project because we do not want to shh into the system every time we want the code to run. Rather, we want it to run upon supplying power to the Raspberry Pi.

In order to bootstrap the Raspberry Pi to start the Treat Dispensing code simply run the following code snippet. What this will do is execute the python script upon boot each time. You must do this as a super user as the bashrc file is a protected file and requires super user to perform this task.

```
sudo echo “sudo python /home/pi/MasterFile.py” >> /home/pi/.bashrc
```

Printed Circuit Board

Part Requirements

555 Timer Circuit

1x NE555 IC (Link)
1x BC547 NPN Transistor (Link)
1x 220 Ohm Resistors (Link)
2x 1k Ohm Resistors (Link)
1x 10k Ohm Resistors (Link)
1x 47k Ohm Resistors (Link)
1x 0.01u Farad Capacitor (Link)
1x 1u Farad Capacitor (Link)
1x 100u Farad Electrolytic Capacitor (Link)
2x Mono Jack Input (Female Port) (Link)

Feedback Circuit

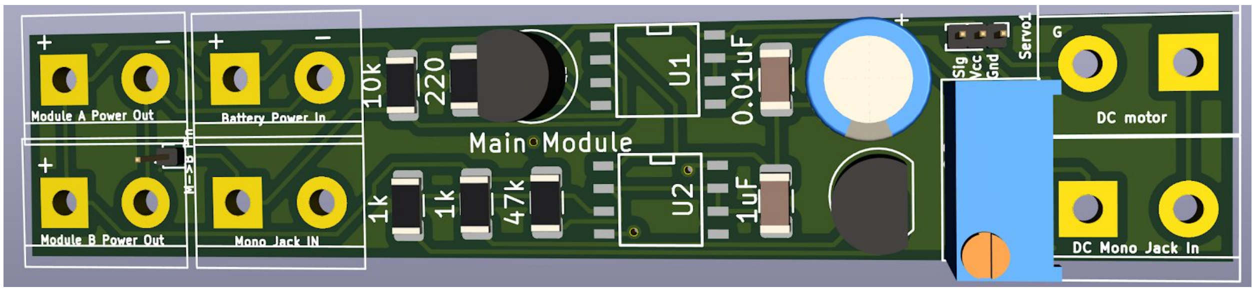
1x IR Emitter and Receiver Pair (Link)
1x 50k Ohm Potentiometers (Link)
2x 220 Ohm Resistors (Link)
1x 10k Ohm Resistors (Link)
1x BC547 NPN Transistor(Link)
2x LM358 IC (Link)
1x Icstation Recordable Sound Module (Link)
1x Vibrating Motor (Link)

Treat Level Indicator Circuit

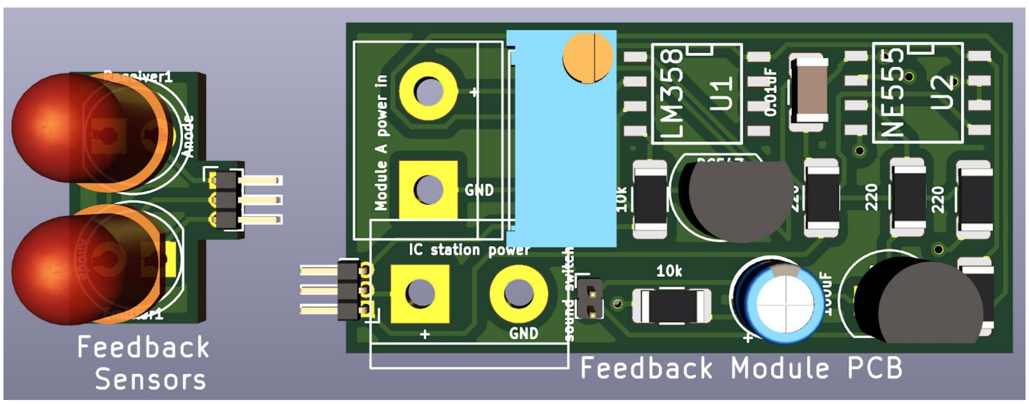
2x IR Emitter and Receiver Pair (Link)
2x 10k Ohm Potentiometers (Link)
2x LM358 IC (Link)
1x NE555 IC (Link)
1x BC547 NPN Transistor (Link)
2x 5mm LEDs (Link)
5x 220 Ohm Resistors (Link)
3x 10k Ohm Resistors (Link)
1x 47k Ohm Resistors (Link)
1x 100u Farad Electrolytic Capacitor (Link)
1x 0.01u Farad Capacitor (Link)

Printed Circuit Boards and Connections

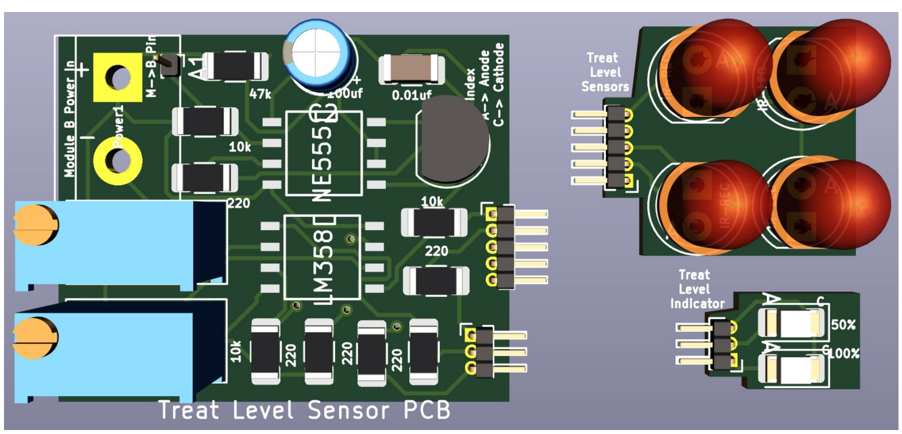
1. **Servo Control Module**



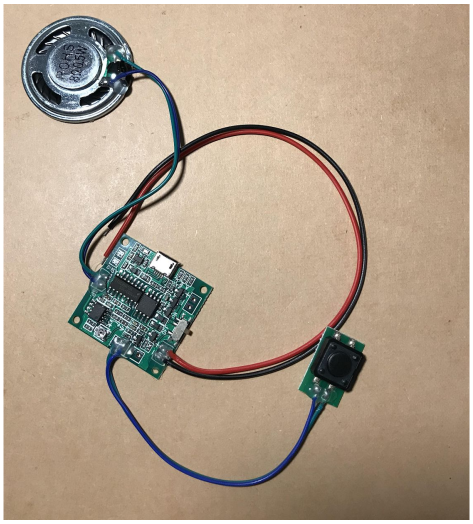
2. **Feedback (Click Sound) Module**



3. **Treat Level Indicator Module**



4. Sound Module PCB



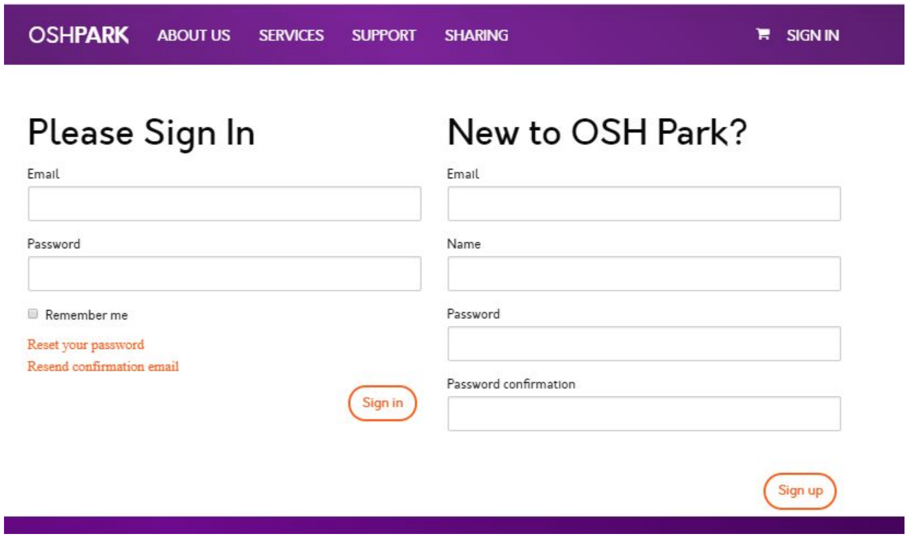
How to Solder Components onto Printed Circuit Board

The installation for the modules is simple. The PCBs are designed with the position of each and every component, component orientation and component values printed on the silk screen as seen on the PCBs above. The user has to install each component carefully as seen in the PCB silkscreen and solder them to the board. Once the installation is complete power on the module to test it.

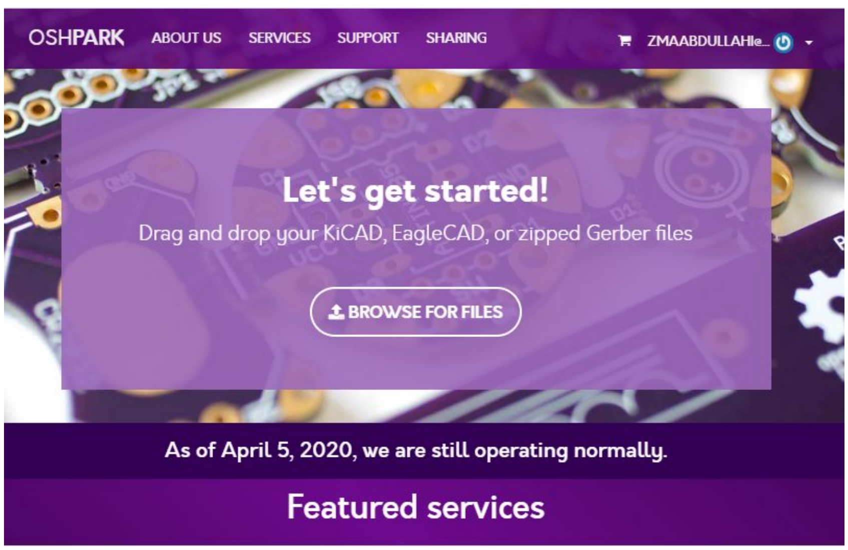
How to Order Printed Circuit Boards using .kicad_pcb Files

If you would like to place an order for one of the Printed Circuit Boards, we highly recommend you place an order through Oshpark. OSH Park is a community printed circuit board (PCB) manufacturer that produces high quality, lead-free boards which are manufactured in the United States and shipped for free to anywhere in the world. All of the PCB files for the Treat Dispenser can be found here http://treatdispenser.onmason.com/pcbs/.

Step 1 : Create an Account using the following link (Create an Account)

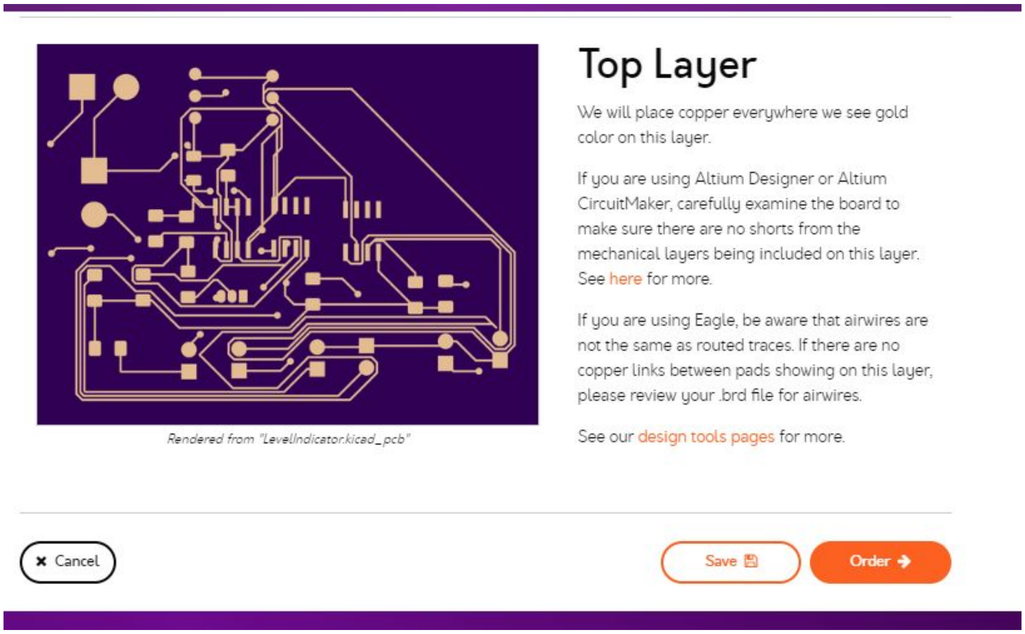


Step 2 : Click on the “Browse for Files” button.



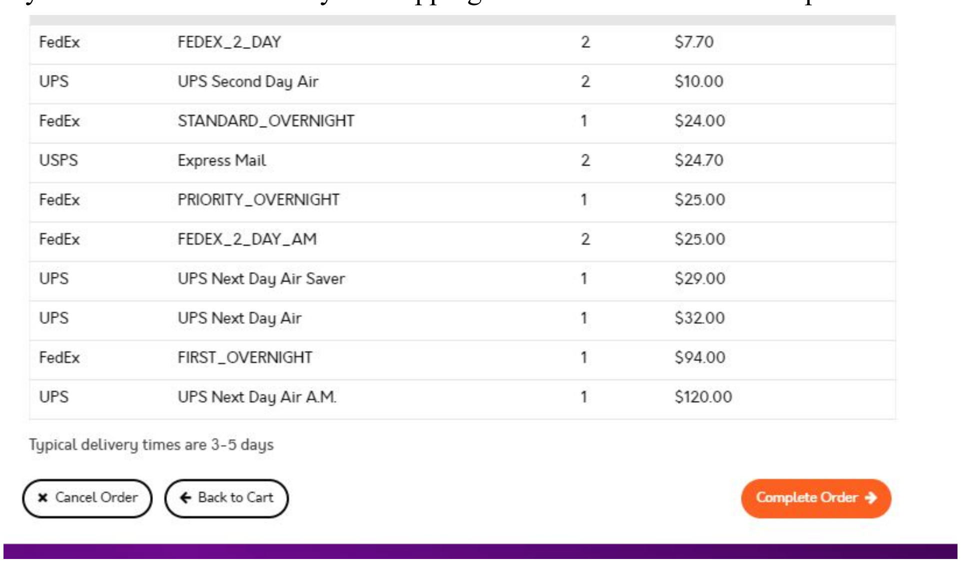
Step 3 : Upload the **.kicad_pcb** file and click “Continue”

Step 4 : Click on the "Order" button



Step 5 : Click on the "Checkout" button.

Step 6 : Enter your address and choose your shipping method and click on "Complete Order"



FedEx	FEDEX_2_DAY	2	$7.70
UPS	UPS Second Day Air	2	$10.00
FedEx	STANDARD_OVERNIGHT	1	$24.00
USPS	Express Mail	2	$24.70
FedEx	PRIORITY_OVERNIGHT	1	$25.00
FedEx	FEDEX_2_DAY_AM	2	$25.00
UPS	UPS Next Day Air Saver	1	$29.00
UPS	UPS Next Day Air	1	$32.00
FedEx	FIRST_OVERNIGHT	1	$94.00
UPS	UPS Next Day Air A.M.	1	$120.00

Typical delivery times are 3-5 days

Cancel Order | Back to Cart | Complete Order

You will receive a confirmation email shortly along with a tracking number to track your package.

As designed, the Wheelchair-Mounted Treat Dispenser consists of four main parts: the dog treat storage area, the dog treat staging area, the dog treat dispensing area, and the circuitry/power area. The idea was to make all these parts modular and detachable so the device can be easily cleaned without damaging the electronics.

The overall conceptual design is as shown in Figure 1 below, and provided during the first update. The treat dispenser still maintains this overall design, but some slight differences have been made during construction due to feasibility and practicality.

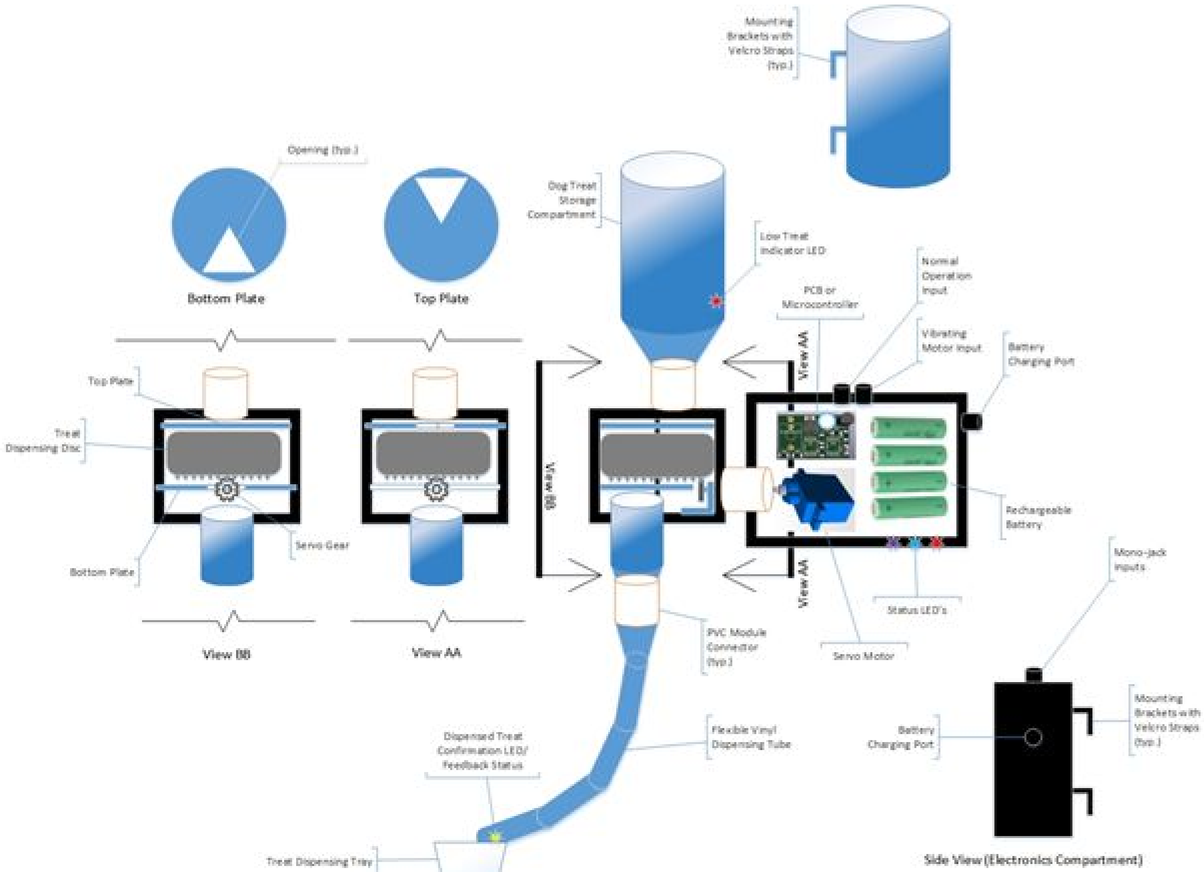


Figure 1: Overall Wheelchair-Mounted Treat Dispenser Design

Dog Treat Storage Area:

The dog treat storage area is comprised of three main pieces as shown in Figure 16 (left) below: 3” PVC Cap, 3” PVC Pipe, and 3” to 3/4” PVC Reducer. The ¾” reducer then fits into the hole in the top cap as shown on the right side of Figure 16. This will allow the treats to be fed directly to the loading zone in the dispensing disk.

Figure 16 : Planned Dog Treat Storage Area

The 3” PVC Cap is to be fitted with the treat level sensor consisting of two IR sensors and two LEDs. The two IR sensors will face down, into the container while the two LEDs will face up to be visible by the user. The circuit board for these sensors and LEDs will be located in the Electronics compartment and only the IR sensors and LEDs will be mounted on the cap. The treat dispenser storage area holds at least a cup of dog treats at a time. When both LEDs are illuminated, the storage area should be full of dog treats. It will also have hooks and straps for wheelchair attachment in order to keep the device mounted at the highest point and keep from toppling off the wheelchair.

Dog Treat Staging Area:

This portion of the treat dispenser is the most difficult to put together as it has all the moving parts. The treat staging area is responsible for taking treats in from the storage area, taking input from the servo motor in the electronics area to turn the gears, and for dropping treats to get them to the dispensing area successfully. Thus, this is the heart of the design and the connection point for the other three modules. This piece is comprised of the following components :

- Food safe plastic bottle (potentially to be replaced with 3” PVC tube later)
- Top plate
- Gumball machine dispensing disk
- ¼-20 x 3” all thread stainless steel rod for alignment (2ea.)
- ¼-20 x 6” all thread stainless steel rod to function as spinning axis for dispensing disk
- L-bracket supports (2ea.)
- Gumball machine “receiver” piece
- Bottom plate with hole for dropping treats
- Gear, wooden dowel, and bearings for attachment to servo motor

There are two axes that must be perpendicular to each other in order for the device to work correctly. These axes are the dispensing disk axis and the control gear/servomotor axis. Again, this is one of the more difficult parts to put together since space is limited and there are moving parts. The first axis to be considered will be the control gear axis controlled to the servomotor. This axis must extend from the dog treat staging area all the way to the electronics compartment for connection to the servomotor. The construction of this axis is as shown in Figure 17 below.

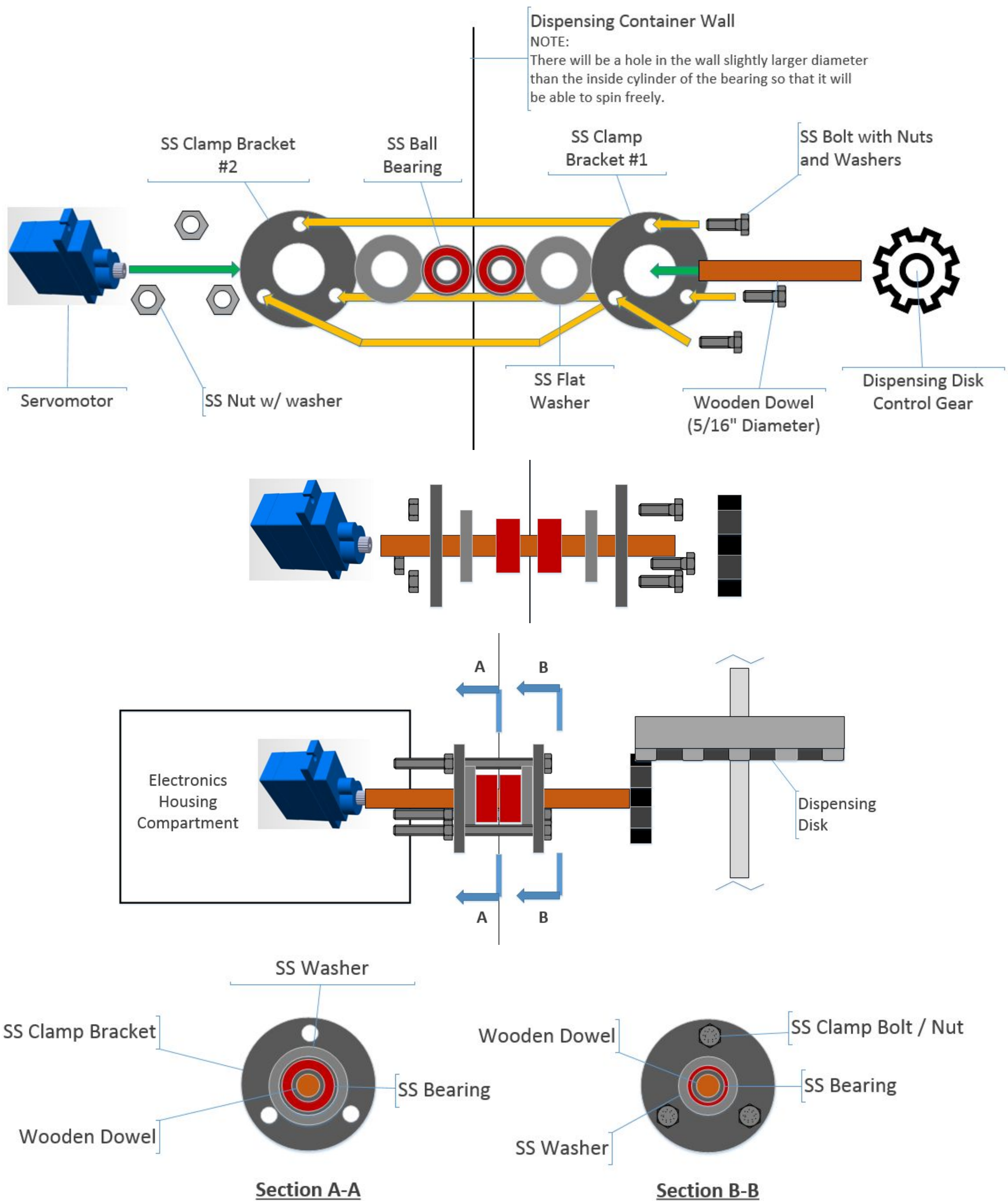
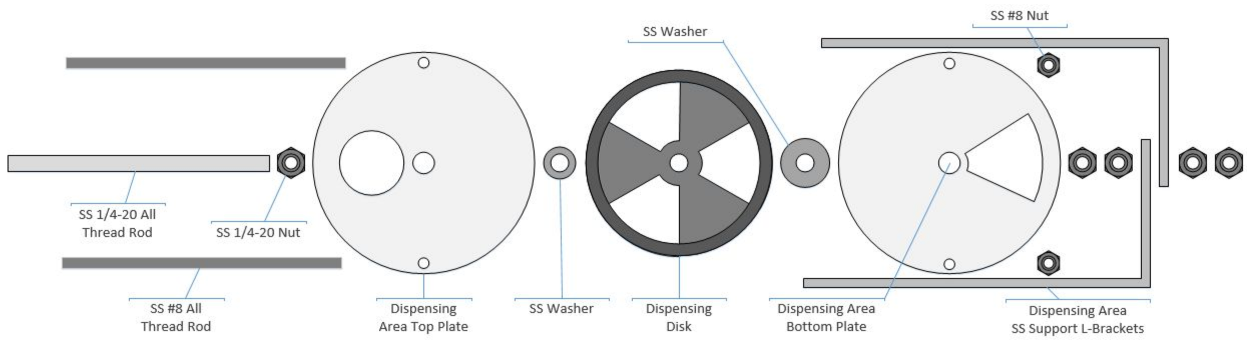


Figure 17: Control Gear / Servomotor Axis Construction

A hole is drilled in the side of the plastic bottle to allow insertion of the wooden dowel that will be controlled by the servomotor. This hole should only be slightly larger than the diameter of the dowel so it can spin freely. A bearing will be placed on either side of the plastic bottle and the dowel will be slid through these to keep them straight. A clamp will be used to hold the bearings tight against the wall of the plastic bottle to keep the gear at a 90 degree angle to the spinning disk.

Next, the construction of the Dispensing Disk axis will be considered. The details of this axis are as shown in Figure 18 below. The top plate should have 4 holes in it as shown in Figure 18: 2 for the ¼-20 x 3” all thread rods, 1 for the ¼-20 x 6” all thread rod, and 1 for the ¾” input from the treat storage area. The longer all thread rod will be centered and used as the center axis for the spinning disk. The shorter all thread rods will be on either side of the center and will be slightly farther from the center than the radius of the spinning disk. These are responsible for keeping the dispensing area top and bottom plates in place so they will not misalign when the dispensing disk is spun.

The bottom plate is made of a slightly flexible, but rigid plastic and will be responsible for keeping the spinning disk at the right height as well as not turning so as to keep the dispensing hole in place at all times. There should be two holes and a notch in this plate. The center hole should be ¼” to accept the center all thread rod, and there should be a roughly 1” diameter hole on the side that treats will drop from. On that same side, a notch should be cut out on the edge to allow for the servomotor gear to spin freely.



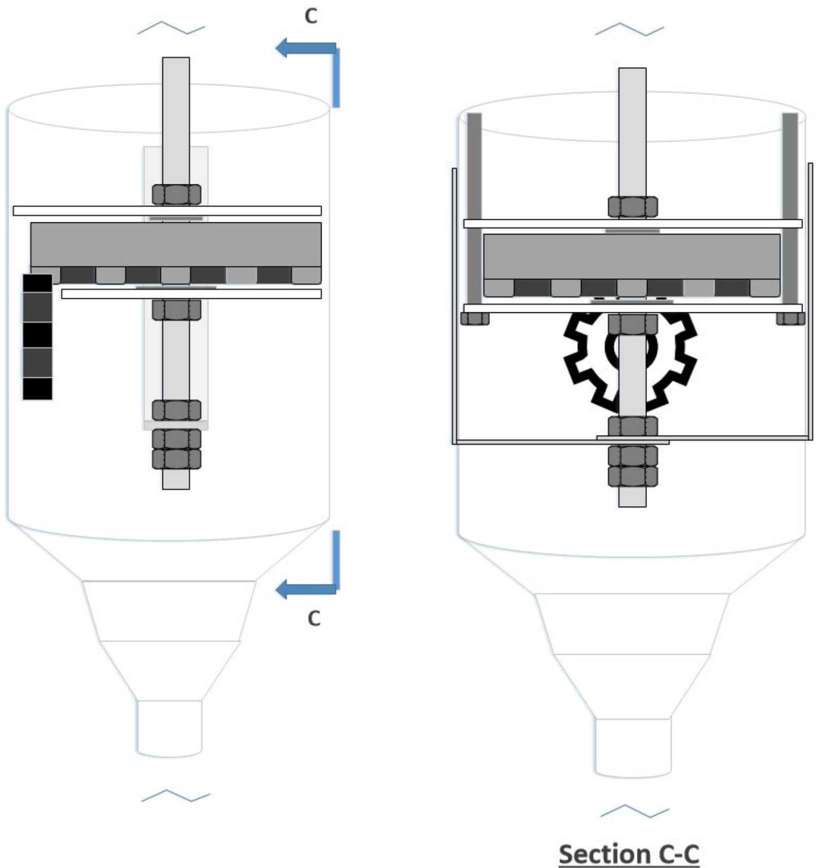


Figure 18: Dispensing Disk Axis Construction

There will be ½" notches cut into the side of the food safe plastic bottle to allow L-bracket insertion on opposite sides of the bottle and 90 degrees to where the servomotor dowel will be attached. These should meet in the middle and receive the center all thread rod to help keep it centered and anchored at the bottom. The center rod is anchored at the top plate and at these L-brackets to keep everything together.

By using nuts and washers along the all thread rods, the different pieces can be held at their correct heights. During testing, this optimal height is still being established, but everything should be placed so the spinning disk does not move vertically and can still spin freely.

The bottom of the plastic bottle is cut off to allow a large opening to insert all the mechanical pieces. The bottom then becomes the top of the staging area. By turning the bottle over, there is now a funnel shape at the bottom that can direct the treats to the dog treat dispensing area. The dispensing area will be connected to the bottle using the bottle cap threads, utilizing some plumber's tape if needed to ensure a tight connection.

Electronics Storage Area:

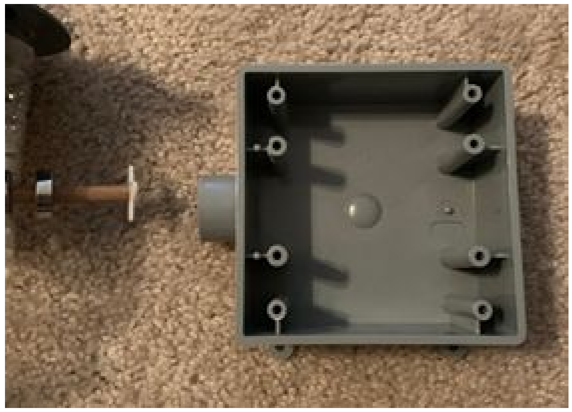


Figure 19: Electronics Housing Compartment

The Electronics storage area will be made of a square PVC gang box as shown in Figure 19 above. There is a ¾" hole in the side that the servo motor dowel can be inserted through. The servomotor is then mounted to the inside of the electronics housing and cannot move. This piece needs to remain as square to the opening as possible to ensure the dispensing disk is operated correctly.

This piece will be covered with a flexible, translucent piece of plastic with some rubber gaskets to help keep the electronics safe from the environment. The battery will be velcroed to the backside of the electronics compartment to allow for easy charging and power access as shown in the images below. On the opposite side of the opening for the servomotor control dowel, there will be another ¾" opening to allow ingress of the power cable from the battery pack as well as allow access to the 3.5mm mono-jack ports.

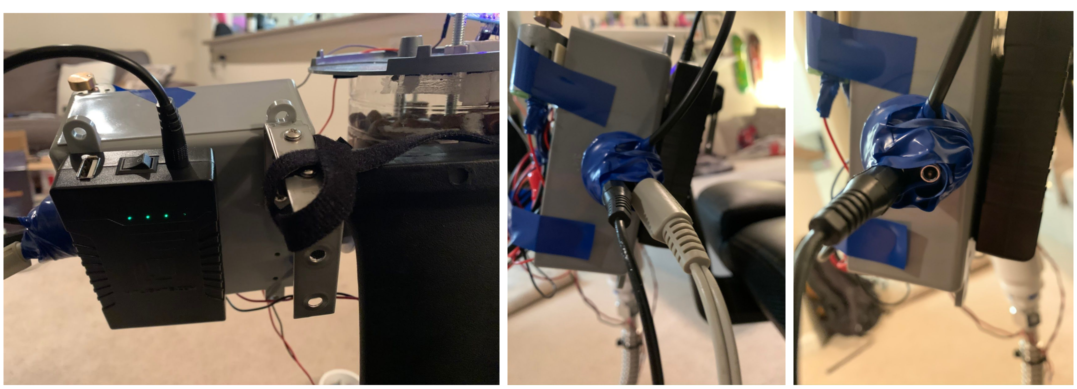


Figure 20: Electronics Housing Compartment from Prototype

There will also be hooks on the back of this storage area with Velcro straps to allow attachment to the wheelchair. It is important to keep this piece somewhat tight against the wheelchair so the electronics do not rattle too much and become damaged throughout a day.

This area will house the one circuit board needed for the 555 timer design or the Raspberry Pi and associated components for the microcontroller design along with the servo motor.

Treat Dispensing Area:

The treat dispensing area consists of PVC and Stainless Steel pieces. The PVC is used to connect the dispensing area to the staging area. The dispensing area is made mainly of a 2’ stainless steel corrugated tube that is flexible and maintains position once set. This gives the user flexibility when installing on their wheelchair, allowing the treats to dispense almost wherever needed. The end of the dispensing area will be fitted with a small dog food bowl to catch the treats and present them to the service dog.

Figure 21: Dispensing Area of Treat Dispenser

Dispensing Area is flexible for an array of mounting options while maintaining rigidity to hold position. It can be easily detached from the Staging Area for cleaning or clearing of jams (if needed). There will also be mechanisms added to the end of the dispensing area to attach it to a wheelchair and keep the food dish securely in place.