Automated Fish Feeder

A Major Qualifying Project Report

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Abstract

It is not feasible for fish owners to leave extra food in their fish's tank before leaving for an extended period. This creates the need for a device that can automatically and reliably feed a fish. The purpose of this project is to design an automated fish feeder for household use. The device was developed to feed a single goldfish for at least 14 days without any additional input from the user. Using an Arduino unit to control two stepper motors, the multi-stage design feeds the fish while avoiding failures that could result in too much food being dispensed. The compact design attaches directly to the tank for easy setup.

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Authorship

Every group member contributed equally to the writing of this report.

Acknowledgements

We would like to thank Professor Cobb for his support and expertise. His guidance throughout this project was paramount. We would also like to thank Barbara Fuhrman and Payton Wilkins for their assistance throughout the project, as well as Erin Heinle and Shanelle Reilly for helping us structure our report and for being patient with us.

1. Introduction

1.1 Purpose

This report details the process our group used to design, build, and test an automated fish feeder. We discuss our initial designs and the subsequent decision matrices that went into determining our final design. Later chapters describe the process of designing, prototyping, building, and testing our final product.

1.2 Background

Pet ownership in America has increased by 14% over the past 29 years. With 68% of households having a pet, numbering almost 85 million homes, pet ownership is at an all-time high (Pet industry market size). According to the 2017-2018 American Pet Products Association (APPA) National Pet Owners Survey, 12.5 million homes own freshwater fish and 2.5 million homes own saltwater fish (Pet industry market size & ownership statistics.). There are a total of 139.3 million freshwater fish owned in the United States, about one and a half times the number of dogs.

It is not feasible for fish owners to leave extra food in their fish's tank before leaving for an extended period. Overfeeding fish is one of the leading causes of fish fatality. When the food begins to break down in the tank, the proteins release ammonia, nitrites, and reduce the amount of oxygen in the water, all of which are harmful to the fish (Drs. Foster and Smith, n/a). This can put a strain on fish owners who need to leave home and do not have a consistent pet sitter. While there are many options available for feeding cats and dogs while away from home, there are not as many choices for fish owners.

1.3 Goal Statement

Fish have a feeding schedule of once per day every day, making it difficult for the fish owner to be away from home, whether it be for school, work, or leisure. This creates the need for an automated device that can reliably feed a fish.

The goal for this project is to design a system for automatically feeding a fish.

1.4 Scope

This report outlines the steps that our group took to develop our final prototype as well as recommendations for future versions of our device. Not included in this report are customer responses and feedback to the product.

2. Background

This chapter includes the necessary research to produce an effective fish feeder.

2.1 Automated Systems Background

Before we could begin designing our own automated fish feeding system, we needed to learn about any existing products, relevant patents, and any regulations regarding the project. In this section we discuss commercially available feeders, other automatic dispensing units, patents for feeding systems, OSHA requirements, different fish tanks, foods, and fish species. We also list the functional requirements that drove our project.

2.1.1 Existing Fish Feeder Designs

There are many different kinds of automated fish feeders from which consumers can choose. We aim to design a feeder that improved upon these current systems. Below are three products currently on the market. The first system is the eBoTrade Aquarium Auto Fish Food Timer. This device is shown in Figure 1 below. The eBoTrade Aquarium Auto Fish Food Timer can feed between one and four times per day, has manual and automatic capabilities, an adjustable serving size, and a ventilation system to keep the food dry. For this system, the food reservoir rotates and a door on the bottom will open to allow the proper amount of food to be released into the tank (Fish feeder, automatic fish feeder, eBoTrade aquarium tank auto fish food timer.). This system has mixed reviews on Amazon. Some of the concerns about the system are that even at the smallest serving size it feeds too much food for a single fish, and condensation formed inside the food reservoir causing the food to rot. Also, the mounting system is not very stable so the user must be careful not to bump it, and the door would not open when expected.

The second system is the EHEIM Automatic Feeding Unit. This device, like the one described above, rotates the food tank to dispense the food. The system is pictured in Figure 2 below. The EHEIM Automatic Feeding Unit features an adjustable opening for different serving sizes, “simple digital programming for different intervals,” a manual snack option, a food reservoir large enough to feed for six weeks, and up to eight feedings per day (EHEIM automatic feeding unit.). The system has many customer reviews on both Amazon and the Petco website; some of the negative reviews were that it was difficult to get the appropriate amount of food to come out and that as the device rotates it dumps some food onto the tank's cover resulting in both a mess and waste.

Figure 1: The eBoTrade Aquarium Auto Fish Food Timer

Figure 2: The EHEIM Automatic Feeding Unit

The final system that we will discuss is the Hydor Ekomixo Digital Aquarium Feeder. An image of the system is shown in Figure 3 below. The system features the versatility of dispensing flakes, pellets, and tablets, vibrations to prevent clumping, and 10 different dosage settings

(Hydor ekomixo digital aquarium feeder.). There are not many user reviews of the Hydor Ekomixo Digital, but the majority of the ones available are not very positive. The system appears to be unreliable, clog easily, and allow moisture into the food reservoir if left for more than a long weekend.

Figure 3: The Hydor Ekomixo Digital Aquarium Feeder

2.1.2 Automated Dispensing Designs

There are many different automated dispensing systems out on the market today for numerous applications other than fish feeding. The most common are for pet food and medication. While there are several different types of devices, there appear to be two different basic designs. The first design is a circular rotating dish with many pre-fillable compartments. When it is time for the feeding or time to take the medication, the compartments rotate to reveal the serving. An example of this system is the Med-e-lert Automatic Pill Dispenser, pictured in Figure 4, which includes features like sounds and lights when it is time to dispense and a locking top to prevent getting the pills too soon (Med-E-LERT automatic pill dispenser.).

The second system has a large holding container on the top that releases the contents into a dish at the appropriate times. The Petmate Portion Right Programmable Pet Feeder is an example of this system and pictured in Figure 5. A flaw in the pet feeder is the ability for the pet to tip the appliance over and remove the lid (Petmate portion right programmable pet feeder.).

Both of these concepts could be altered to be used as fish feeders. Adjustments would have to be made so the food can be released into the tank rather than the pet coming and getting the food from the dispenser. The possibility of the holding tank being knocked over is not a major concern since the system would be held above the water that houses the fish.

Figure 4: The Med-e-lert Automatic Pill Dispenser

Figure 5: The Petmate Portion Right Programmable Pet Feeder

2.1.3 Patents Relevant to Our Design Problem

There are numerous existing patents for automated fish feeders. The ones that will be discussed in this section are: the Automatic Aquarium Feeder, an Air-operated Fish Feeder, and an Automated Fish Feeder. Although many of these patents are now expired, we still need to be aware and ensure we are not infringing on any of them.

The first patent is for an Automatic Aquarium Feeder, US patent publication number US20090255474A1. This patent describes a pre-filled automatic feeder that can be hung over a pond or an aquarium to feed fish on a predetermined schedule. This idea utilizes a spiral-shaped piece in the food reservoir to pull the food down (Gleesing). Figure 6 shows the schematic of the system.

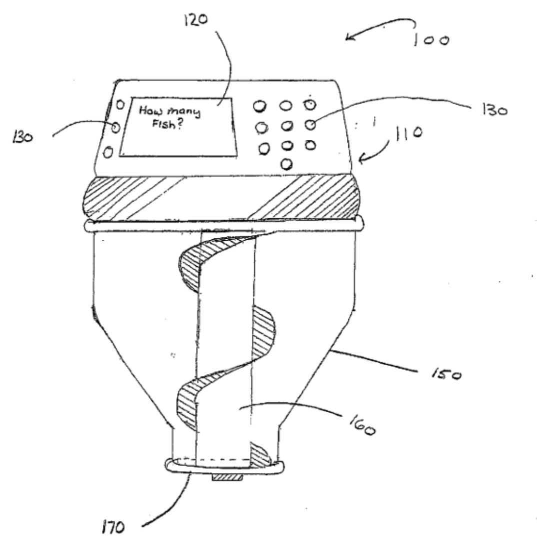


Figure 6: Patent Publication Number US20090255474A1: Spiral Deposition System

The second patent we saw was for an Air-operated Fish Feeder, with patent publication number US4089299A. This design consists of a measuring cup that scoops the food out of a food supply and dumps it into the fish tank (Suchowski). Figure 7 shows the schematic of the system. This design is air-powered, which is a unique innovation on the fish feeder.

The patent with publication number US4628864A, an Automated Fish Feeder, used a unique water powered system. This patent gives us ideas about different ways to drive our design besides batteries or electricity. This design uses the water to move an arm, which rotates a predetermined amount, then vibrates once it has completed rotating to deposit the food in the tank and avoid clumps (Smeltzer,). It is shown in Figure 8 below.

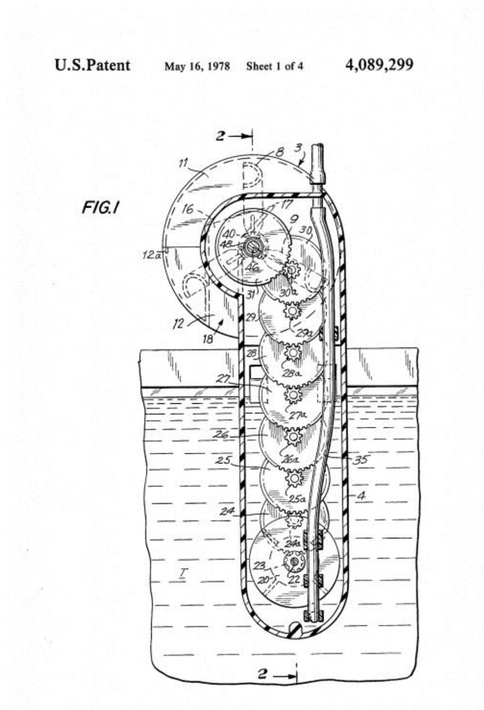


Figure 7: Patent Publication Number US4089299A: Air-Powered Scoop

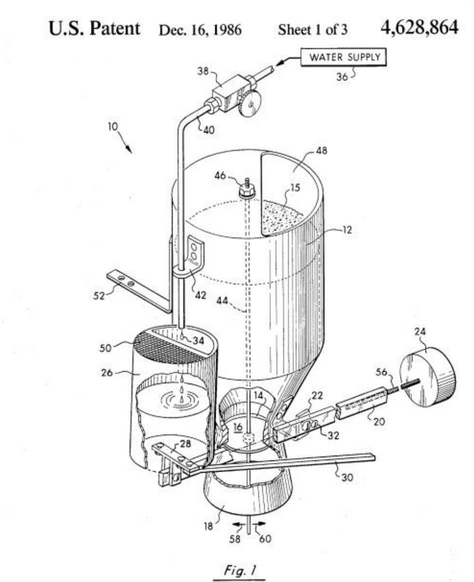


Figure 8: Patent Publication Number US4628864A: Water-powered arm

2.1.4 ANSI, NSF, and OSHA Requirements

The Occupational Safety and Health Administration (OSHA) has created guidelines for products and systems used for cooking, handling, and selling food. These guidelines aim to keep kitchens safe for employees as well as keep food free of bacteria and other contaminants. One such OSHA guideline that pertains to the system for automatically feeding a fish is that all gears on any device must be fully enclosed so that neither people nor food can come into contact with them. This ensures that fingers, hair, etc. cannot become stuck in the rotating gears and cause injury, but it also will help maintain the life of the system by keeping any moving parts free of contamination from dust, food, or debris (Bakery equipment, 1996).

The American National Standards Institute (ANSI) and the National Sanitation Foundation have developed standard ANSI/NSF 51 – 1997, whose purpose "is to establish minimum food protection and sanitation requirements for the materials used in the construction of commercial food equipment" (ANSI/NSF 51 – 1997, page vii). Standard ANSI/NSF 51 – 1997 sets forth requirements and definitions of criteria such as heat resistance, abrasion resistance, impact resistance, and surface cleanability for numerous materials such as copper, aluminum, and steel, as well as any of their common alloys (Food equipment materials.). The final manufacturing of any product intended to be used near food should be planned with this standard in mind.

2.2 Arduino Technology

Arduino is an open-source circuit board for use with its own programming language. The Arduino board can be programmed to control a variety of devices, such as turning an LED on or off or controlling motors. The small size and easy-to-understand language make it a popular choice among hobbyists, but the versatility makes it viable for a variety of projects. With a wide range of support products and add-ons available to expand the capability of the Arduino unit, we decided that an Arduino would be perfect for the needs of our project.

We determined that stepper motors would be the best motor option for our device. The most effective way to control stepper motors with an Arduino is to utilize an Arduino motor shield. The Arduino motor shield is an add-on to the original Arduino unit, usually made by a third party company. The motor shield includes all necessary circuitry for controlling motors, and stacks directly on top of the Arduino, easily integrating with the device as well as maintaining its compact design. To begin writing the code, we first needed to understand the language that is used by Arduino boards. The Arduino support website offers sample code for utilizing stepper motors, so this was our starting point. The final code can be found in Section 6.5.2.

We purchased an Adafruit Motor Shield V2, as there were stepper motors available that were designed to work in tandem with this shield, allowing us to more easily integrate the Arduino circuit into the completed design. The Adafruit shield contained sample code for running stepper motors. Between this sample code and online tutorials from the Adafruit website, we were able to create a code that suits the needs of our project.

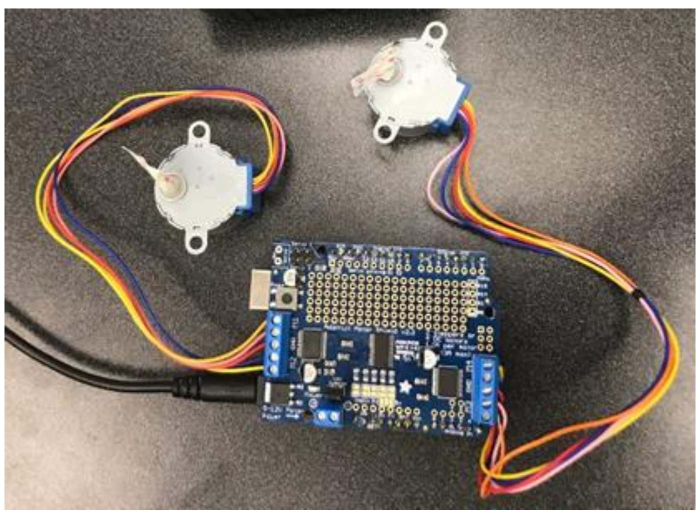


Figure 9: Arduino Unit with Motor Shield and Stepper Motors

2.3 Fish Keeping

In a recent 2017 study conducted by the APPA, over 12.5 million homes own fish with a total of 139 million fish in the United States. (Facts + statistics: Pet statistics.). In this section we introduce various aspects of fish ownership including food, feeding schedules, species, and tanks. We then analyze the criteria and determine the most appropriate parameters for our project.

2.3.1 Food and Feeding Schedule

There are a variety of different types of fish foods, including flakes, pellets, and tablets. Most small fish feed on flakes, while larger fish require pellets, and more exotic fish may require more exotic food. Fish flakes tend to float on the top of the tank while pellets sink to the bottom. Ultimately the decision of which type of food to use is up the owner.

Most common freshwater fish only require feeding once a day, however it is crucial to not overfeed the fish. Uneaten food can break down into ammonia and nitrites which can be very harmful to the fish, and the decaying of the food reduces the oxygen in the tank. Overfeeding can lead to fin rot or fatty liver in the fish, both of which can lead to health problems. The amount of food per feeding should be no more than an amount of food that can be consumed in 3-5 minutes, or else it will begin to break down into the water of the tank.

2.3.2 Fish and Tank Sizes

The most popular fish for aspiring fish owners are typically freshwater fish, as a saltwater fish tanks require more upkeep. Saltwater tanks require skimmers, filters, heaters, as well as testing equipment for the salinization of the water to ensure that it is livable for the fish. For the first time fish owner, a freshwater tank is a much less daunting task, as they only require a basic heater and filter. There are numerous species of freshwater fish, such as neon tetra, guppies, and goldfish, and most can share tanks with one another, while some such as the betta fish require isolation. The species is up to the owner, as most have similar feeding schedules and tank requirements.

According to an interview we conducted with a Petco employee in the freshwater fish department, the most common tank size is 10 gallons. This size tank is large enough that it can house a variety of different fish, while being small enough to be unobtrusive to install in a home.

2.3.3 Our Decision

We chose a goldfish for the focus of our project. With a once a day feeding schedule and no additional tank equipment it is very easy to take care of. Goldfish require more space than other freshwater fish, typically one goldfish per 10 gallons of tank size, so we developed our project to feed one goldfish in a 10 gallon tank. We began our project using the Tetrafin Plus

Goldfish Flakes, but after failed testing (see Chapter 6) we made the design decision to use Omega One medium goldfish pellets instead.

2.4 Functional Requirements

The goal of this project is to design a system for automatically feeding a fish. The following is a list of the functional requirements for the system.

2.4.1 Tank and Fish Requirements

1. Feeds a single goldfish
2. Usable with a 10 gallon tank
3. Tank will not have a lid
4. Dispenses food once per day
5. Works for Omega One medium goldfish pellets
6. Food in a closed container to keep fresh and dry
7. Device must not touch the water when hung over the tank.

2.4.2 Operational Requirements

8. Mountable to tank without damaging any part of the tank
9. Dispenses proper amount of food per serving
10. Should dispense food at set intervals
11. Can hold a minimum of 14 days' worth of food
12. Can be filled in advance
13. Ability to resolve/avoid food clogging
14. Waterproof/resistant

2.4.3 Miscellaneous Requirements

15. Does not damage or affect the surrounding environment
16. Setup within 10 minutes out of the box
17. Set up with basic tools
18. Must cost less than our budget to design and prototype: $700-$1000

19. Producible with our group’s skills
20. Must be no larger than 5in x 5 in x 10 in, not including any external mount

3. Preliminary Design Concepts

We split the design of our system into two parts: the dispensing mechanism and the mounting system. This chapter describes each of our preliminary design concepts for the two parts before any decisions were made.

3.1 Dispensing Mechanisms

The following five designs are our preliminary concepts for the dispensing mechanism.

3.1.1 Horizontal Wheel Design

The basic concept of the Horizontal Wheel Design is that the food is placed into a reservoir and dispensed into a compartment in the wheel. The wheel then turns 180 degrees to release the food into the tank. The reservoir has a sliding door that moves aside to allow the proper amount of food to fall into the wheel's compartment. Once the food is in the compartment, the wheel will spin until the compartment aligns with a hole and dispenses the food into the tank, as depicted in Figure 10. The left picture shows the wheel and the compartment where the food would be first added and the right picture shows the opening from which the food would be released into the tank. This process repeats each day.

Figure 10: Horizontal Wheel Concept Build

3.1.2 Vertical Wheel Design

The Vertical Wheel Design follows the same basic concept of the Horizontal Wheel, except the wheel rotates along a different axis. The reservoir empties by a sliding door into a compartment on the top side of the wheel and then the wheel rotates to dump the food into the tank, shown in Figure 11. There are two compartments across from each other so the wheel can rotate 180 degrees per feeding.

Figure 11: Vertical Wheel Concept Build

3.1.3 Sliding Pre-portioned Design

The concept behind the Sliding Pre-portioned Design is that there are fourteen compartments sitting on a rail that are manually prefilled with food. Each of these compartments has a hole in the bottom that will release the food when it is slid over the main hole in the unit, as seen in Figure 12 below. At the time of feeding, the slider will be moved across the rails to release the food from a single compartment.

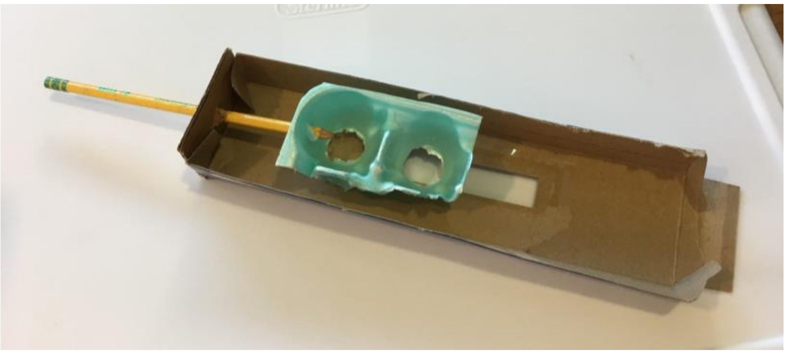


Figure 12: Sliding Pre-portioned Design Concept Build

3.1.4 Trap Door Design

In the Trap Door Design, the door at the bottom of the food reservoir slides out from under the reservoir to allow the fish food to fall into the dispenser. From there, the door on the dispenser is released, and the food falls into the tank. The concept can be seen in Figure 13 below.

Figure 13: Trap Door Design Concept Build

3.1.5 Pre-portioned Wheel Design

The Pre-portioned Wheel Design consists of 14 manually-filled compartments to hold the fish food. The pre-portioned wheel rotates each day so that a new compartment is over the tank, and the food from that compartment is released. The hole that the food falls through is located at the 6 o'clock position in Figure 14. This design is made to last up to two weeks without needing to be refilled.


Figure 14: Pre-portioned Wheel Concept Build

3.2 Mounting Systems

The following five concepts are our preliminary designs for the mounting system of our fish feeder. The mounting systems were developed independently from the dispensing systems.

3.2.1 Spring Clamp

The idea for this mounting system is inspired by the chip clips found in most home kitchens. This method consists of two paddles fixed together by a spring, creating a clamp that can easily be adjusted to the object to which it is clamped. The bottom of each side of the spring clamp would have a large rubber bumper to prevent damage to the tank, as well as grip the tank to provide support for the fish feeder. The concept is pictured in Figure 15.

Figure 15: Spring Clamp Mounting Concept

3.2.2 Around the Side Clamp

The concept for the Around the Side clamp is that of a large carpenter's clamp. The mounting system extends around the short end of the tank and clamps into place. The clamps would have rubber bumpers to protect the tank and improve the grip on the tank. A bar extends vertically from the horizontal part of the clamp to connect to the dispensing mechanism and hold it over the tank's edge. The concept is pictured in Figure 16 below.

3.2.3 Top Mounted Clamp

This mounting system sits over the top of the tank. The mount includes two clamps that tighten the system over the short side of the tank. While the mount is essentially resting on the top of the tank with no need for a clamp, the clamp prevents any children or other pets from sliding the device off the top of the tank. The clamps feature rubber bumpers to prevent damage to the tank. The dispensing device would need to be secured to the mount. The Top Mounted Clamp is pictured below in Figure 17.

Figure 16: Around the Side Clamp Design Concept Build

Figure 17: Top Mounted Concept Build

3.2.4 Screw Clamp

The Screw Clamp features a threaded stopper that can be tightened to secure the feeder to the tank. The adjustable nature of the clamp allows the device to be mounted to a variety of different tank sizes and shapes, and features large rubber bumpers so as not to damage the tank. Consisting of only one screw mechanism, installation is quick, simple and understandable by users of any age. The concept is shown below in Figure 18.

Figure 18: Screw Clamp Concept Build

3.2.5 Suction Cup Mount

Another preliminary mounting strategy is the use of a suction cup to keep the fish feeding system securely on the tank. The system is suctioned onto the side of the fish tank with the feeding mechanism hanging over the edge. This idea has a simple setup, much like the spring clamp, with the user sticking the suction cup to the tank.

4. Initial Design Decisions

In this chapter the design concepts presented in Chapter 3 are evaluated using decision matrices in order to eliminate potentially flawed designs.

4.1 Decision Matrix for Dispensing Mechanism

This section details the decision matrix that was used to narrow down our preliminary design concepts for the dispensing mechanisms from five to three.

4.1.1 Ranking System

We chose Performance Reliability, Cost, Setup, and Size to be the four categories of the decision matrix. The Performance Reliability category encompassed the capability of the system to reliably dispense the proper amount of food at the proper time. This category considered the number of moving parts required for dispensing food as well as the overall simplicity of the system, with the simplest system receiving the best score. The Cost category took into account the cost of the materials and supplies that were required to build the system, namely the number of motors that would be required and the anticipated volume of ABS 3D printing material relative to the other designs. The Setup category encompassed the extent of user interaction, including how often the user has to fill the device with food, setting the timer, and how much "out of the box" setup is required. The final category, Size, took into account the overall size of the device, with smaller being better, and if it could be smaller than the Functional Requirement of 5 in. x 5 in. x 10 in.

We weighted each of the categories so the final sum would add up to 1.

- Performance Reliability: 0.6
- Setup: 0.2
- Size: 0.15
- Cost: 0.05

Performance Reliability had the greatest weight because we needed to make sure the device would function properly. Setup was of the next most importance to us because the device needed to require minimal effort from the user when installing. Size was weighted just less than Setup because we thought the ease of installation was more important than the device's size. Finally, Cost was given least amount of weight because at the preliminary stage cost was not as important as the other factors.

Table 1: Preliminary Decision Matrix for the dispensing device. The designs highlighted in green moved on to the detailed design stage.

	Performance Reliability	Cost	Setup	Size	TOTAL	Rank
Weight Factor	0.6	0.05	0.2	0.15	1	
Horizontal Wheel Design	3	4	5	3	3.45	2
Vertical Wheel Design	2	4	5	4	3	3
Sliding Pre-portioned Design	4	2	1	1	2.85	4
Trap Door Design	1	1	5	2	1.95	5
Pre-portioned Wheel Design	5	5	2	5	4.4	1

4.1.2 Reasoning for Our Scores

Performance Reliability:

We ranked the designs best to worst in the performance reliability section of Table 1 as follows:

1. Pre-portioned Wheel Design
2. Sliding Pre-portioned Design
3. Horizontal Wheel Design
4. Vertical Wheel Design
5. Trap Door Design

We ranked the Pre-portioned Wheel design the highest because we thought that it was the most reliable design due to its low chance of failure and ability to consistently dispense the proper amount of food. Both pre-portioned designs would be extremely reliable since the food is correctly portioned by the user, however we believed that the Sliding Pre-portioned Design was more likely to jam due to its large size, leading to it being ranked second. The inconsistencies that could be presented by using a reservoir to portion out the food made the rest of the designs less reliable than either of the pre-portioned designs. The horizontal wheel was ranked third over the vertical wheel because we believed that the food was less likely to get stuck in the compartments in the horizontal system than the vertical. We ranked the Trap Door Design the lowest due to it having multiple ways to potentially fail. By using two trap door mechanisms, the design effectively had double the chance of failure compared to any of the designs that utilize only one, since trap doors make it difficult to control the amount of food dispensed with each use.

Size:

We ranked the designs best to worst in the size category of Table 1 as follows:

1. Pre-portioned Wheel Design
2. Vertical Wheel Design
3. Horizontal Wheel Design
4. Trap Door Design
5. Sliding Pre-portioned Design

We ranked the Pre-portioned Wheel Design the highest because it only needed one motor and did not require a reservoir. The Horizontal Wheel and Vertical Wheel designs were similar with both requiring two motors and a reservoir for the food, but we ranked the Vertical Wheel higher than the Horizontal Wheel because it would not hang as far into the tank. The horizontal wheel would extend further into the tank whereas the vertical would have the capability to remain more compact. The Trap Door Design was ranked as the second lowest design because it required two motors plus two reservoirs. We ranked the Sliding Pre-portioned Design the lowest because of the bulk associated with its design. It would cover the entire tank in order to incorporate the rails and compartments for all 14 days. The motor would also have been placed in an odd position, adding to the design's large size.

Setup:

We ranked the designs best to worst in the setup category of Table 1 as follows:

1. Trap Door Design
1. Vertical Wheel Design
1. Horizontal Wheel Design
4. Pre-portioned Wheel Design
5. Sliding Pre-portioned Design

We decided to rank the Horizontal Wheel Design, the Vertical Wheel Design, and the Trap Door Design the same since they all had a reservoir to hold the fish food until it was ready to be fed to the fish. They all would have approximately the same outer case and mounting system, making the setup for each of these equally simple. The Pre-portioned Wheel Design has to be filled every two weeks with fish food, which would be more time consuming than filling a large reservoir. The Pre-portioned Wheel was ranked higher than the Sliding Pre-portioned Design due to its compact nature. This design was ranked highest in size, making it easier for the user to handle and attach to the tank. On the contrary, the Sliding Pre-portioned Design would be very long, and thus very difficult to mount onto the tank by only one person. This design also had the same issue where the 14 compartments would need to be filled in advance, which made it our worst design in terms of setup.

Cost:

We ranked the designs best to worst in the cost category of Table 1 as follows:

1. Pre-portioned Wheel Design
2. Horizontal Wheel Design
2. Vertical Wheel Design
4. Sliding Pre-portioned Design
5. Trap Door Design

The Pre-portioned wheel design was ranked the highest because it only required one motor and the amount of material required for it to be manufactured was substantially less than the other designs due to its compact size. The Vertical and Horizontal Wheel designs were both ranked second. They were ranked equally because both designs required two motors and the all of the same components, leading to the amount of material required for each design to be approximately the same. The Sliding Pre-portioned Design was ranked below the other designs because it required much more material to manufacture than the remaining designs due to its large footprint. We ranked the trap door design the lowest because it required two trapdoor mechanisms, as well as two motors to move said doors.

4.1.3 Results

Based on the weights and rankings we gave to each design, the top ranked design was the Pre-portioned Wheel with 4.40 points. It was followed by the Horizontal Wheel with 3.45, the Vertical Wheel with 3.00, the Sliding Pre-portioned with 2.85, and finally the Trap Door Design with 1.95 points. Based on these results, we decided to move forward into the detailed design phase with the Pre-portioned Wheel, Horizontal Wheel, and the Vertical Wheel designs. Due to their low scores, we no longer considered the Trap Door and Sliding Pre-portioned Designs.

4.2 Decision Matrix for Mount

This section details the decision matrix that was used to narrow down our preliminary design concepts of mounting systems from five to three.

4.2.1 Ranking System

The decision matrix for the mounting system was broken down into six categories, Performance Reliability, Installation, Size, and the Compatibility with each of the three dispensing mechanisms. For the first three categories we ranked the mounts against each other, with 5 being the best and 1 being worst system. For compatibility we used a binary system where the mount would receive a 1 if we believed it would be compatible with the specific dispensing design, and a 0 if it would not be. This was used to discourage the selection of a mounting system that was incompatible with the selected dispensing design. The weights of each of the categories was as follows:

- Performance Reliability: 0.35
- Installation: 0.2
- Size: 0.15
- Compatible with Horizontal Wheel: 0.1
- Compatible with Vertical Wheel: 0.1
- Compatible with Pre-portioned Wheel: 0.1

With these weightings, the highest possible score a design could receive was a 5.2.

We gave the Performance Reliability category the largest weight because the system had to be stable on the tank indefinitely. Installation was given the next largest weight because it was important that the user could install the system by themselves without difficulty. The size requirement was weighed less than the previous two because while it was important that the device not be a nuisance to the user, the performance and ease of installation were more important. The compatibility with each of the dispensing mechanisms was ranked the lowest because while compatibility is essential, the mounting designs could be modified in later stages to accommodate any dispensing mechanism.

Table 2: Preliminary Decision Matrix for the mounting system. The designs highlighted in green will move on to the detailed design stage.

	Performance Reliability	Installation	Size	Compatible with Horz. Wheel	Compatible with Vert Wheel	Compatible with Pre-portioned	TOTAL	Rank
Weight Factor	0.35	0.2	0.15	0.1	0.1	0.1	1	
Spring Clamp	3	5	5	1	1	1	3.1	1
Screw Clamp	5	3	3	1	1	1	3.1	1
Top Mounted Clamp	4	2	2	1	1	1	2.4	4
Around the Side Mount	1	1	1	1	1	1	1	5
Suction Cup	2	4	5	1	1	1	2.55	3

4.2.2 Reasoning for Our Scores

Performance Reliability:

We ranked the designs best to worst in the Performance Reliability category of Table 2 as follows:

1. Screw Clamp
2. Top Mounted Clamp
3. Spring Clamp
4. Suction Cup
5. Around the Side Mount

We ranked the Screw Clamp the highest because it could be securely tightened to the tank upon installation, thus ensuring a reliable hold. The Top Mounted Clamp was ranked below the Screw Clamp because even though it would be one of the most secure mounts since it balanced over the entire width versus just one side, it required electronics to be directly over water. The Spring Clamp was ranked above the Suction Cup because it gripped both sides of the tank as opposed to just the outside. Finally, the Around the Side Mount was ranked last because it had the potential to slide down the tank.

Installation:

We ranked the designs best to worst in the Installation category of Table 2 as follows:

1. Spring Clamp
2. Suction Cup
3. Screw Clamp
4. Top Mounted Clamp
5. Around the Side Mount

We ranked the Spring Clamp the highest because it could be easily installed with only one hand. The suction cup was ranked next because even though it could also be applied with one hand, it required more pressure to use and potentially would not stick on the first application. The screw clamp was ranked next because it would require two hands to install: one to hold the device and one to tighten the screw. The Top Mounted Clamp came next because there would be multiple screws needed to clamp it into place, thus requiring more effort than any of the previous three concepts. Lastly, the Around the Side Mount was ranked fifth because it could possibly require two people to install. There would be one person holding the mount at the proper height and another tightening the clamp.

Size:

We ranked the designs best to worst in the Size category of Table 2 as follows:

1. Spring Clamp
1. Suction Cup
3. Screw Clamp
4. Top Mounted Clamp
5. Around the Side Mount

We ranked the Spring Clamp and Suction Cup together as the best designs because they were both very compact and would not take up a lot of additional space. The Screw Clamp was ranked next because it needed additional space for the padding against both sides of the tank. The Top Mounted Clamp and Around the Side Mount were ranked the lowest because they were substantially larger than any of the three previous designs.

Compatibility:

The compatibility category was binary: either the mount would work with the individual dispensing designs or it would not. We decided that all of our mechanism designs could be used with all of the mounts, so each design was given the same ranking.

4.2.3 Results

Based on this decision matrix, we decided to move forward with the Spring Clamp, Suction Cup, and Screw Clamp.

5. Final Designs and Decision

In this chapter we explain each of the detailed designs for the dispensing and mounting mechanisms that we chose to move forward with from Chapter 4. We then discuss our final decision for the design of our device.

5.1 Detailed Dispenser Designs

The following are our detailed designs for the Pre-portioned wheel, horizontal wheel, and vertical wheel.

5.1.1 Pre-portioned Wheel

In our initial decision matrix, the Pre-portioned Wheel design was determined to be the best design. It ensured that the proper amount of food was always dispensed on a given day because the food was preloaded by the user, thus eliminating any risk of error from a portioning mechanism. In our detailed design for the system, the stepper motor was housed in the back of device. There was then a gear train that linked the motor to the food wheel. The stepper motor was controlled by an Arduino and rotated the food wheel so that one portioning compartment was over the tank at a time. This action would occur once per day for the 14 days' worth of compartments, meeting the functional requirement. The CAD models for the overall design and the torque transfer system can be seen below in Figures 19 and 20, respectively.

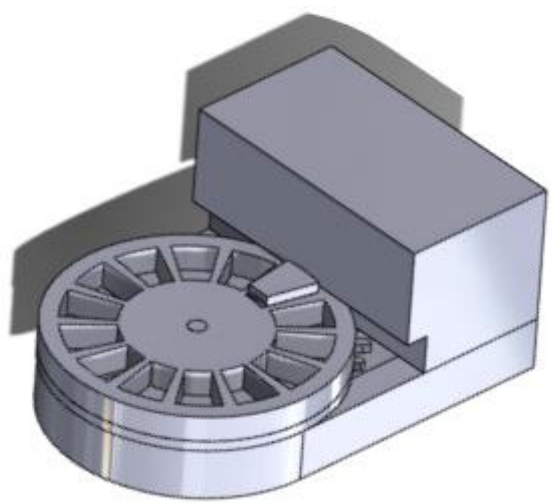


Figure 19: Isometric CAD Model for the Pre-Portioned Wheel Design

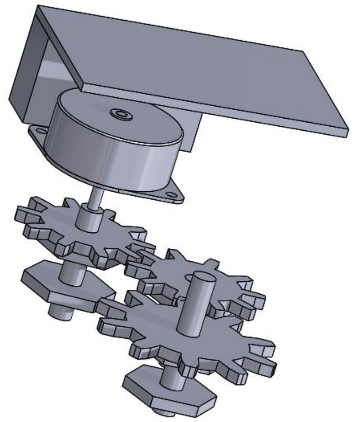


Figure 20: Torque Transfer System for the Pre-Portioned Wheel Design

5.1.2 Vertical Wheel

The Vertical Wheel design was ranked third in our initial decision matrix. This design would require two stepper motors: one that controls a rack and pinion mechanism that functions as a food gate to let the food out of the reservoir, and a second that rotates the food wheel to dispense the food into the tank, as shown in Figure 21. An Arduino would control both of these motors in this sequence: open gate, close gate, rotate the food wheel. The motors would most likely be attached to the back wall of the housing and the Arduino would be located near the top, by the food reservoir.

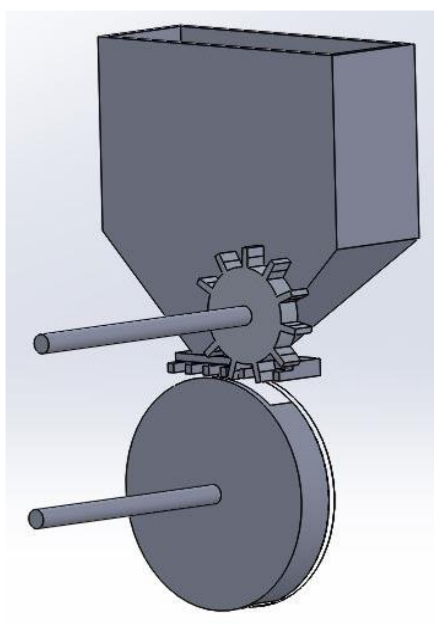


Figure 21: The Vertical Wheel Dispensing Mechanism

5.1.3 Horizontal Wheel

From the decision matrix we determined that the Horizontal Wheel design was our second-best concept for dispensing food. The design for the Horizontal Wheel operated in the same way as the vertical wheel, except that the wheel was oriented horizontally. One stepper motor controlled a rack and pinion system that dispensed a single portion of food out of the reservoir and into the food wheel. A second stepper motor transmitted torque through gears to rotate the food wheel, dispensing the food into the tank. An Arduino controlled the two stepper motors and ran them in sequence. The Arduino and a battery pack would both be located in the rear of the design. The CAD models for the overall design and the dispensing system can be seen below in Figures 22 and 23, respectively.

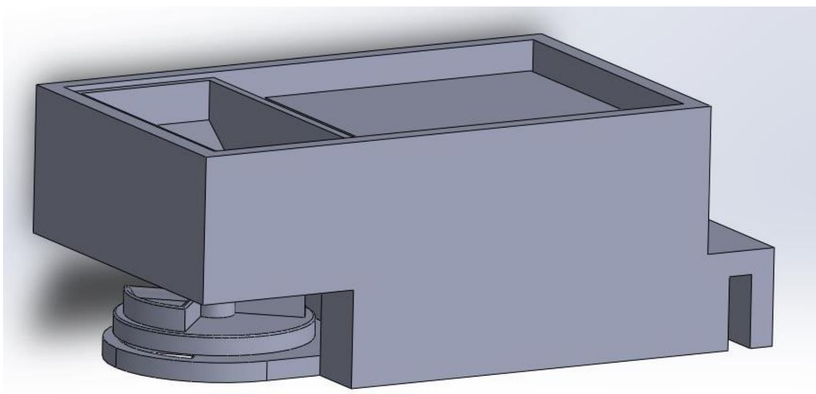


Figure 22: Horizontal Wheel Design

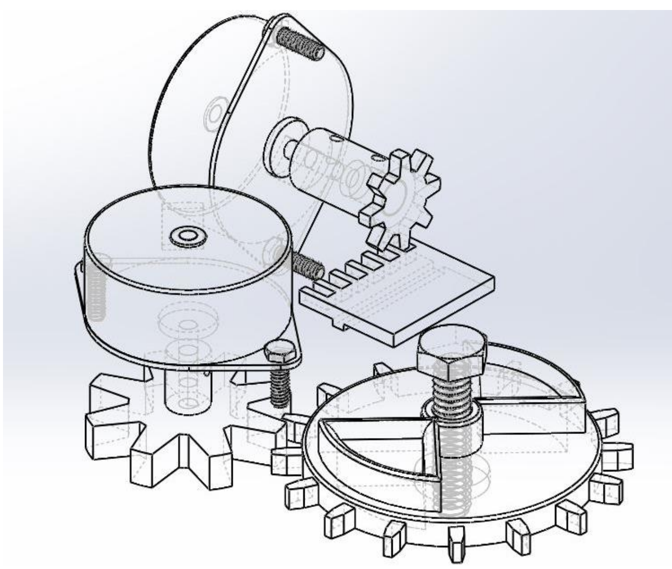


Figure 23: Stepper Motors and Gears for the Horizontal Wheel Design

5.2 Final Dispenser Decision

After doing some additional market research, we found a number of products that are currently available that are nearly identical in both appearance and function to our Pre-portioned Wheel design. As we began creating the CAD model for the Vertical Wheel concept, we concluded that there were substantial stability issues because the entire rotating wheel system would be held up by just the motor shaft. The design was also potentially too tall to be easily mounted to the fish tank. As we refined the concepts it became apparent that the Horizontal Wheel was our most promising design. With the orientation of the food wheel being horizontal, it eliminated the stability issues presented by the Vertical Wheel design while still retaining the ability to both portion fish food as well as dispense every day.

While the Pre-portioned Wheel design had many strengths over the other designs, we chose not to pursue it due to the fact that it is currently available in stores and our design is not a significant improvement. The Vertical Wheel and Horizontal Wheel designs feature many similarities, but they differed in stability. The Horizontal wheel, because of its horizontal plane of motion, was a sturdier and more reliable choice, and we continued to develop this design to create our final prototype.

5.3 Final Mounting Decision

We decided that we would move forward with the Screw Clamp design as our mounting system. We chose not to pursue the Suction Cup and Spring Clamp because of stability concerns and the Top Mounted Clamp because it was considerably bulkier than the other designs and potentially more difficult to install.

5.4 Final Design

Our final design is the Horizontal Wheel dispensing system with the Screw Clamp mount. The dispensing unit contains a food reservoir that can hold 14 days' worth of food, a food gate, a food wheel, an external power supply, and an Arduino to control the feeding schedule. The system works using an Arduino that activates one stepper motor so the food gate moves aside for a set period of time to release the food from the reservoir to the food wheel. The Arduino then activates the second stepper motor which rotates the food wheel, dropping the food into the tank. This process takes place every 24 hours to fulfill the once-per-day feeding requirement.

The mounting system is a removable screw clamp that attaches to the bottom of the housing. The connection is made in the middle of the unit so that the food wheel will remain suspended over the tank for proper feeding. The mounting system grips the wall of the tank and has a screw to tighten it into place.

6. Testing and Proof of Concept

In this chapter we detail the initial prototype we built and discuss any changes that lead to our final design iteration. We will also explain the testing that was done in order to prove our design.

6.1 Food and Reservoir Testing

In order to ensure that our device would feed the fish, we conducted various different tests on both the food and the reservoir.

6.1.1 Food Reservoir Testing

As a way to learn about how the food would behave, we started with some experiments using a cardboard box and the neck of a Gatorade bottle. The setup can be seen in Figure 24 below. The flakes were put into the bottle, and we observed both the amount of food that fell out at different intervals, and if the food fell straight downwards. After a few rounds of this, we determined that this method was not an accurate test because the shape of the reservoir we designed was more of an angled square than a round bottleneck. We made the decision to 3D print a prototype of our design to make sure that it would work.

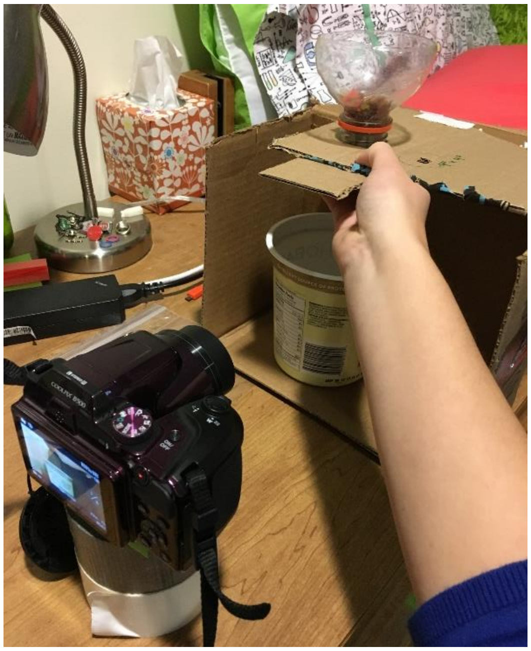


Figure 24: Initial Food Testing Setup

When we received the reservoir prototype, we filled it with food and used a card or piece of paper like a door to see if the food would fall out. The opening of our reservoir was too small and the flakes immediately clogged and blocked any food from leaving. The clogging in both the reservoir and the cardboard tests are shown in Figure 25. As discussed in the next section, we ultimately decided to change the fish food we were using from flakes to medium sized pellets.

Figure 25: Flakes Clogging in 3D-Printed Reservoir (Left) and during Cardboard Test (Right)

6.1.2 Fish Food Decision

After several different attempts to use the flakes with our reservoir, we determined that the flakes would not work. We tried crushing the flakes into smaller pieces, and they still clogged the opening. They were too lightweight to fall without an external force. Our team was faced with a dilemma: whether to redesign the entire reservoir, which would result in multiple other design changes in the system, or change the type of food we were using. Since it was nearing the end of December and drastically altering the design would take too much time, we chose to make the design decision of changing the fish food. We switched from Tetrafin Plus Goldfish Flakes to Omega One Medium Goldfish Pellets. The pellets had more mass to them and a uniform spherical shape that made them easier to guide through the system.

6.1.3 Final Reservoir Design

When we got the new pellets we performed the same test in the 3D-printed reservoir. While the pellets did fall much better than the flakes, they jammed after a few tries. Based on this, we chose to expand the opening of the reservoir from 0.4 in. x 0.4 in. to 0.5 in. x 0.6 in. so the food would fall consistently. After switching to pellets, we also put dishwasher safe Mod Podge on the reservoir because we needed to make the ABS material food safe. The addition of the Mod Podge did not appear to affect the food’s ability to exit the reservoir, so we will continue with it in the final product.

6.2 Housing Prototype

In this section we describe the housing prototype used to determine if the components and mechanisms would fit and function properly.

6.2.1 Acrylic Prototype

With the initial design process complete, we prototyped our housing to verify that the components and mechanisms could be oriented as intended. This gave us the chance to make sure that the spacing between each component was adequate, and also to confirm that all parts could be assembled into the housing.

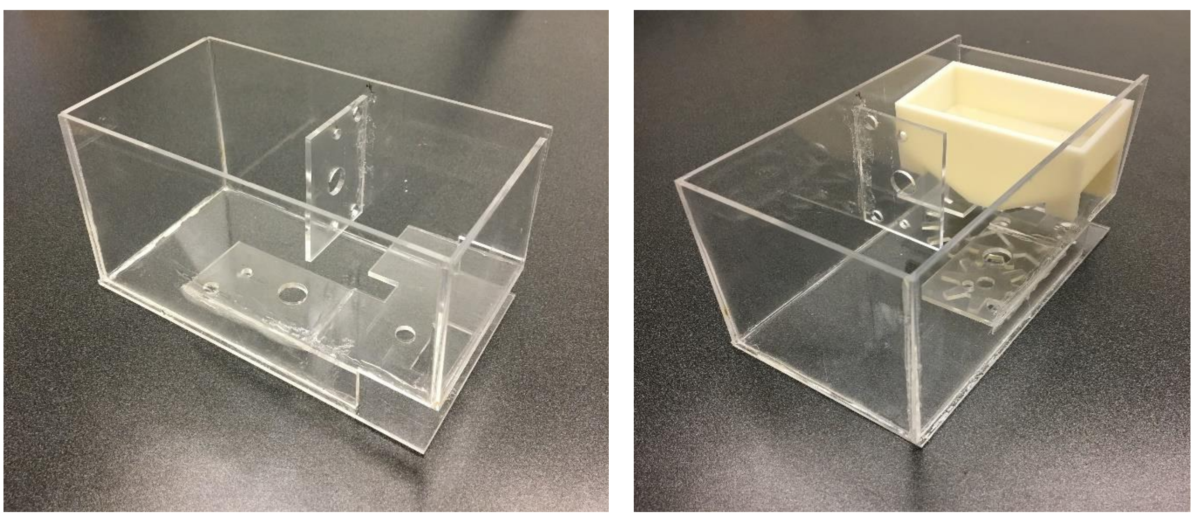


Figure 26: Acrylic Prototype

We laser cut the walls of the housing out of 0.1 in.-thick clear acrylic. Once we had the walls cut out of the acrylic, we began assembling the housing. We used a two-part epoxy to bond the walls together, as well as some weighted blocks to hold the components square while the epoxy set. We had some trouble with the alignment of the prototype walls, but were able to correct most of the issues before the adhesive completely dried. In addition to the exterior walls of the housing, we added the walls for the motors and the ledge on which the food reservoir sits. It can be seen in Figure 26.

6.2.2 Housing Redesign

Once the acrylic prototype was completed, we saw that all components fit into the housing as intended; however, the spacing below the food reservoir was insufficient to assemble some of the components by hand. This observation led us to change the geometry of the CAD model, namely increasing the height of the ledge that the food reservoir rests on. Additionally, we used this acrylic prototype to determine where on the housing to place the mounting apparatus. We did this by placing the motors inside the prototype and determining where the center of mass would be located.

6.3 Gear Testing

In this section we detail the process we used to reach our final gear train.

6.3.1 Initial Gear System

Our initial main mechanism, shown in Figure 27, featured two distinct motor/gear systems. First, the rack and pinion gear system uncovers the hole at the bottom of the food reservoir so the food can fall into the food wheel. We now refer to this system as System 1. Then, the second motor turns a gear train to dump the food from the food wheel into the tank. We now refer to this system as System 2. As we began designing our mechanism and laying out the gearing system, we decided that 3D printing our own gears would be easier than attempting to match our custom 3D printed food wheel and gear rack to standard purchased gears. To ensure these gears would match up correctly after we 3D printed them, we tested the system by laser cutting the gears.

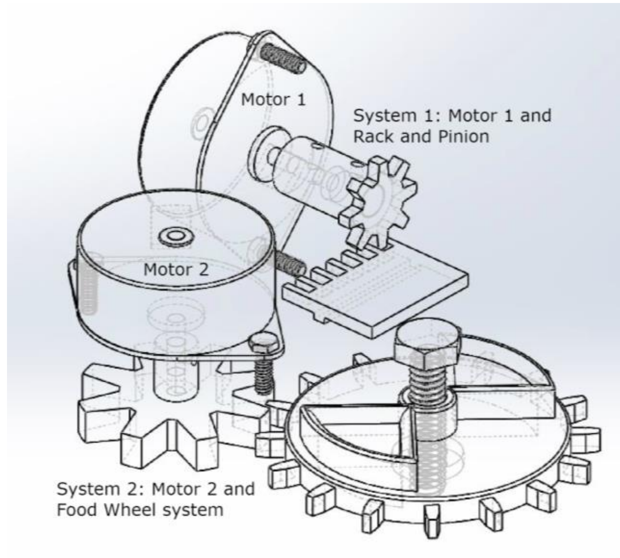


Figure 27: Initial Gearing System

We used the extra acrylic from our housing prototype to laser cut the gear profiles. Upon testing, we discovered that System 2 worked without any issues, pictured in the Figure 28 below, but System 1 did not. The rack and pinion gears did not mesh together the way we had hoped. We realized we needed to reevaluate our decision to 3D print our own gears, so we began our search for standard gears to replace our custom ones.

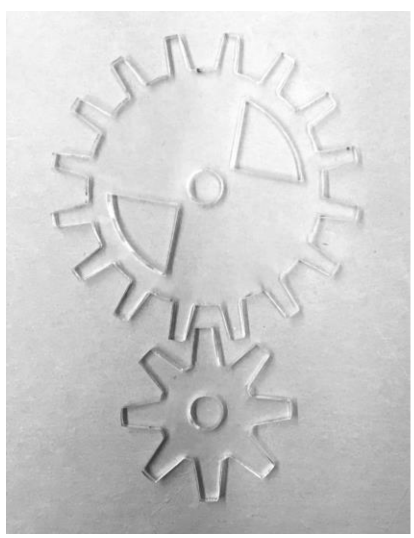


Figure 28: Initial Laser Cut Gears for System 2

For System 1, we found purchasable rack and pinion gears to ensure the system would mesh properly. To adapt this rack into the food gate, we downloaded the CAD model and extruded its side to make a flat surface for the gate (See Figure 29, Appendix B). Since we customized the gear rack, it had to be 3D printed. We bought the accompanying pinion gear.

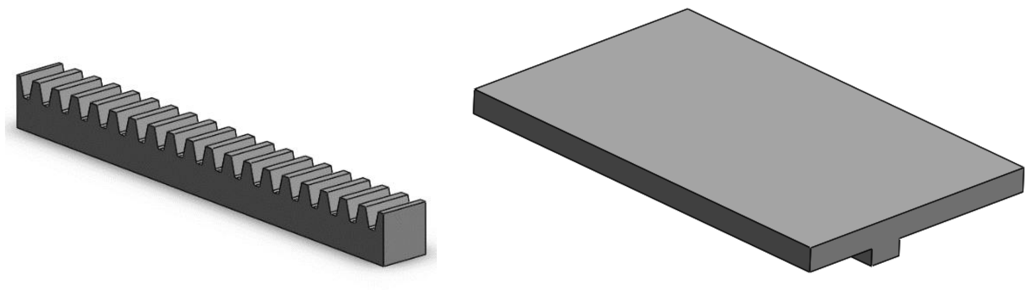


Figure 29: The Rack and Gate Models that Were Combined to Create the Complete Food Gate

Since our housing dimensions changed during the redesign process, we needed to add a third gear to System 2 to adjust for this size change. The food wheel and the two smaller gears required the same gear ratio for the system to work. We found a gear with an inner diameter large enough to fit around our food wheel. To make a single part to 3D print we combined the gear's CAD model with that of our food wheel, as shown in Figure 30. This ensured that our food wheel worked with the two gears that we purchased.

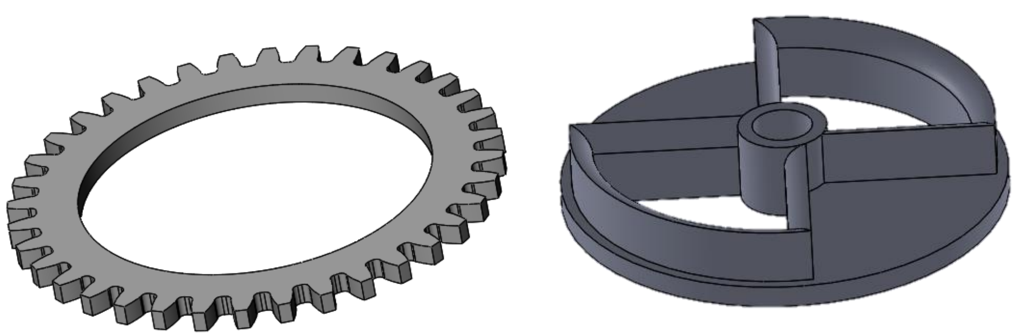


Figure 30: Large inner diameter gear (Left) and the food wheel model (Right) that we combined to make our complete food wheel

6.3.2 Food Gate Adjustments

When we assembled System 1, we noticed that the pinion gear was placing significant pressure on the end of the rack, causing it to become angled. The resolution of the teeth on the 3D-printed rack was too low and the teeth would not mesh with those on the pinion gear. With the food gate in this position, food was able to slip out of the reservoir into the housing, which caused the system to jam. To solve this problem, we purchased and adhered a gear rack to a 3D printed food gate. This ensured that the rack would mesh with the pinion gear and that the food gate would sit flat, keeping food from spilling out of the reservoir.

6.3.3 Reworked Gear Train

Once all of the necessary gear testing was completed, we arrived at our final gear system shown in Figure 31. We added a third gear to System 2 and replaced most of our custom gears with gears purchased from McMaster Carr. The only gear that we 3D printed was the food wheel, which we adapted from the McMaster Carr CAD model.

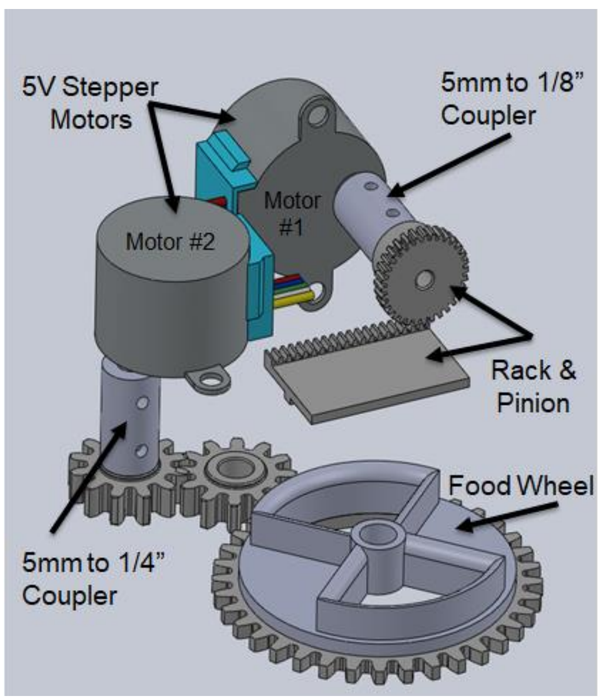


Figure 31: Final Gear Train

6.4 Mounting System

In this section we discuss the process used to develop the mounting system.

6.4.1 Housing/Mounting Connection

Initially we planned to have the mount as one piece within the housing; however the Arduino unit was taller than originally planned, making this impossible. We decided to make the mounting system detachable from the housing so that the user can remove the fish feeder without unclamping the mount from the tank. The mounting system utilized a T-shaped sliding mechanism, shown in Figure 32 below. Having the main connection in the housing also increased the stability of the system as a whole.

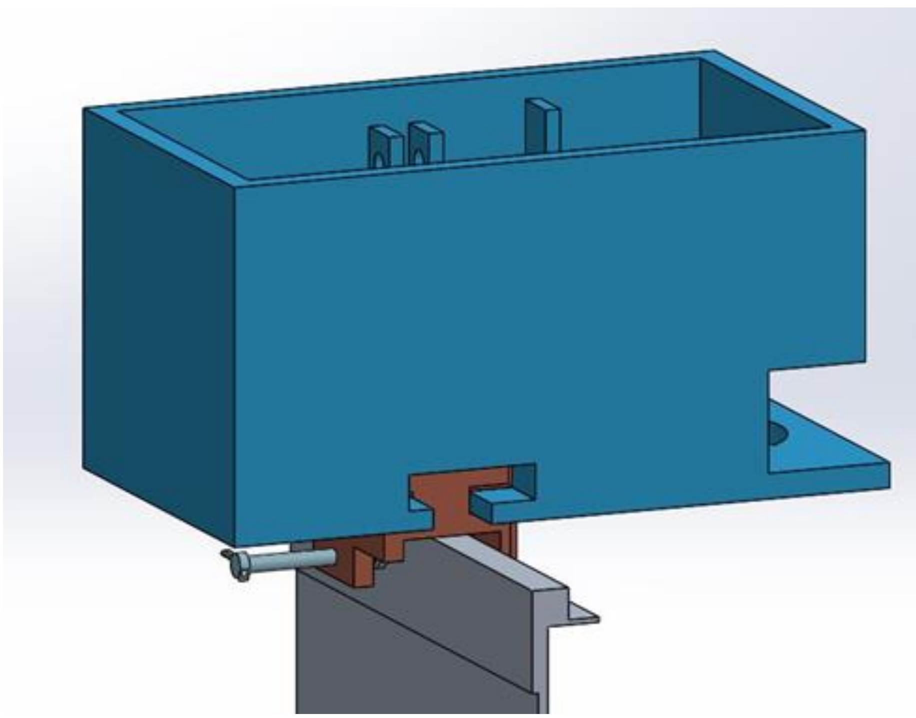


Figure 32: Mounting System attached to the Housing

6.4.2 Screw Mechanism

While designing the mount, our main dilemma was determining how to make the screw mechanism function properly. Since we were customizing the system, threading a 3D-printed part would be difficult, as we did not think we could achieve the accuracy needed. In order to achieve our desired design, we chose to use a press-fit threaded insert. After two attempts with

3D-printed parts, we determined that this threaded insert did not work as intended. Once it was clear that using a threaded insert was not a feasible option, we epoxied a nut to the mount to be the threading that we needed. This solution worked as expected and was incorporated into the final design.

6.4.3 Rubber Bumper Adjustment

After we assembled the mount and attached it to the tank, we realized that even when the screw was tightened the device could still tip backwards. In order to remedy this issue and get a tight and secure fit to the side of the tank, we added additional rubber padding to the mount as shown in Figure 33. This padding better gripped the inside of the tank and helped provide additional protection to the tank glass.

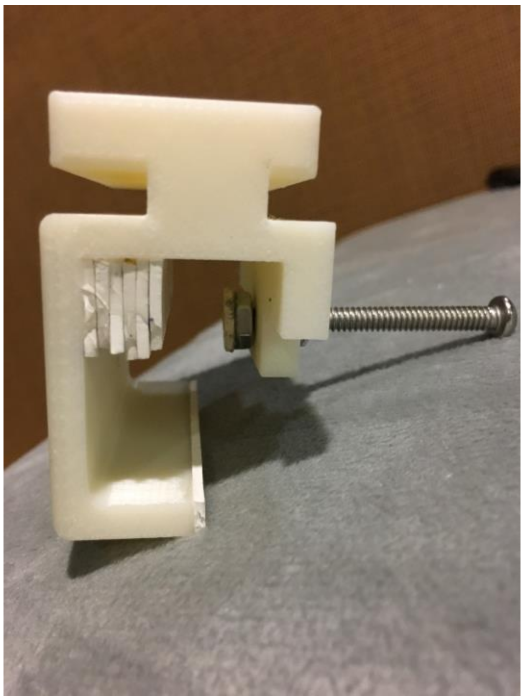


Figure 33: Mount with the Rubber Bumper

6.5 Arduino Circuit

The fish feeder utilized an Arduino Uno as a controller for the stepper motors. To most effectively control stepper motors with an Arduino, a motor shield was required. Upon installing the Adafruit Motor Shield V2 on to the Arduino, we connected the stepper motors to the Arduino unit. The Arduino kept the motor controller, timing mechanism, and power supply all in one unit, allowing us to maintain our compact design. This section details the code and testing for the Arduino.

6.5.1 Dispensing Process

The code runs Motor 1 for a set amount of time to open the food gate, correctly portioning out one serving of food. The same motor then runs again, closing the food gate. Once this action is complete, the second stepper motor rotates the food wheel, dispensing the serving of food into the fish tank. This series of actions is repeated once per day. A flowchart of this process is shown below in Figure 34.

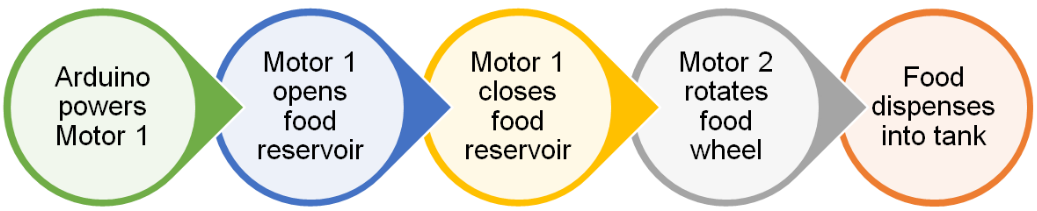


Figure 34: Flowchart of the Dispensing Process

6.5.2 Arduino Code

The code for the feeder is shown in Figure 35. Lines 1 - 8 are necessary to create the motor shield and stepper motor objects so that they are recognized by the Arduino. The motors are declared in Lines 7 and 8. The parentheses in these lines specify the number of steps per revolution for each motor (513 for our motors) followed by which input on the shield the motor is connected. Input 1 runs Motor 1 for System 1, and Input 2 runs Motor 2 for System 2. After the motors are declared, the "void.setup" function begins. Lines 11 and 12 are necessary to communicate with the shield and Lines 14-16 set the motor speed, in RPM. The maximum safe operating speed for our motors is 50 RPM.

The "void.loop" function contains the series of functions that run repeatedly until the device is powered off (Lines 21-36). The "step" function activates the motors, requiring inputs for the number of steps the motor should move, the direction of movement, and the stepper mode. We used the "single" stepper mode for our program. The "step" functions in Lines 23 and 25 control Motor 1. Line 23 opens the food gate and Line 25 closes the food gate. The "release" function in Line 27 cuts power to the motors and prevents them from overheating. After System 1 has finished, there is a slight delay before the food wheel begins rotating. This delay is found in Line 29. The final step function in Line 32 controls Motor 2. It does not require a backwards function since the food wheel rotates 180 degrees each cycle, aligning the next compartment with the food reservoir. Motor 2 is released in Line 33. Lastly, the device waits 24 hours (Line 35) before repeating the “void.loop” function.

```
Fish_Feeder_Code
1 #include <Wire.h>
2 //#include <AccelStepper.h>
3 #include <Adafruit_MotorShield.h>
4
5
6 Adafruit_MotorShield AFMS = Adafruit_MotorShield();
7 Adafruit_StepperMotor *Motor1 = AFMS.getStepper(513, 1);
8 Adafruit_StepperMotor *Motor2 = AFMS.getStepper(513, 2);
9
10 void setup() {
11 Serial.begin(9600);
12 AFMS.begin();
13
14 Motor1->setSpeed(50);
15 // speed in RPM for motor 1 (max 50)
16 Motor2->setSpeed(25);
17 // speed in RPM for motor 2 (max 25)
18 delay(600000);
19 }
20
21 void loop() {
22   //delay in milliseconds, amount of time it waits before running
23   Motor1->step(60, BACKWARD, SINGLE);
24   // ^^number of steps the food gate opens
25   Motor1->step(72, FORWARD, SINGLE);
26   // number of steps the food gate closes
27   Motor1->release();
28
29   delay(500);
30
31 //these lines rotate the food wheel
32   Motor2->step(770, FORWARD, SINGLE);
33   Motor2->release();
34
35 delay(43200000);
36 }
```

Figure 35: Full Arduino Code

6.5.3 Arduino Testing

After we finished writing the code and completely assembled the device, we performed testing to determine the proper number of steps required to dispense the correct serving of food. We decided that the feeder should dispense between one and six pellets per cycle. If the feeder dispensed zero or more than six pellets we considered that cycle a failure. This testing only focused on System 1.

Testing began with a speed of 45 RPM and 63 steps backwards and forwards. We observed that more than 15 pellets were being dispensed per cycle, which was not within our acceptable range. We chose to increase the speed to 50 RPM with the same number of steps, which reduced the number of pellets to roughly 10 per cycle. While we were doing this testing, we observed that a pellet would occasionally jam the food gate, not allowing it to close completely. Since our stepper motors did not return to an initial home position each cycle, the food gate would not completely cover the food reservoir following a jam. This led to an increased number of pellets dispensed on the subsequent cycles. To remedy this issue, we elected to increase the number of steps that the motor turned when closing the food gate. This change allowed the device to readjust after a jam.

After making the above changes, we had to determine which number of steps would dispense the proper amount of food. We tested four different step values, each for 30 cycles:

- 58 steps open, 70 steps close
- 59 steps open, 70 steps close
- 60 steps open, 69 steps close
- 63 steps open, 72 steps close

We also added a test with 58 steps open and 70 steps close at 48 RPM to see if the slight speed change affected the results. This test resulted in the most number of zeros, so this speed was no longer considered. The full data set can be found in Appendix A.

Based on the 30-cycle tests, we decided to do shorter 14-cycle tests to make our final decision. We chose to do this test for the opening steps of 58, 59, and 60 because they delivered the most promising results. We did not do additional testing with 63 steps, despite having the lowest failure rates in the 30-cycle tests because it had the highest standard deviations. After conducting 14-cycle tests on each step combination, we observed that opening 60 steps and closing 72 steps had a 93% success rate with only one failure. We chose this step count for the final design.

7. Final Design

This chapter explains our final design and the confirmation test we did to validate our device.

7.1 Final Design

This section details the specifics of the components in our device. A picture of our final device can be seen below in Figure 36. Drawings, exploded assemblies, and bill of materials for the following can be found in Appendix B.

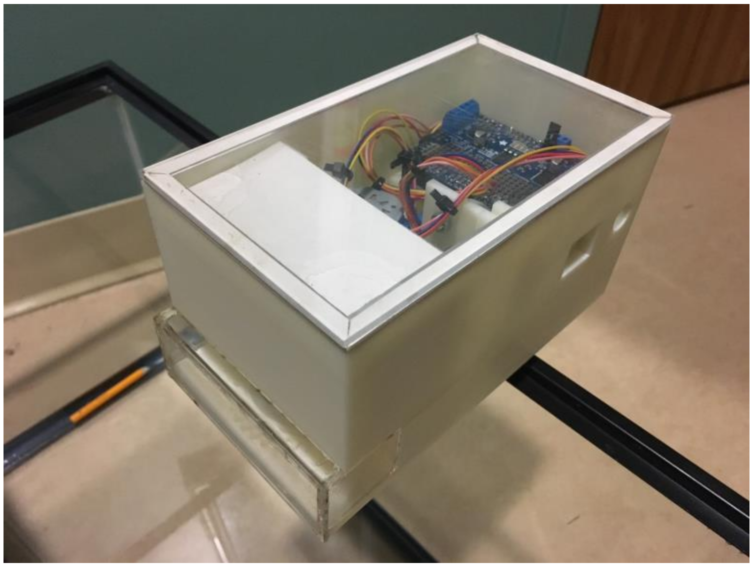


Figure 36: Final Device

7.1.1 System 1

System 1, which contains the rack and pinion system, consists of a 5V stepper motor, a .125 in. shaft extension, a 0.125 in. to 0.125 in. coupler, a purchased 0.667 in. pitch diameter, 32 tooth pinion gear, and a gear rack modified to be used as the food gate. The pinion gear is press fit and glued onto the shaft extension which is attached to the stepper motor via the coupler. To make the necessary adjustment to the food gate, we 3D printed a door to be attached to the side of the rack, as shown in Figure 37 below. This food gate slides on tracks within the housing and is held in place by the food reservoir.

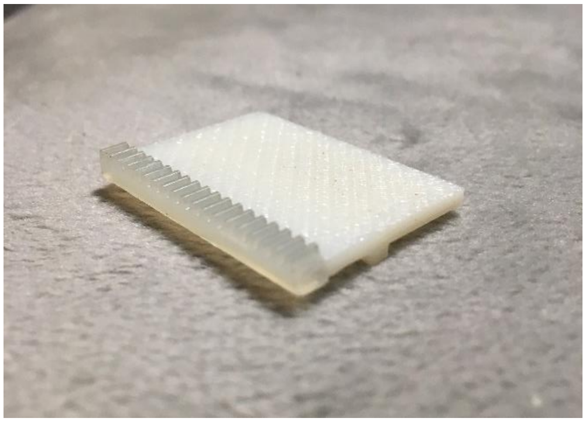


Figure 37: Modified Gear Rack

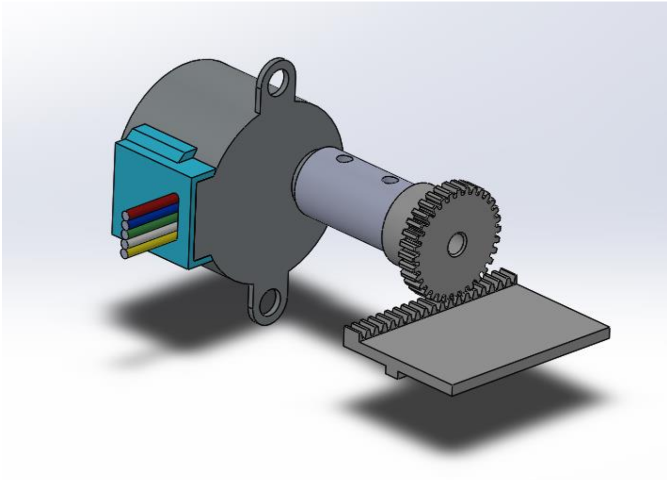


Figure 38: System 1

7.1.2 System 2

System 2 utilizes a 5V stepper motor, a 0.25 in. shaft extension, and a 0.125 in. to 0.25 in. coupler to turn a three gear train to rotate the food wheel and dispense the food. The two small gears are both 0.75 in. pitch diameter, 12 tooth gears offset slightly to accommodate for the space provided in the housing. We 3D printed the food wheel we created by combining the CAD model of a 2.25 in. pitch diameter, 36-tooth gear from McMaster Carr with that of our food wheel. When testing our prototype, we noticed some food pellets were getting stuck under the food wheel. To eradicate this problem, we attached rubber to the bottom of the food wheel on the edge of the compartments.

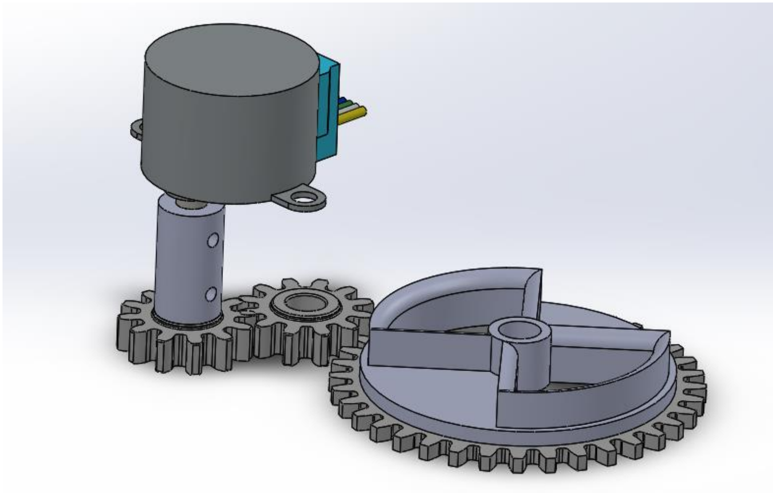


Figure 39: System 2

7.1.3 Arduino

The Arduino is attached to the Adafruit Motor Shield and located on a shelf in the back of the device. The two 5V stepper motors are connected to the motor shield and are controlled by the code explained in section 6.5.2. Motor 1 is connected to shield's Input 1 and Motor 2 is connected to the shield's Input 2. When the Arduino is powered, there is first a 10 minute delay so that the device does not start operating immediately. After the delay the Arduino instructs Motor 1 to go backward 60 steps and then forward 72 steps at 50 RPM to open and close the food gate. There is then a 0.5 second delay before Motor 2 is run for 770 steps at 25 RPM to rotate the food wheel 180 degrees. Another delay is set for 24 hours so the device will operate once per day. The motors are released from power once they have finished their operation in order for them to remain at room temperature and not be safety hazard.

7.1.4 Housing

The feeder housing is a 3D printed body that protects and locates all of the components of the feeding system. The main components of the housing assembly are the main body, two motor walls, a food wheel, a food gate, a food reservoir, an Arduino shelf, and the various hardware used to secure these components in place. The body has a 6.75 in. x 3.75 in. footprint and is 3.50 in. tall. The outer walls of the housing are all 0.25 in. thick.

The bottom of the housing has a 90 degree, 0.95 in.-radius hole with filleted edges through which the food falls from the food wheel into the tank. The 2.00 in.-diameter food wheel has two compartments with filleted edges that catch the portion of food falling from the food reservoir. The bottom surface of the housing has a 0.27 in.-diameter hole where the axle of the food wheel is located. This axle is secured with a clevis pin on top of a shelf 1.00 in. from the bottom surface, upon which the food reservoir and food gate sit. This shelf has a 0.75 in. x 0.60 in. cutout where the food from the reservoir falls into the food wheel. There are two 0.50 in. plastic spacers on the clevis pin to ensure that the top of the pin doesn't interfere with the positioning of the food reservoir. The housing can be seen in Appendix B.

The food reservoir is 3.20 in. x 1.60 in. and is 1.72 in. tall. The reservoir has sloped walls that direct the food down to a 0.60 in. x 0.50 in. hole. The reservoir has two feet that sit on ledges on either side of the housing body to ensure that it is stable and to keep the hole in the bottom of the reservoir located above the hole in the shelf of the main housing body. This location is crucial to the operation of the feeder because the bottom of the food reservoir creates a seal with the 0.77 in. x 1.25 in. food gate. The technical drawings for both the food reservoir and food gate can be seen in Appendix B.

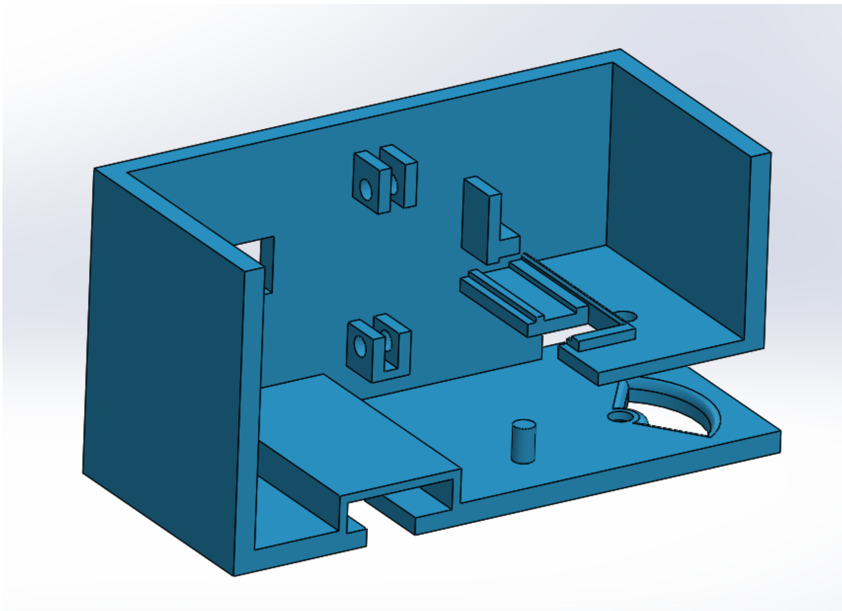


Figure 40: Housing Cross Section

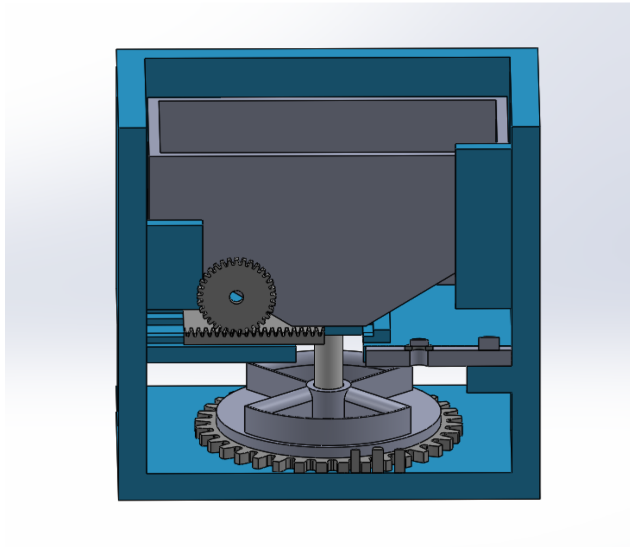


Figure 41: Cross Section of Food Reservoir and Food Gate Interaction

There are two removable walls onto which the two stepper motors are affixed. These two walls are bolted onto the housing body after the motors are installed to aid in ease of assembly. The housing also has holes for the feet of a shelf to support the Arduino unit, which is located at the back of the device. The feet of the 2.00 in. x 3.23 in. Arduino shelf are 0.50 in. long to ensure that the shelf can't fall forward under the weight of the Arduino and shield. Technical drawings for the motor walls and Arduino shelf can be found in Appendix B.

7.1.5 Mounting

The mounting system allows the housing to be securely attached to the tank while ensuring that the device is held level. The system consists of a 3D printed mounting bracket (Appendix B), a threaded nut, a screw, and protective rubber padding. The mounting bracket is shaped such that it sits on the lip of the tank wall and contacts the inside face of the glass. The rubber padding on the inside contact surface helps grip the tank wall and prevents the mount from damaging the glass. The threaded nut and screw allow for the user to tighten the mount onto the exterior face of the tank, restricting the mount from tipping in either direction. The screw has a rubber-padded nut affixed to the end to provide additional protection to the tank wall.

The top of the mounting bracket has a T-shaped connection that fits inside of a channel in the bottom of the feeder housing. This allows for the feeder to be removed from the mount without the mount being removed from the tank. The connection has an asymmetrical shape that forces the user to install the feeder facing the proper direction. Additionally, this connection and channel ensure that the mounting bracket is centered on the bottom of the feeder to provide maximum stability.

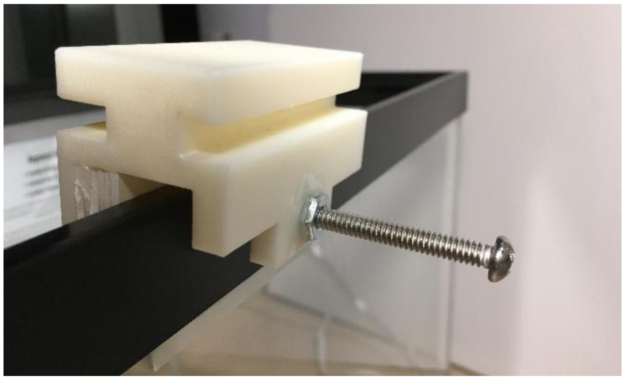


Figure 42: Mount Installed on the Fish Tank

7.1.6 Lids and Covers

In order keep all moving parts covered and add water protection to our device we built two covers. The first is placed on top of the housing and uses rubber to seal the device. This lid covers all of the electrical components in the housing. The second goes over the front of the device to encase the food wheel. This ensures that nothing can come into contact with the gears, which could cause injury and break the device. We made both pieces out of laser cut acrylic. The covers for the top and front of the device are pictured in Figures 43 and 44, respectively.

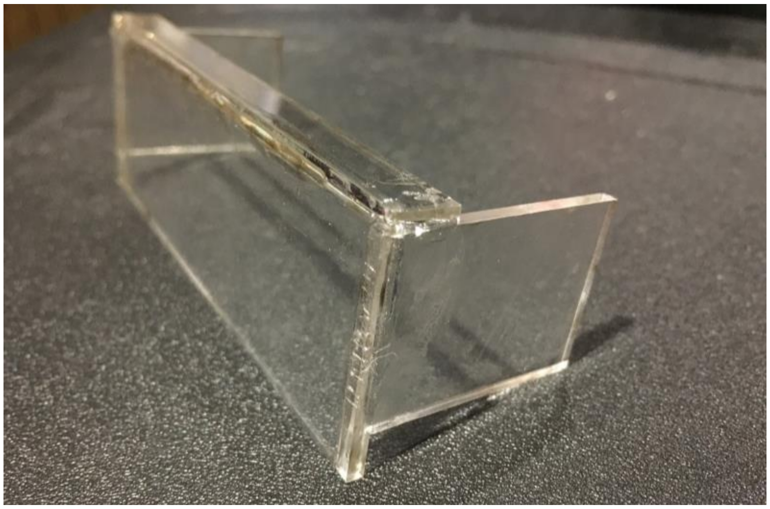


Figure 43: Front Cover

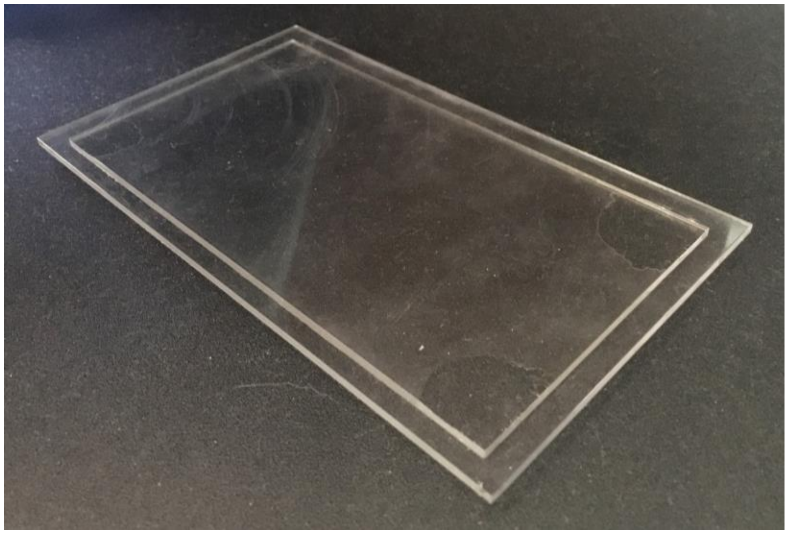


Figure 44: Top Lid

7.2 Final Prototype Confirmation Testing

Upon completing all preliminary testing, we began the final confirmation test. From the data collected in section 6.5.3, we concluded that a speed of 50 RPM, opening 60 steps, and closing 72 steps were the most consistent settings to move forward with for Motor 1. Per our functional requirements, the device needed to run for at least 14 days at one feeding per day. In the interest of time, we tested the device for seven days, with two feedings per day. This allowed us time to make any necessary changes after the confirmation test.

Upon completing this confirmation test, we noted that the device had five failures, all of which were feedings of zero pellets. This data can be observed in Appendix A**.** A failure rate of 36% was too high for us to conclude that the device is reliable long term.

Once the test had concluded, we ran additional 30-cycle tests for various opening step values to see if 60 steps was actually the optimal setting for opening the food gate. We performed tests with opening values of 60 steps, 61 steps, and 62 steps, the data for which can be found in Appendix A. For the two runs of 60 steps, the failure percentages were 77% and 43%, with the first having 21 instances of zero pellets and the second test having 13 cycles with more than 6 pellets. The data was decidedly inconsistent and remained inconsistent throughout the remainder of the testing. With the initial data, confirmation test data, and additional test data, we concluded that our device needs significantly more testing to determine the exact cause for the inconsistencies and to make it more reliable.

8. Conclusion and Future Recommendations

We met 17 of our 20 Functional Requirements. The three requirements we were unable to meet were “dispenses food once per day,” “dispenses the proper amount of food per serving,” and “water proof/resistant.” As shown above in Section 7.2, our device was not consistent with how many pellets it dispensed each cycle. There were also instances where the device dispensed zero pellets, which meant that our device was not feeding once per day as we intended. After additional testing following the confirmation test we concluded that the number of pellets dispensed is more random than originally anticipated. Due to the time constraints of the project, we were unable to perform more extensive testing to determine how to solve this reliability issue. Also, our device is not completely waterproof. To fulfill this requirement, the Arduino port openings would need to be sealed and the covers on the front and top would need to be more robust.

8.1 Future Recommendations

Due to the limitations of the scope of this project, there were a number of aspects of the design and realization of the prototype that we believe could be improved given additional time and resources. The following are our recommendations for anyone who is considering revisiting this design in the future:

1. **Include a battery backup**: The primary concern for an automated fish feeding system is to reliably dispense the proper amount of food when the fish owner is away. Our device is powered by a wall outlet, meaning that the fish wouldn’t be fed if there were to be a power outage. We recommend a battery backup that would activate if the device stops receiving power, thus adding an additional layer of security for the fish owner.
2. **Power the device with 12V Li-Ion Battery**: Our design used stepper motors to precisely control both the food wheel and food gate. Stepper motors constantly draw power from their power source to maintain the stepper’s current position. This would cause the feeder to quickly deplete any standard battery (AA, AAA, D). A lithium-ion battery would have enough life to run the system for the full 14 day duration, and could be rechargeable

between uses. However, these batteries were too expensive for our budget when we had to decide how to power our system.

3. **Injection mold the food wheel/housing**: Injection molding is a cheaper manufacturing alternative to 3D printing, especially for larger production runs. It would provide the opportunity to use a more durable plastic and would result in a more polished final product.
4. **Allow device to accept any type of fish food**: Medium-sized pellets represent just one of the many varieties of fish food on the market. A future iteration of our design should be able to accommodate any type of food, allowing the consumer to use the food that they currently have rather than buying additional food.
5. **Include user interface to change feeding frequency**: As currently designed, a user would need to edit the Arduino code to change the feeding frequency. We recommend implementing an input panel on the device that allows the user to change the frequency in which their fish is fed.
6. **Streamline manufacturing process**: Our design currently implements shaft couplers and shaft extensions connecting the stepper motors to the gears that they drive. This was done to allow us to use standardized gears. If the device were to be mass produced, we would recommend eliminating these couplers and extensions and connecting the gears directly to the motor shafts. This would cut down on assembly time, reduce production cost, and would eliminate opportunities for part failure within the device.
7. **Put on/off button on device**: Currently, the only way to turn the device off is to unplug the power supply. An on/off button would allow the user to visually confirm if the device is in operation, and would be a simpler and more conventional means of powering the device on or off.
8. **Manufacture with food safe materials**: With our limited access to advanced manufacturing methods we were not able to make our device out of food-safe materials. However, any commercially-available automated fish feeder should be made using food-safe materials and conform to any ANSI/NSF/OSHA requirements for products that come into contact with food.
9. **Use metals gears**: Nylon gears are significantly cheaper than metal ones, and for the purpose of this project were more than sufficient, however a more advanced design

should implement metal gears. This would greatly extend the life of the device, as metal gears are much more durable than nylon ones.

10. **Design a tool to remove the reservoir while it is full:** The food reservoir has an open bottom which makes it impossible to cleanly remove it from the device while it still contains food. Creating a tool to block the opening during reservoir extraction would be an extremely useful addition to a finished product.

Appendix A: Testing Data

Table 3: Initial Food Gate Testing

Cycle	50 RPM 63 steps open 72 steps close	50 RPM 63 steps open 72 steps close	50 RPM 63 steps open 72 steps close	50 RPM 60 steps open 69 steps close	50 RPM 58 steps open 69 steps close	50 RPM 59 steps open 70 steps close	48 RPM 58 steps open 70 steps close
1	6	5	3	0	5	2	2
2	6	4	1	2	1	6	6
3	21	9	1	1	2	4	6
4	2	6	1	1	1	1	2
5	4	20	2	8	2	5	0
6	3	18	1	3	1	4	2
7	3	6	19	2	0	11	0
8	23	6	13	1	0	3	2
9	11	4	3	1	1	14	3
10	2	4	5	0	0	6	3
11	2	1	2	3	10	15	2
12	2	1	1	0	5	13	10
13	1	0	1	1	4	7	2
14	0	25	0	2	0	3	0
15	0	6	4	7	1	4	0
16	2	6	11	4	6	2	0
17	0	6	12	4	1	2	0
18	0	5	6	6	1	0	0
19	0	1	6	13	6	13	0
20	9	3	3	5	3	8	1
21	0	1	4	9	3	2	0
22	4	0	3	6	0	8	1
23	1	2	3	22	0	2	10
24	1	1	1	5	1	2	3
25	12	1	1	6	0	0	2
26	2	2	1	1	0	0	2
27	2	0	0	0	0	0	0
28		1	1	1	1	0	1
29		3	1	14	1	0	0
30		1	1	10	6	1	0
Average	4.4	4.9	3.7	4.6	2.1	4.6	2
Std. Deviation	6	6	4.5	5	2.5	4.6	2.7
No. of 0's	6	3	2	4	9	6	12
No. >6	5	4	4	7	1	8	2
No. of 0s or >6	11	7	6	11	10	14	14
Failure Pecentage	36.67%	23.33%	20.00%	36.67%	33.33%	46.67%	46.67%

Table 4: Confirmation Test

Cycle	No. of Pellets Dispensed
1	5
2	1
3	1
4	1
5	0
6	0
7	2
8	0
9	1
10	0
11	3
12	0
13	2
14	2
Avg.	1.28

Table 5: Additional Testing after Confirmation Test

Cycles	50 RPM 60 steps 2s b/n cycles	50 RPM 60 steps 2s b/n cycles	50RPM 61 steps 2s b/n cycles	50RPM 62 steps 2s b/n cycles
1	1	9	12	1
2	2	14	4	0
3	6	16	6	0
4	3	10	7	1
5	1	5	6	1
6	0	1	3	3
7	12	10	1	0
8	12	11	3	2
9	0	20	0	1
10	0	7	0	0
11	1	5	2	2
12	0	16	0	3
13	0	5	3	4
14	1	2	1	2
15	0	1	16	4
16	0	6	4	5
17	0	1	6	4
18	0	3	9	3
19	0	5	2	1
20	0	4	3	2
21	0	3	0	4
22	0	12	0	4
23	0	6	1	3
24	0	6	0	3
25	0	5	0	2
26	0	3	1	8
27	0	7	1	12
28	0	9	2	13
29	0	2	8	18
30	0	10	7	29
Average	**1.3**	**7.1**	**3.6**	**4.5**
Std. Deviation	**3.1**	**4.8**	**3.9**	**6.1**
No. of 0's	21	0	7	4
No. >6	2	13	6	5
No. of 0s or >6	23	13	13	9
Failure Pecentage	77%	43%	43%	30%

Appendix B: Technical Drawings

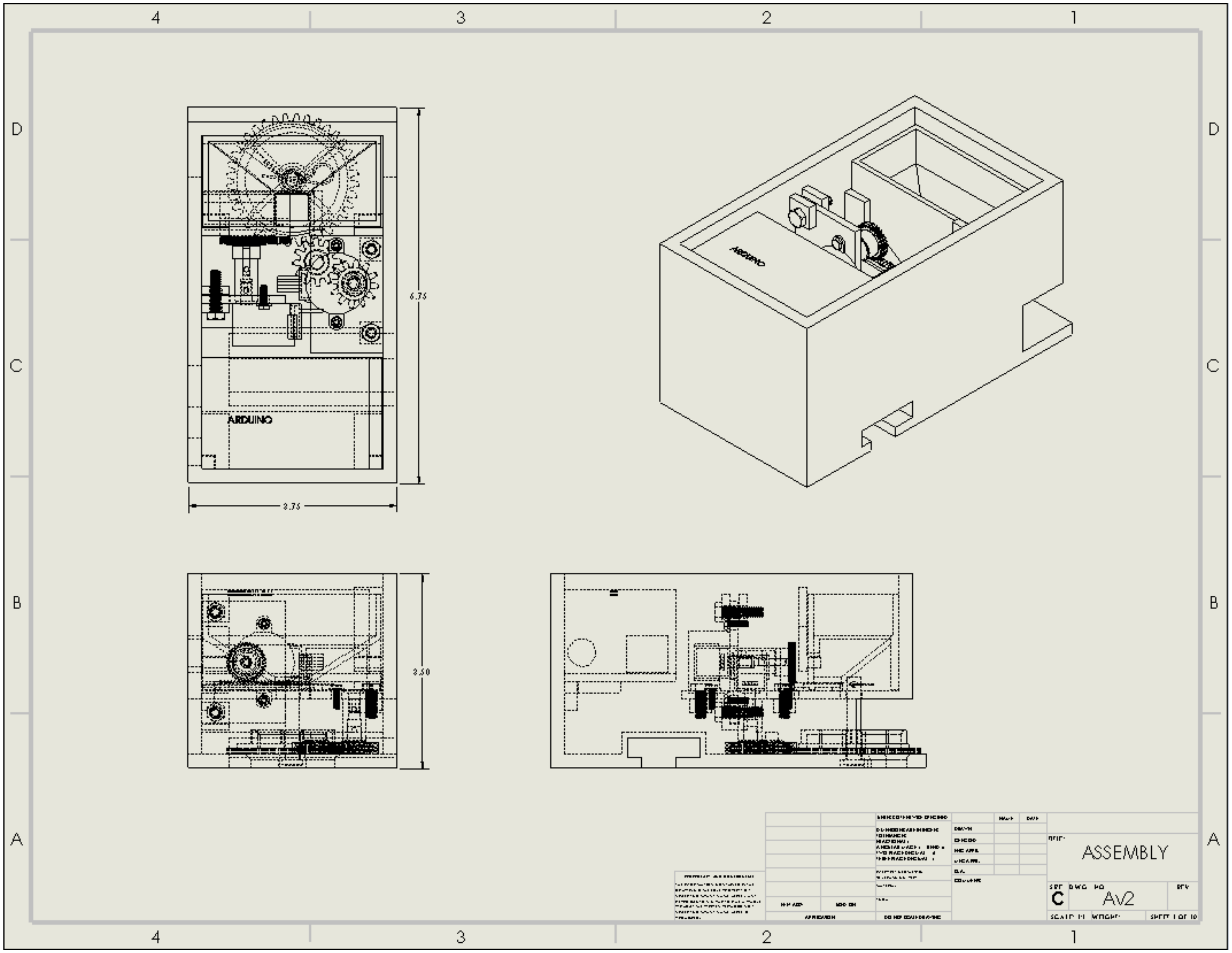
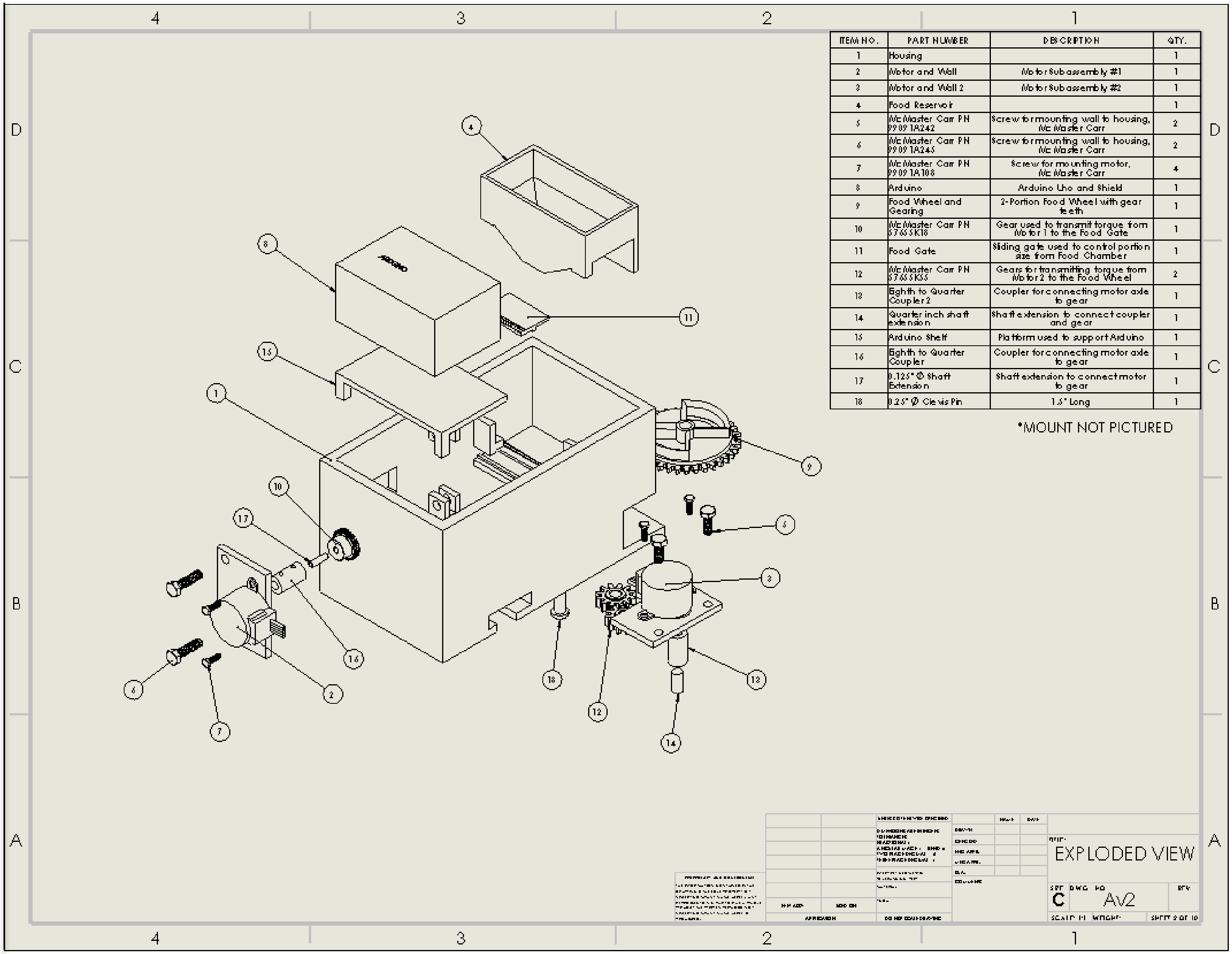


Figure 45: Full Assembly Drawing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Housing		1
2	Motor and Wall	Motor Subassembly #1	1
3	Motor and Wall 2	Motor Subassembly #2	1
4	Food Reservoir		1
5	McMaster Carr PN 99091A242	Screw for mounting wall to housing, McMaster Carr	2
6	McMaster Carr PN 99091A245	Screw for mounting wall to housing, McMaster Carr	2
7	McMaster Carr PN 99091A108	Screw for mounting motor, McMaster Carr	4
8	Arduino	Arduino Uno and Shield	1
9	Food Wheel and Gearing	2-Portion Food Wheel with gear teeth	1
10	McMaster Carr PN 57655K18	Gear used to transmit torque from Motor 1 to the Food Gate	1
11	Food Gate	Sliding gate used to control portion size from Food Chamber	1
12	McMaster Carr PN 57655K55	Gears for transmitting torque from Motor 2 to the Food Wheel	2
13	Eighth to Quarter Coupler 2	Coupler for connecting motor axle to gear	1
14	Quarter inch shaft extension	Shaft extension to connect coupler and gear	1
15	Arduino Shelf	Platform used to support Arduino	1
16	Eighth to Quarter Coupler	Coupler for connecting motor axle to gear	1
17	0.125" Ø Shaft Extension	Shaft extension to connect motor to gear	1
18	0.25" Ø Clevis Pin	1.5" Long	1

Figure 46: Exploded Assembly and Bill of Materials

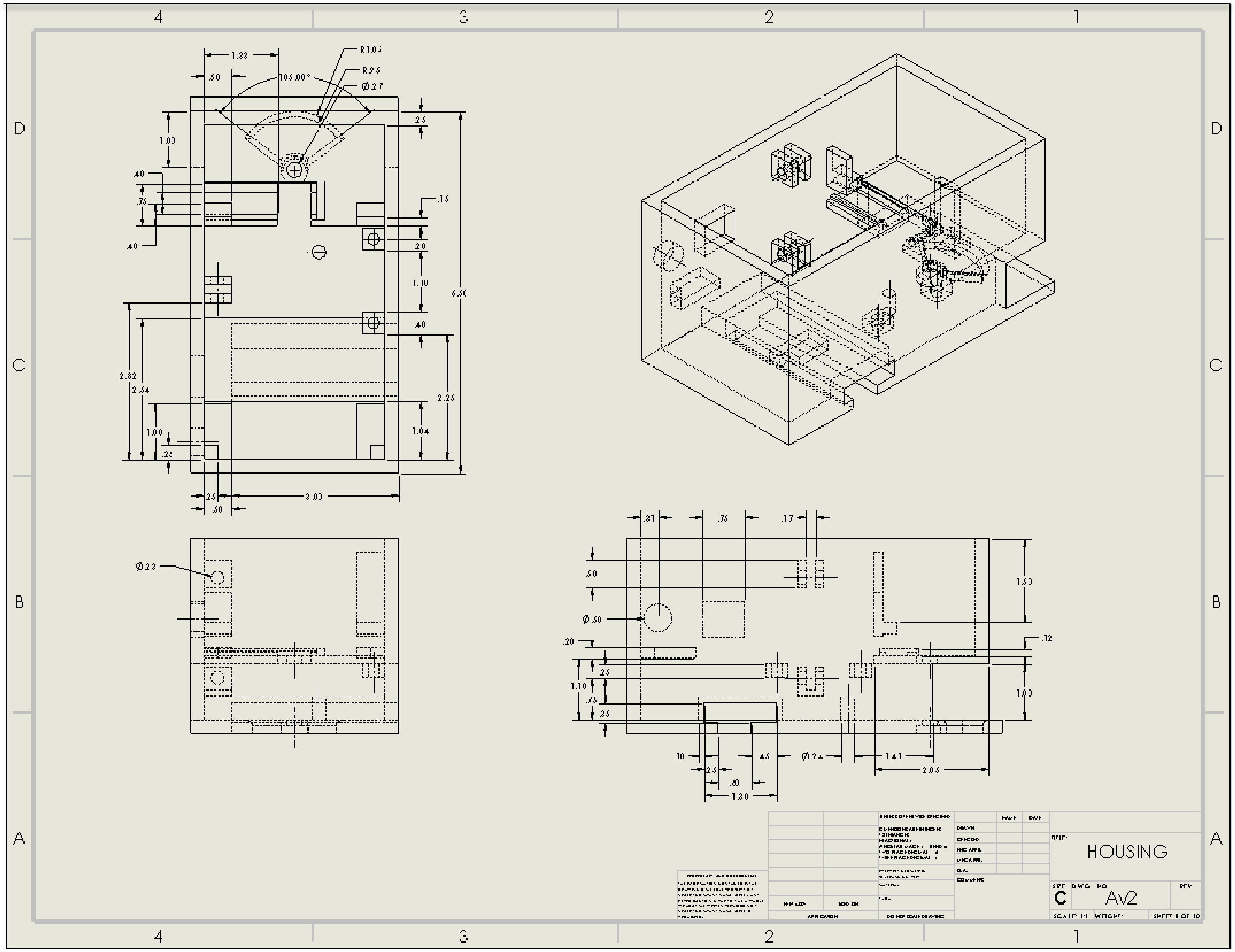


Figure 47: Housing Drawing

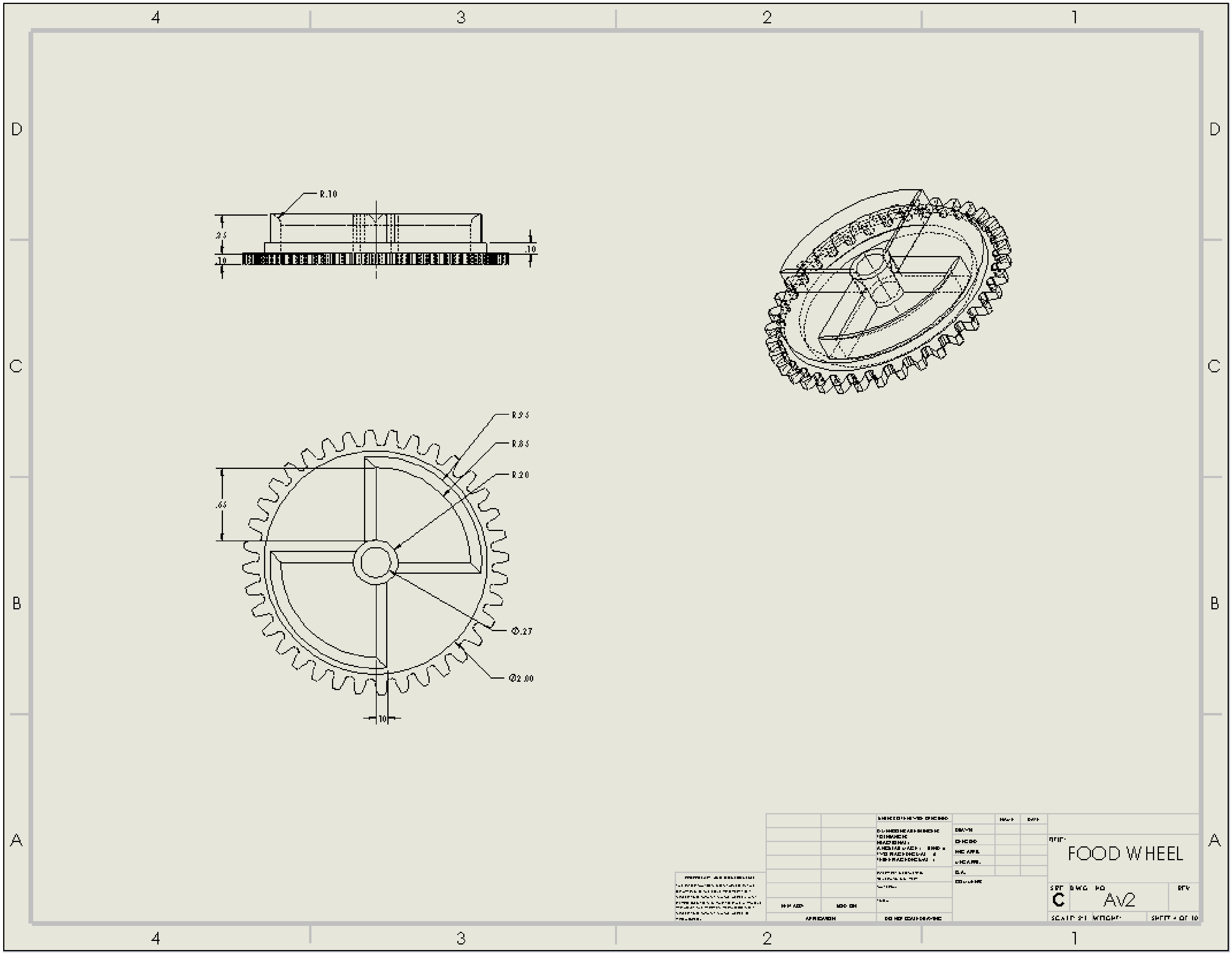


Figure 48: Food Wheel Drawing

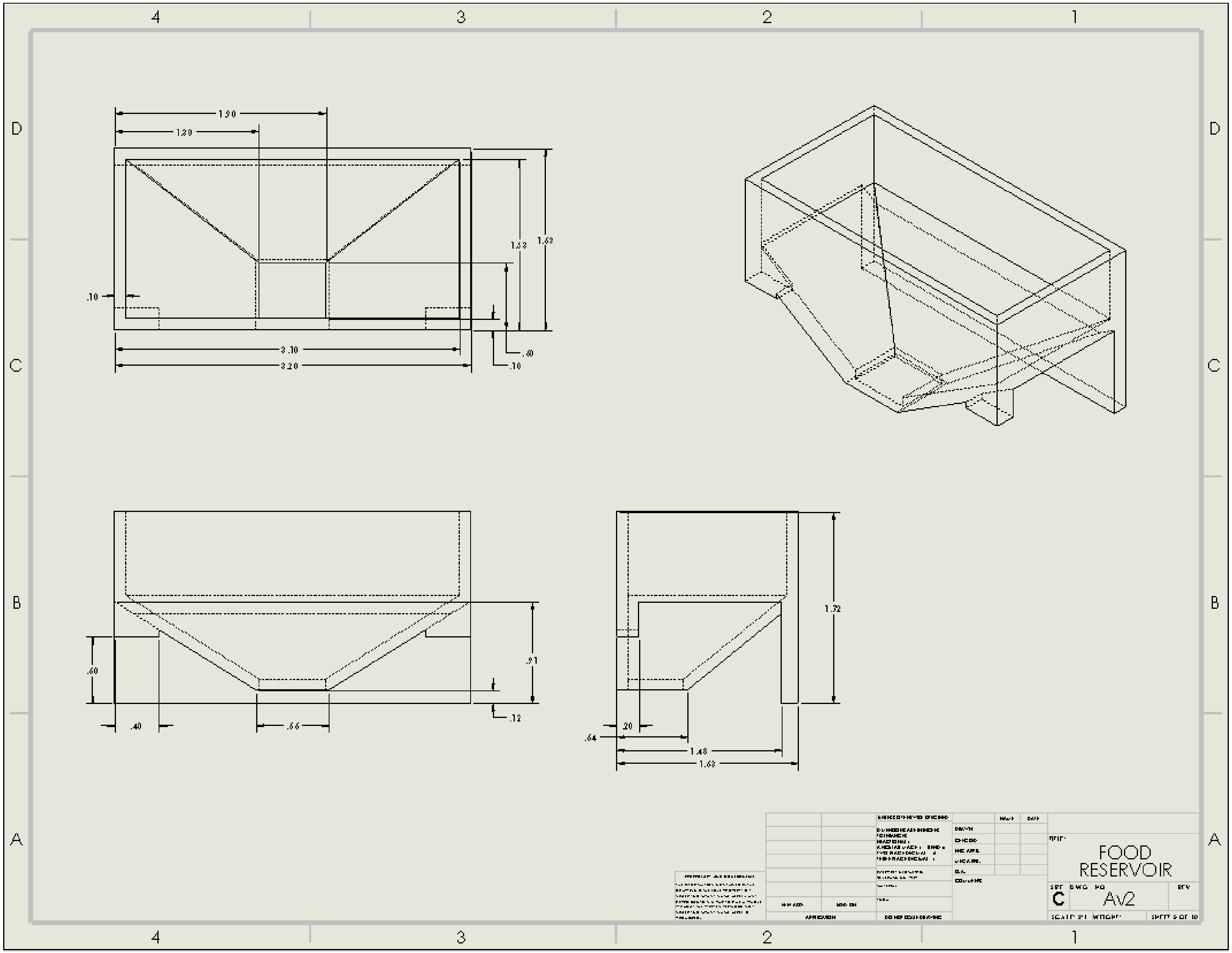


Figure 49: Food Reservoir Drawing

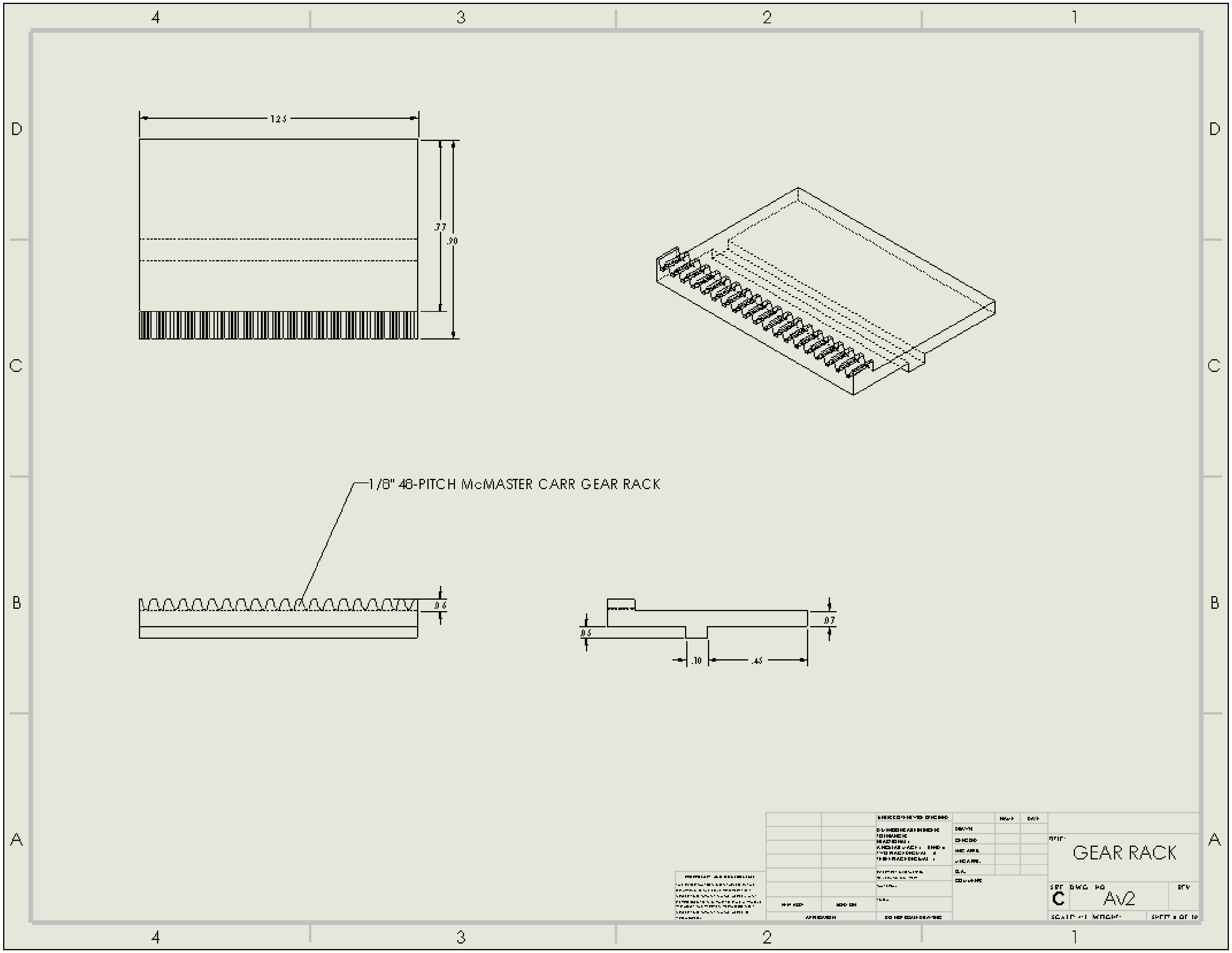


Figure 50: Gear Rack Drawing

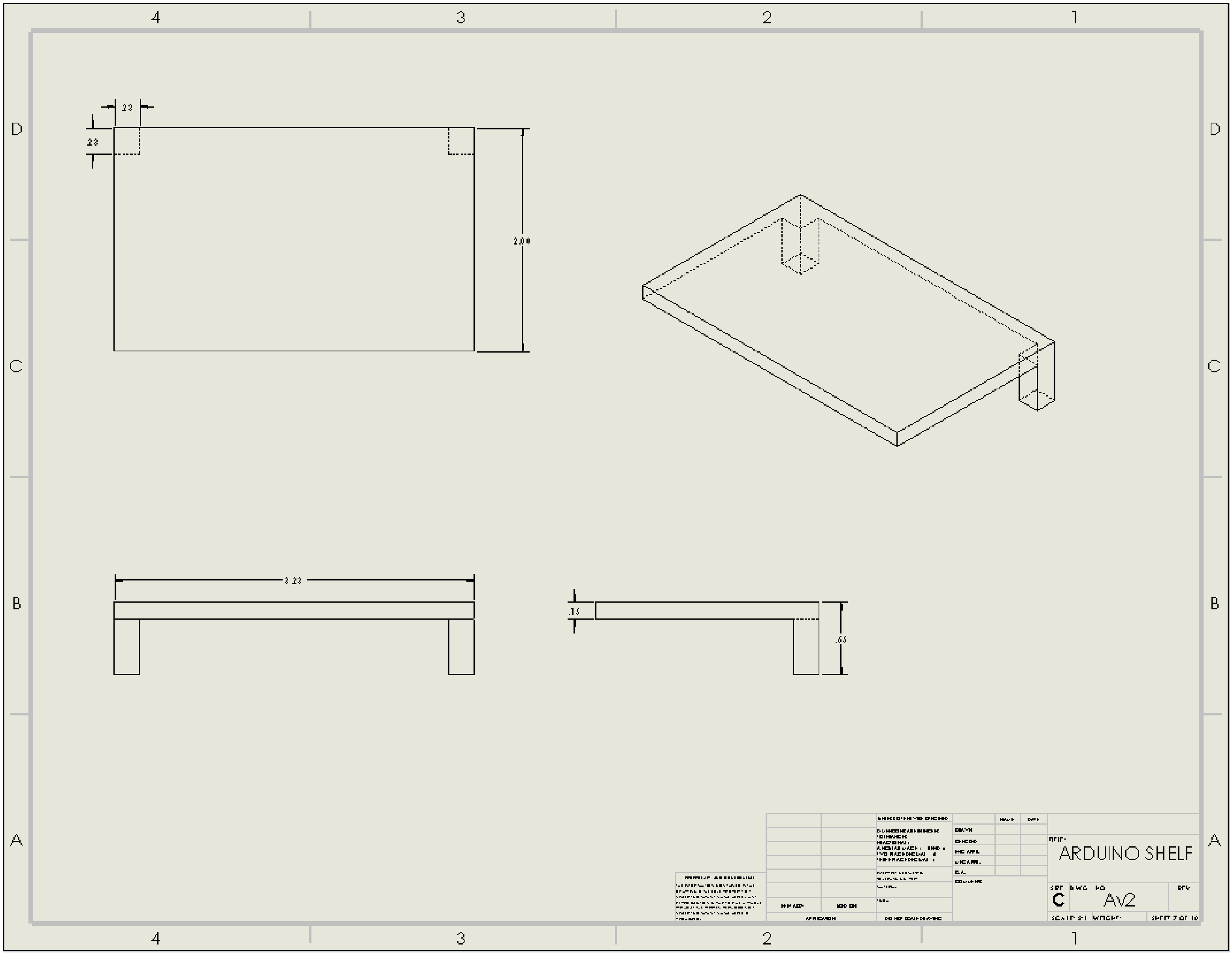


Figure 51: Arduino Shelf Drawing

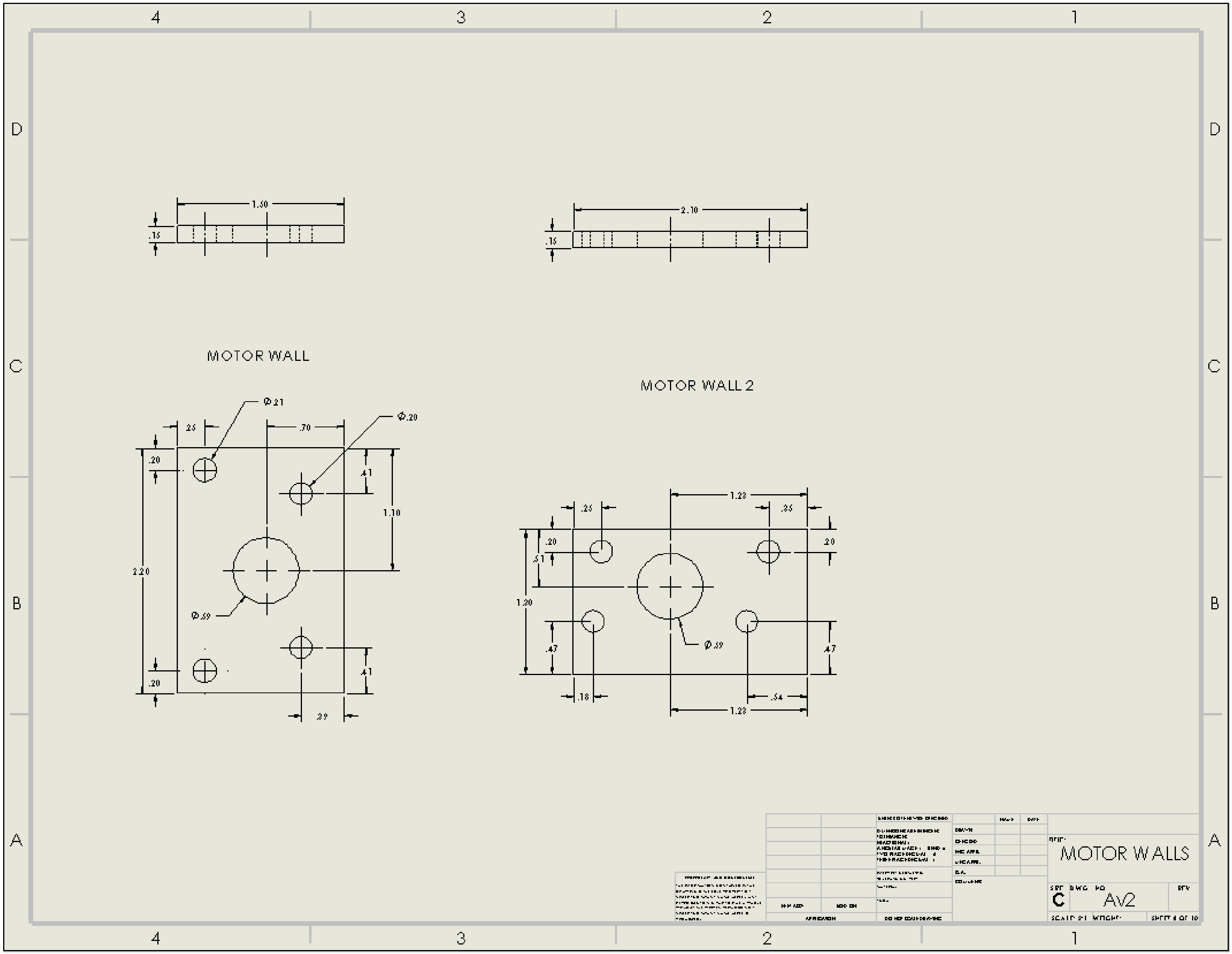


Figure 52: Motor Walls Drawing

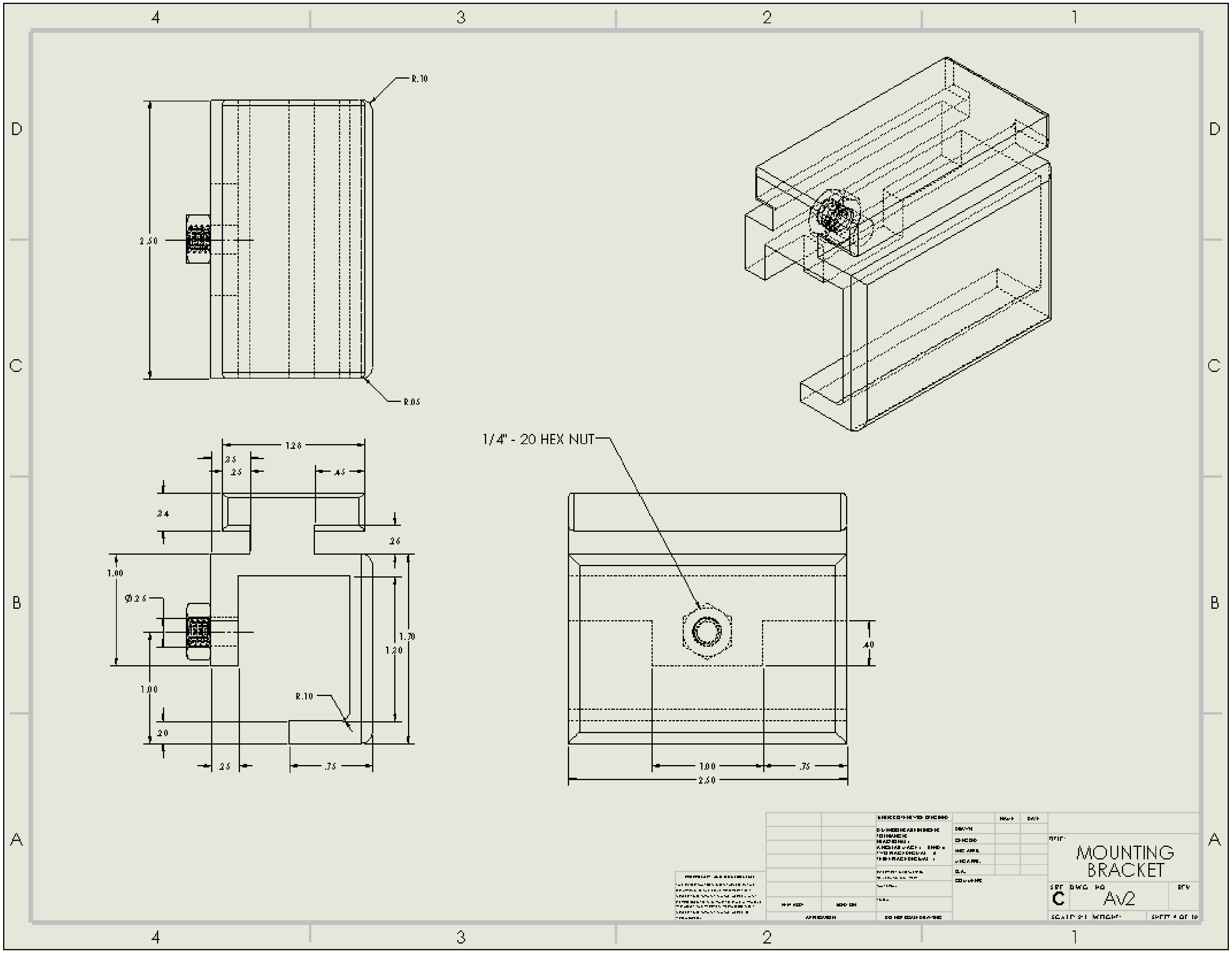


Figure 53: Mounting Bracket Drawing

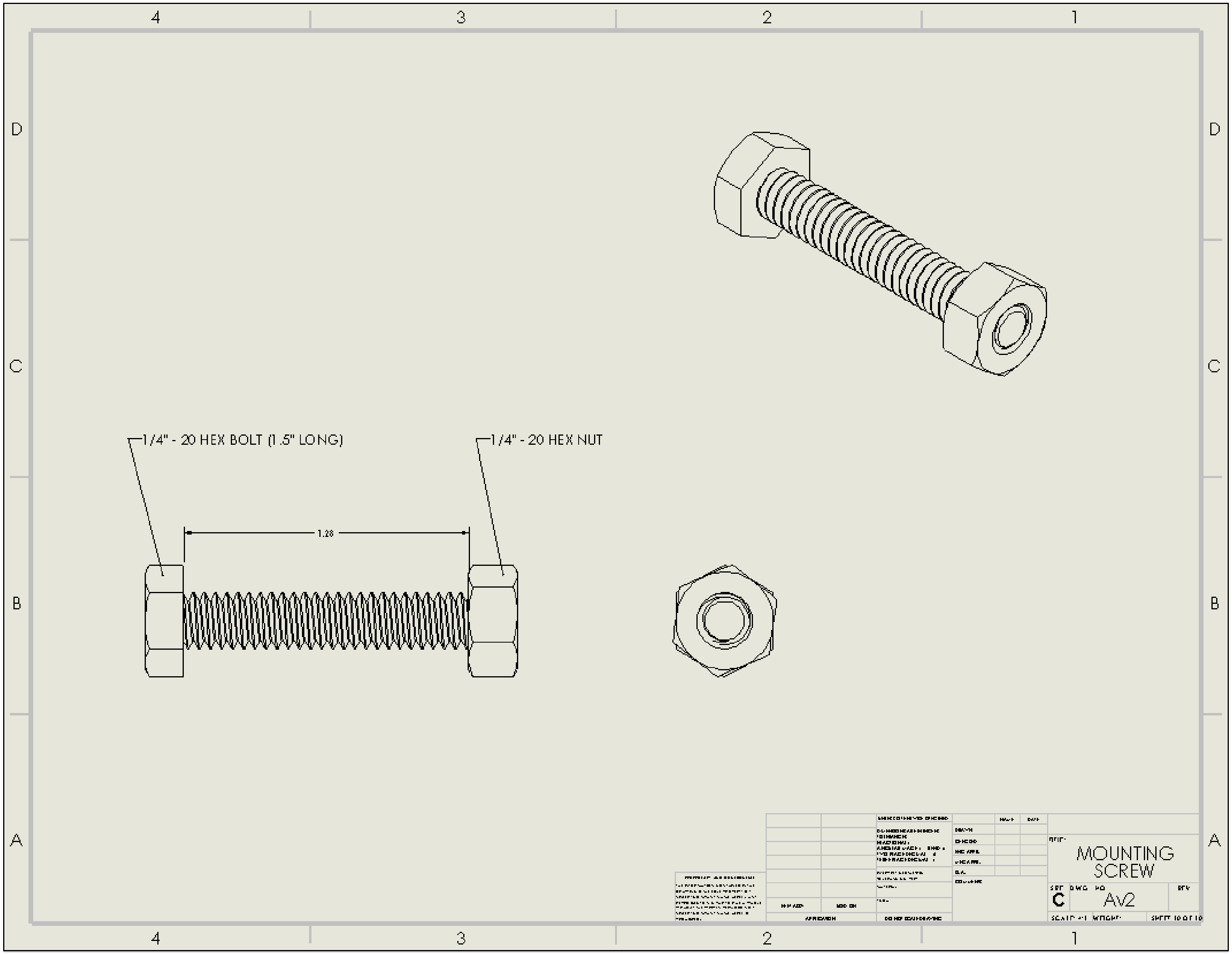


Figure 54: Mounting Screw Drawing

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