Carnegie Mellon University

College of Engineering

24-671 - Electromechanical Systems Design

Final Design Report

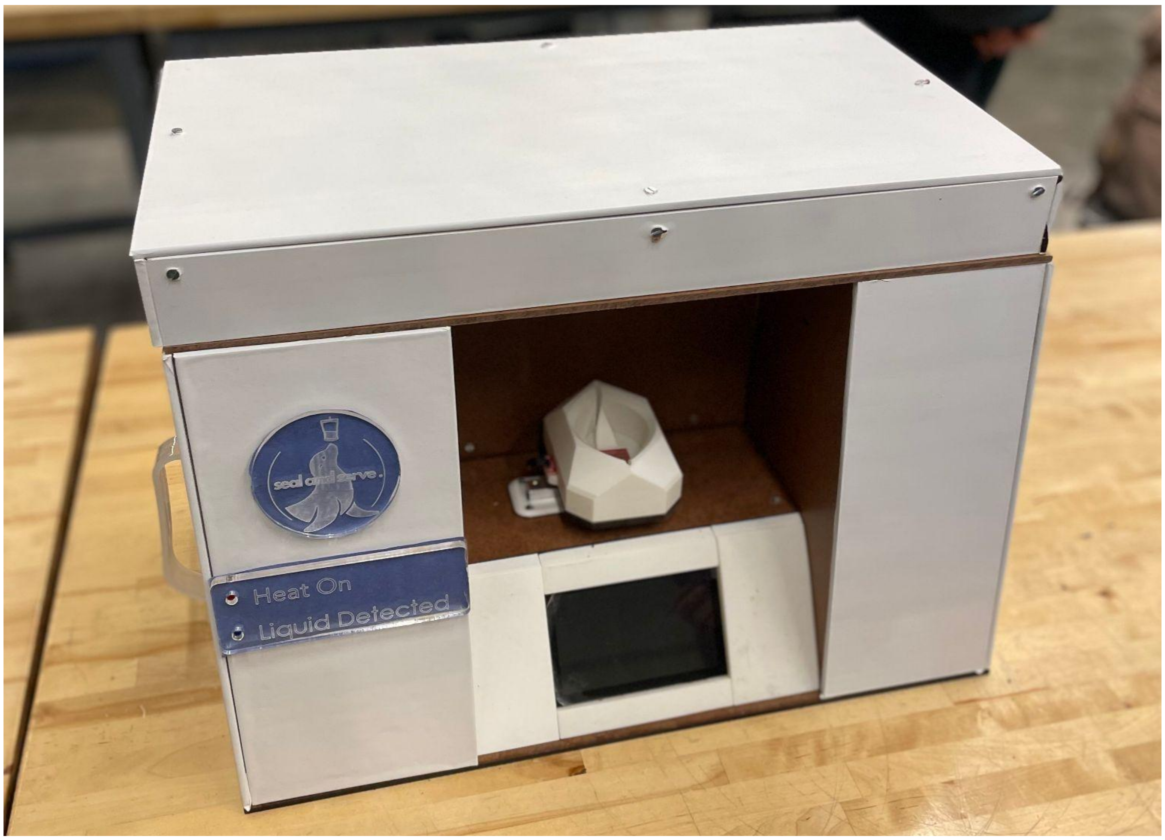

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Table of Contents

Executive Summary **3**
1.0 Problem Definition **4**
1.1 Problem Description 4
1.2 Market & Competitors 4
1.3 Assumptions & Constraints 5
1.4 Summary 5
2.0 Customer Needs **5**
2.1 Stakeholder Analysis 5
2.2 Customer Requirements 7
2.3 Design Objectives 7
2.4 Design Constraints 8
2.6 Summary 8
3.0 Market Investigation **9**
3.1 Competitive Analysis 9
3.2 Summary 10
4.0 Design Process **10**
4.1 Concept Generation 10
4.2 Concept Selection 12
4.3 Summary 15
5.0 Detailed Design **16**
5.1 Engineering Analyses 16
5.1.1 Heating Test 16
5.1.2 Liquid Flow Test 21
5.1.3 Testing Summary 22
5.2 FMEA 23
5.3 Manufacturing and Assembly Techniques 23
5.3.1 Bill Of Materials 23
5.3.2 Design For Manufacturing 24
6.0 Final Prototype Description **26**
6.1 Design Problem Context 26
6.1.1 DfX Factors 26
6.1.2 Human Factors 26
6.1.3 Economic Impact 26
6.1.4 Service Environment 27
6.1.5 Societal Impact 27
6.2 Demonstration of the Design 27
6.2.1 UI 27
6.2.2 Liquid Dispensal 30
6.2.3 Package Sealing 30
6.2.4 Enclosure 31
6.2.5 Wiring & Electronics 33
6.2.6 Video Demonstration 35
6.3 Full System Testing and Results 36
6.3.1 Testing Set-up & Procedure 36
6.3.2 Results 36
6.3.3 User Feedback 37
7.0 Conclusion **37**
References: **38**
Appendix A: CAD Drawings **39**
Appendix B: Concept Sketches, Lists **40**
Appendix C: Code **43**
Appendix D: Off-Shelf Components **44**
Appendix E: Work Distribution **45**

Executive Summary

The "Seal and Serve" Automated Drink Maker aims to address a notable gap in the market of pre-packaged beverages and automated drink makers: the lack of customization coupled with secure packaging. The existing products in this space typically offer limited options in terms of ingredient proportions, flavor varieties, and safety features, leading consumers to compromise on their preferences, particularly in public settings where beverage integrity can be a concern.

The design of Seal and Serve is a response to these market limitations. It allows users to customize their drinks with a range of ingredients and also offers the unique feature of sealing the beverages in tamper-proof pouches, enhancing both the safety and convenience aspects. Key features include a modular design facilitating ease of cleaning, a compact size suitable for various settings, and a touchscreen interface for ease of use. Despite these innovations, there are areas where the product could potentially be improved, such as material selection and ergonomics, which were noted during user feedback sessions.

The prototype of Seal and Serve has shown that it can meet basic functional requirements, such as dispensing ingredients, sealing pouches, and providing a user-friendly interface. However, it’s important to acknowledge that while the product brings new features to the market, its success depends on several factors including user acceptance, manufacturing feasibility, and competition with established brands. The device represents an effort to blend customization with convenience in beverage making, yet its real-world applicability and long-term viability in the market remain to be fully evaluated.

In conclusion, Seal and Serve introduces a novel approach to beverage preparation and packaging, offering features that address specific consumer needs. While it presents a step forward in terms of functionality, further development and user testing are necessary to refine the design and ensure its practicality and appeal to the intended market segments.

1.0 Problem Definition

1.1 Problem Description

The existing market of pre-packaged beverages presents a clear limitation when it comes to customization. The standardized nature of these products doesn't allow for personal adjustments in ingredient proportions, flavor varieties, or even the level of sweetness in a drink. This lack of customization restricts consumers to the available options, often leading to a compromise on personal preferences.

When consumers decide to customize and transport their drinks, they generally use thermoses or similar containers to carry their beverages. However, this method inherently limits them to a single type of drink, posing a challenge especially in social or outdoor settings where a variety of beverages might be preferred. This scenario highlights a clear market gap where the need for a device that allows for beverage customization while also providing a convenient and safe packaging solution is evident.

Furthermore, the issue of beverage safety, especially in public or communal settings, is another problem. The current market offerings don't provide a tamper-proof packaging solution which could ensure the integrity and safety of the beverages. This lack of a safety assurance mechanism can deter individuals from enjoying their drinks in public settings due to fear of contamination or adulteration, posing a significant concern in scenarios where health and safety are paramount.

1.2 Market & Competitors

The primary market segment for a solution to this problem includes home users who value the ease and variety in beverage preparation, along with the assurance of safety. Besides home users, commercial establishments such as cafes, bars, or any place that serves beverages to customers could significantly benefit from a device that addresses the identified market problems, thereby potentially expanding the market reach.

In terms of competition, several products have emerged in the automated drink-making sector, albeit with various shortcomings in addressing the identified market problems. There's a substantial consumer base that values customization, variety, and safety in their beverage choices. [4]

Bartesian cocktail machine and Black&Decker cocktail makers offer a level of automation but significantly restricts customization due to their proprietary capsule system. The lack of a feature for personal recipe registration further limits its appeal to consumers seeking customization. The Bartesian is sold for $370 and the Black & Decker is sold for $400.

Barsys 2.0 and 360 are two products that are on the higher end of the market. Barsys 2.0 can store 5 alcoholic beverages and 3 mixers. This product relies on a phone app with bluetooth connection instead of a built in controls to communicate with the user. The use of an app allows the company to keep the user interface up to date, while also giving the user high control over their machine. The user can select from a wide range of predefined drinks or create their own recipes. However because there is no built-in control method, any third party, such as guests would either need to download the app or ask the host to make drinks. Barsys 2.0 has a unique way of working where instead of liquid coming out of a single nozzle the glass placed slides under each of the ingredients. Barsys 360 uses the same phone application as the 2.0. Along its perimeter it has 6 built-in drink containers. The user simply places a glass in the center of the machine and pours the required drinks automatically. These products offer a higher level of customization through an app interface, but they do not address the packaging and safety concerns. The absence of a secure packaging solution in these machines underscores the market gap in ensuring beverage safety. [2] [3]The primary market segment for a solution to this problem includes home users who value the ease and variety in beverage preparation, along with the assurance of safety. Besides home users, commercial establishments such as cafes, bars, or any place that serves beverages to customers could significantly benefit from a device that addresses the identified market problems, thereby potentially expanding the market reach.

1.3 Assumptions & Constraints

The budget for this project was $750 and the time to complete was 13 weeks. Along with that we were also mainly limited to the use of techspark resources for building the actual prototype.

1.4 Summary

In summary, the current market for prepackaged drinks doesn't allow the user to customize the drinks to their preferences and the current cocktail making machines are not able to produce drinks in sealed packages. Some cocktail makers on the market work with a proprietary capsule technology which again takes away from the customizability of the drink, whereas other machines directly use beverages to craft cocktails. None of these machines produce sealed containers.

2.0 Customer Needs

2.1 Stakeholder Analysis

The stakeholders encompass a diverse group, each with a unique interest in the Seal and Serve Drink Maker project. Primarily, the customers are college students as per the survey, but there's a broader market of individuals or establishments keen on an automated drink making solution. Suppliers are essential, providing the materials, components, or technologies needed to propel the project forward. Regulatory bodies, notably the FDA, play a key role in ensuring the product aligns with food and beverage safety standards, guaranteeing a safe user experience. Manufacturers or producers are crucial in transitioning from design blueprints to a functional product. Retailers, whether they are physical outlets or online platforms, handle the sale and distribution of our Drink Maker. Lastly, industry competitors in the drink making machine market provide a framework for market positioning, helping to shape the potential strategic trajectory of the project.

Figure 2.1: Survey Results - Market Validity

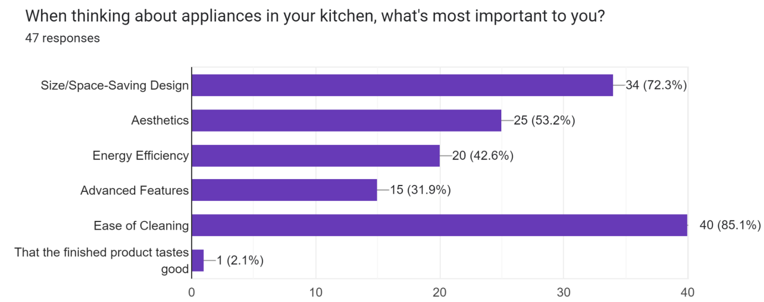


Figure 2.2: Survey Results - Important Features

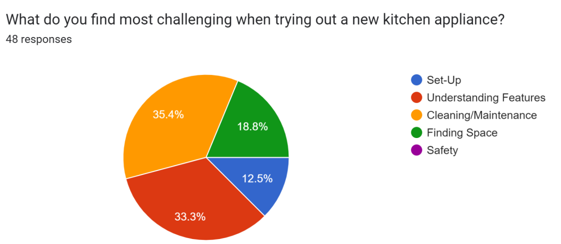


Figure 2.3: Survey Results - Current Challenges

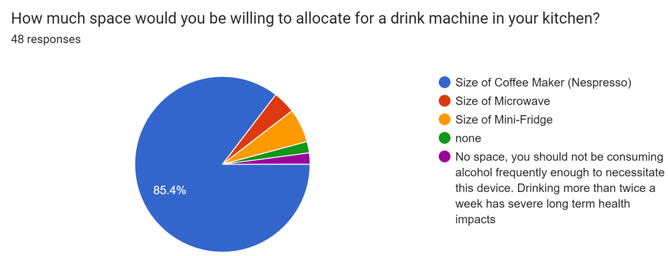


Figure 2.4: Survey Results - Space

External outreach was vital in order to understand the market for the Seal and Serve Drink Maker. The survey whose results can be seen through Figures 2.1 through 2.4 was conducted among college students and provided valuable insights into the drinking habits and preferences of potential customers. The findings indicated a strong market, with a notable frequency of drink making and consumption of prepackaged drinks, along with a tendency to entertain guests.

Moreover, the survey helped in identifying key elements that could set the product apart from competitors, with ease of cleaning and ease of use emerging as significant factors, as can be seen in Figure 2.3.

Additionally, requirements were established for the drink maker to be compact in size, and capable of making drinks fast. Furthermore, a competitor analysis was carried out, as can be seen in Target Specifications, to understand the offerings and limitations of existing products in the market, ensuring the Drink Maker addresses unmet needs and offers additional value to potential customers.

The feedback given by the survey led to our iterative idea generation, specifically the implementation of a modular design to address the ease of cleaning, which was identified as a valued feature by potential customers. Additionally, the feedback could drive further design improvements, such as a compact design to address the size preference indicated in the survey, without compromising on aesthetics. Moreover, speeding up the drink-making process emerged as a priority, leading to considerations around optimizing the mechanical and software operations of the machine to reduce the time taken from selection to serving.

2.2 Customer Requirements

The customer needs were found from the survey shown earlier. The survey had approximately 50 responses and gave the following conclusions.

1. An important customer need is that the product should be easy to clean.
2. Customers also valued a product that wouldn't take up too much space in their homes.
3. The product should have a space saving design.
4. The product should be easy to use.
5. The product should prepare and package drinks in a timely manner.

2.3 Design Objectives

To ensure the device meets the customer requirements in a feasible way, the following objectives were created by the team.

Objectives	**Metric**	**Goal**
Easy To Clean	Modularity of Product	The device should be easy to disassemble and clean, with considerations for potential leaks.
Customizability	Number of Ingredients	The design should allow for a variety of combinations, using 6 ingredients.
Compactability	Weight and employability of design	The design should be a feasible size to fit on a countertop.
Aesthetic Design	Result of customer feedback	Customers should find the design aesthetically pleasing
Time-Saving	Time to Make a Drink	The design should make a drink in less than 5 minutes.
Intuitive	Time needed to understand device's functionality	The design should not take longer than 2 minutes to learn to use
Cost-effective	The overall cost of manufacturing and maintenance	The design should be cheaper than current market products

Table 2.1: Design Objectives

2.4 Design Constraints

Constraint	**Metric**	**Limit**
Budget	$ (USD)	The prototype must not cost more than $750.
Timeline	Weeks	The prototype must be completed within 11 weeks.
Safety	Contamination	Sealed products must be safe to drink from. Compliance with the health, safety, and quality standards as stipulated by regulatory bodies is mandatory.

Table 2.2: Design Constraints

2.6 Summary

Stakeholder analysis identifies key groups such as college students, suppliers, regulatory bodies like the FDA, manufacturers, and retailers. A survey conducted among college students revealed key insights into drinking habits and preferences, indicating a strong market for this product, particularly emphasizing the importance of ease of cleaning, compact size, and fast drink preparation. These findings guided the team's design objectives, including modularity for easy cleaning, customizability with multiple ingredients, compactness, aesthetic appeal, time efficiency, intuitiveness, and cost-effectiveness. Additionally, design constraints were established, including a budget limit of $750, an 11-week timeline for prototype completion, and strict adherence to safety and health standards. This comprehensive understanding of customer needs and market dynamics shaped the project's approach, focusing on creating a user-friendly, efficient, and safe product.

3.0 Market Investigation

3.1 Competitive Analysis

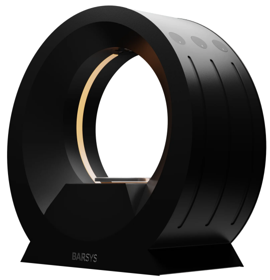


Figure 3.1: Barsys 2.0   Figure 3.2: Barsys 360   Figure 3.3: Bartesian   Figure 3.4: Black&Decker

Figures 3.1 through 3.4 show some of the cocktail markets that are currently in the market. The product shown in Figure 3.1 is the Barsys 2.0 Cocktail maker. It can store 5 alcoholic beverages and 3 mixers. This product is on the premium side of the product range. It weighs 55 pounds and has dimensions of 19.25" x 13.5” x 13.25” and can prepare a drink in under 30 seconds. This product relies on a phone app with bluetooth connection instead of a built in controls to communicate with the user. The use of an app allows the company to keep the user interface up to date, while also giving the user high control over their machine. The user can select from a wide range of predefined drinks or create their own recipes. However because there is no built-in control method, any third party, such as guests would either need to download the app or ask the host to make drinks. The working principle of Barsys 2.0 is also different from other cocktail makers. Instead of relying on a single nozzle to pour the drink, the glass is placed on a sliding mechanism that moves it under each ingredient. The cost of this product is $1500.

The Barsys 360 shown in Figure 3.2 is made by the same company as Barsys 2.0. One of the big selling points of this product is its aesthetic ring design. It has 6 built in beverage containers that can either take mixers for alcoholic drinks. The user simply places a glass in the center of the machine and pours the required drinks automatically. Similar to Barsys 2.0, the 360 also uses the same phone app to communicate with the user. The Barsys 360 is sold for $475. The 360 weighs only 10 pounds and has dimensions of 17.36 x 8.03 x 16.93 inches.The final 2 big competitors in the market are the Bartesian and Black&Decker and Bartesian Cocktail makers shown in Figures 3.3 and 3.4. These products are similar in the sense that they both use capsules to prepare the desired drink. The Bartesian has its own storage containers, it stores 4 beverages + water, whereas the Black&Decker relies on the drink bottles themselves and inserts a hose in them to retrieve the liquid. It can store 6 beverages + water. The downside of both of these products is that they rely on capsules to actually make drinks. The machines don’t function without capsules present and have a barcode scanning method to ensure only the capsule made by the company is used in the machine. The use of capsules decreases the customizability of the product as the user cannot make their own recipes. The Bartesian is sold for $370 and the Black & Decker is sold for $400. Table 3.1 shows the customer needs, how well the competitors achieve them, the marginal and ideal target specifications.

Need #	Metric #	Metric	Importance	Barsys 360	Bartesian	Marginal	Ideal
1	1	# of removable parts	9	6	8	7	9
2	2	# of drinks that can be made	7	10	4	8	10
3	3	Device Footprint	6	8	9	7	9
4	4	Subjective	8	8	8	6	10
5	5	Time to prepare a drink	7	10	10	6	8

Table 3.1: Competitor Analysis

3.2 Summary

The competitive analysis compares several cocktail makers in the market, highlighting their features and customer needs. The Barsys 2.0 and 360 stand out for their design and quick drink preparation, with the former being more premium. Both Bartesian and Black&Decker models rely on capsules, limiting customizability. Table 3.1 compares these products against customer needs like the number of removable parts, drink variety, device size, appeal, and preparation time, providing insights for positioning Seal and Serve in the market.

4.0 Design Process

4.1 Concept Generation

The end goal of this product is to make a packaged or unpackaged drink. In order to do that, the product must be able to: store materials, engage with users, measure materials, move ingredients, and package the drink (if applicable). These different functions can be broken down into more subfunctions, thus creating the hierarchical functional decomposition see below in Figure 4.1. In order to see how these different functions interact with each other, the black box flow diagram in Figure 4.2 was created.

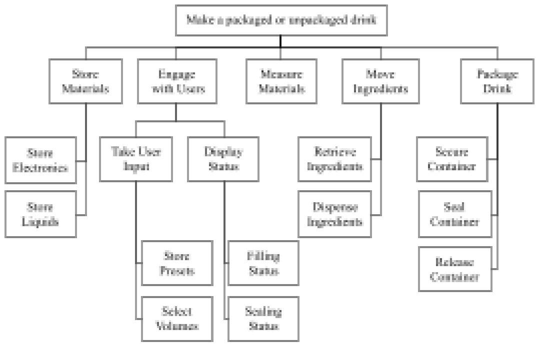


Figure 4.1: Hierarchical Functional Decomposition

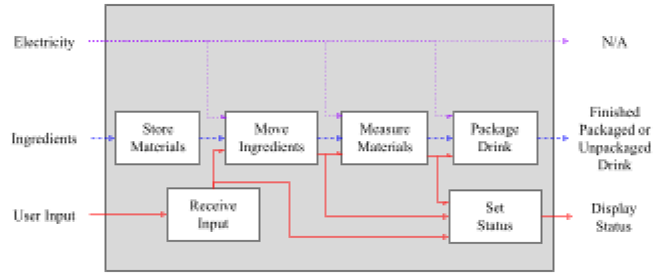


Figure 4.2: Black Box Flow Diagram

After completing the functional decomposition the findings were translated into system architecture. Since user testing called attention to the importance of ease of cleaning, modular architecture was selected, where each physical component implements one or few functions. In addition to satisfying customer needs, the modular design facilitates testing and fixing parts, which is also beneficial. After the modular design was decided, a product schematic seen in Figure 4.3 was created to show a rough view of functions or components of systems. From this product schematic, these functions were clustered into different physical subsystems and a rough geometric layout shown in Figure 4.4 was created.

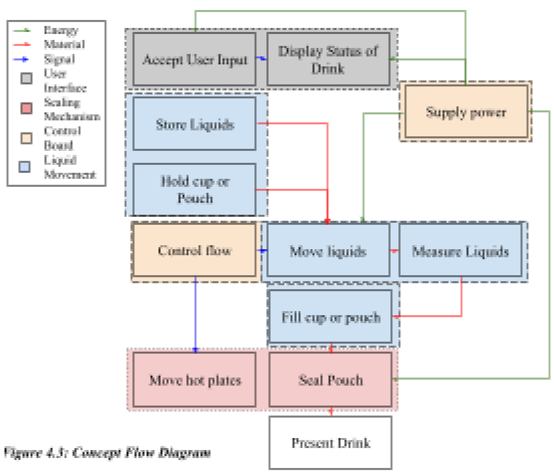


Figure 4.3: Concept Flow Diagram

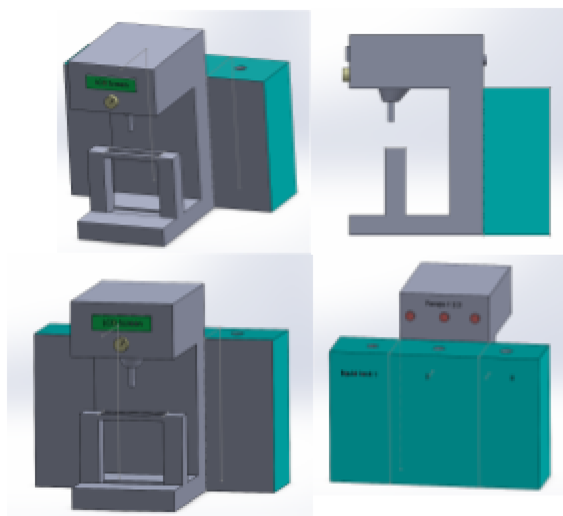


Figure 4.4: Rough Geometric Layout

After completing this, various interfaces were determined, such as: the interface between user interface and the mechanical systems (in order to determine which liquids and what amounts the system would have to move around) and the interface between the electrical system and the mechanical systems (in order to control the movement of liquids and movement of mechanisms such as the sealing one). Next, a list of incidental interactions was created, since they can degrade performance. One of the greatest concerns is the liquid and electronic interface in the enclosure. Another concern is the interface between the sealing mechanism and the cup or pouch holding mechanism, since the sealing movement might cause vibrations that could potentially knock over the liquids container. The last concern involves the interface between the liquid movement mechanism and the cup or pouch holding mechanism, since the liquid movement could cause vibrations that might potentially know over the liquids container.

Based on the knowledge collected, concepts were generated. First an external search was conducted and products that fulfilled the same functions as this product were found. Some of these products included: Barsys360, Tabletop Impulse Sealer, and a video on juice pouch production lines (link). From the Barsys360, general ideas about how to move the liquids throughout the system and how to make the product aesthetic were generated. From the Tabletop Impulse Sealer, ideas about the sealing mechanism were generated. Lastly, from the video of the pouch production line ideas concerning the holding mechanism were created.

After searching externally and finding general concepts, the internal search began. Each team member came up with 5-10 concepts for each critical subfunction. Then, as a group these ideas were shared in order to weed out the bad ones and combine others. An initial screening was conducted and a sub-function classification table (in appendix) was made in order to end up with around 5 main concepts for each critical sub function. After finishing the concept generation for each critical subsystem, different designs for the final product were created based on the concept combination as shown in Table 4.1.

Full System Design	STORING	MOVING	MEASURING	SEALING	UI
#1	Wooden Barrels	Moving Glass Under	Force Sensor	Parallel Jaw Grip	Touchscreen
#2	Drink Bottles	Moving Glass Under	Timer	1 Plate Moving: Screw	Touchscreen
#3	Upside Down Bottles	Turntable	Optical Sensor	1 Plate Moving: Gear	Knobs/Sliders
#4	Proprietary tanks	Moving Glass Under	Timer	1 Plate Moving: Scotch-Yoke	Knobs/Sliders
#5	Upside Down Bottles	Turntable	Force Sensor	1 Plate Moving: Piston	Touchscreen
#6	Proprietary tanks	Pumps	Force Sensor	Parallel Jaw Grip	Touchscreen
#7	Wooden Barrels	Pumps	Timer	1 Plate Moving: Piston	Bluetooth/WiFi
#8	Upside Down Bottles	Gravity	Optical Sensor	Parallel Jaw Grip	Touchscreen
#9	Proprietary tanks	Pumps	Optical Sensor	1 Plate Moving: Gear	Bluetooth/WiFi
#10	Drink Bottles	Pumps	Force Sensor	1 Plate Moving: Screw	Bluetooth/WiFi

Table 4.1: Concept Combination Table

4.2 Concept Selection

In the process of selecting the most suitable design concept for each subsystem, a Pugh screening matrix followed by a decision matrix was employed as a systematic approach. Screening matrices are a quick method of downselection that brings ten full system concepts down to five by comparing the concept to a reference design. The reference is given a score of 0 and the design concept is given a 1, 0, or -1 depending on if it is better, the same, or worse than the reference, respectively. The criteria we chose and their definitions are as follows:

- *Feasibility:* Given the team's resources and capabilities, can this design be achieved?
- *Maintenance:* Will the user have difficulty in cleaning and maintaining the system?
- *Safety:* Does the system ensure the user's safety?
- *Aesthetic:* Is the product good looking and user friendly?
- *Accuracy:* Can the product create a drink that perfectly matches the user's preferences?
- *Efficiency:* How quickly do we expect this system to create a drink?
- *Space Efficiency:* Does this system have capability of having all components packaged in a small volume?

		Full System Design #									
Criteria	**Ref**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Feasibility	0	1	-1	-1	0	-1	1	-1	0	1	0
Efficiency	0	0	0	-1	-1	1	1	1	0	0	1
Accuracy	0	-1	0	0	-1	0	-1	1	0	-1	0
Maintenance	0	1	0	1	1	1	1	1	1	-1	1
Safety	0	1	0	1	0	0	-1	1	0	0	1
Aesthetics	0	0	1	-1	0	1	1	0	1	1	0
Space Efficiency	0	-1	1	-1	1	0	1	0	-1	1	1
TOTAL	0	2	1	-2	0	2	3	4	1	1	4

Table 4.2: Screening Matrix

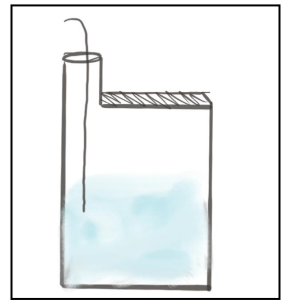
Decision matrices are a valuable tool as it allows for multiple designs to be compared and scored against certain predefined criteria, offering more specific insights by considering the priority of each criteria as compared to a screening matrix. In this context, each full system concept from the screening matrix output was assessed against the same custom-created criteria. Each criteria was then given a weight score (1-5, with 1 being the least important) based on importance and each subsystem was ranked. Scores were totalled and a final system was chosen.

	Design	**1**		**5**		**6**		**7**		**10**	
Criteria	WEIGHT	R	T	R	T	R	T	R	T	R	T
Aesthetics	3	2	6	4	12	3	9	1	3	3	9
Maintenance	2	1	2	3	6	4	8	2	4	4	8
Accuracy	4	2	8	4	16	4	16	1	4	4	16
Repeatability	2	3	6	5	10	5	10	3	6	5	10
Safety	1	2	2	2	2	2	2	2	2	2	2
Efficiency	2	3	6	2	4	4	8	2	4	1	2
Feasibility	4	2	8	2	8	4	16	2	8	3	12
TOTAL			**38**		**58**		**70**		**31**		**59**

Table 4.3: Decision Matrix

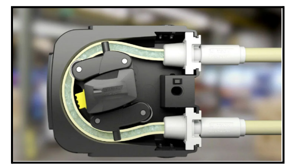
The outcome of the exercise resulted in subsystem 6 as the chosen concept. The deciding factor was primarily the feasibility component of the system. This exercise also resulted in a top concept for each of our subsystems. Given below are the justifications for each subsystem along with pictorial representations.

1) **Storing Ingredients**



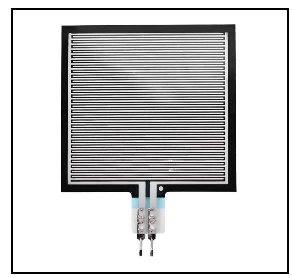
The chosen concept is six, clear, rectangular tanks that will stand up right. The tanks can be easily switched out via a door-like enclosure, allowing for easy switching out and maintenance. The clear tanks will allow the user to see the liquid levels in each, indicating a need to refill. This design meets the highest priority criteria of aesthetics, maintenance, feasibility, and modularity.

2) **Moving Ingredients**



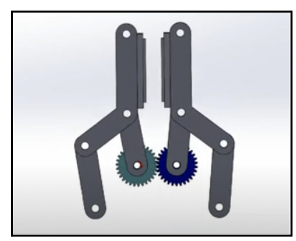
The chosen concept is Peristaltic Pumps (one for each tank). Peristaltic pumps ranked highest based on their ability to provide accurate flow, low cost, and low maintenance. Further, as a full system concept, peristaltic pumps are easy to integrate with upright tanks with appropriate tubing.

3) **Measuring Ingredients**



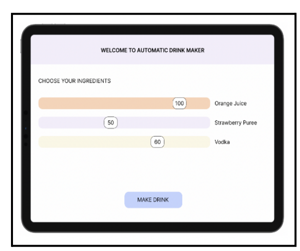
The chosen concept is Force Sensing Resistors (FSR) placed under each drink tank. These sensors provide precise values, allowing the drink maker to dispense accurate levels of each ingredient as requested by the user. Further, they do not come in direct contact with the ingredients, ensuring safety.

4) **Sealing Mechanism**



The chosen concept is two-finger parallel jaw grippers. The pouch sealing will take place using two heated plates coming together. The two-finger jaw grippers are justified by their greater accuracy and space efficiency when integrated within the full system.

5) **User Interface**



The chosen concept is a screen-based touch screen user interface. User experience and customizability is vital to the functionality of the Drink Maker. A touchscreen UI scored high in the criteria of user-friendliness and aesthetic.

Based on these selections, an initial mock-up of the full system was created:

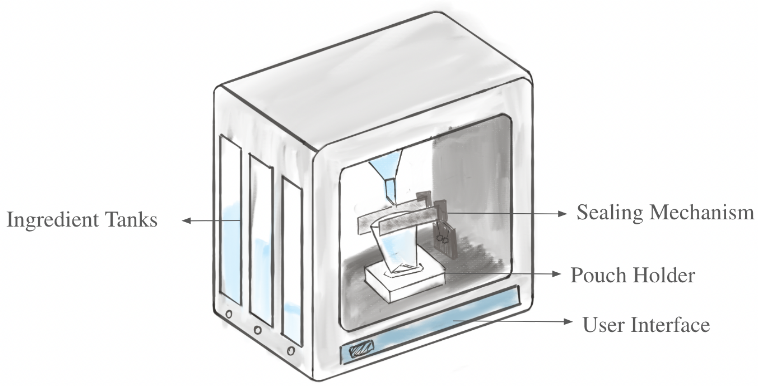


Figure 13 : Full System Concept Drawing

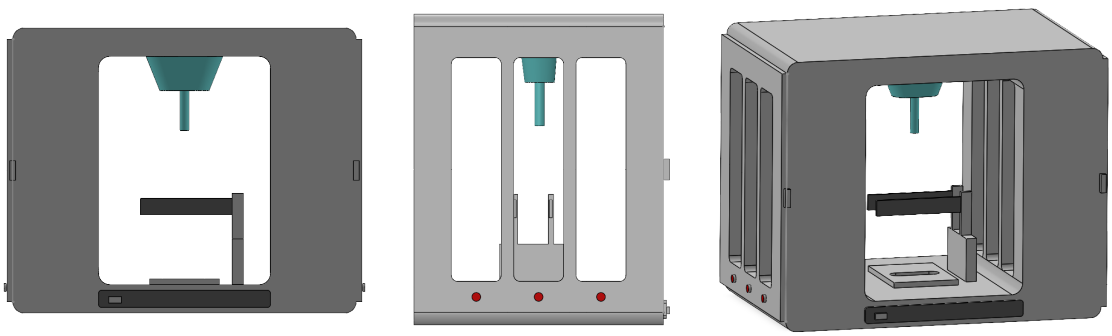


Figure 14 : Full System CAD (Front, Right, Isometric Respectively)

4.3 Summary

Section 4.0 of the document outlines the design process for the Seal and Serve Drink Maker, focusing on concept generation and selection. The process involved a detailed breakdown of necessary functions like storing and moving ingredients, and packaging drinks, leading to a modular design for ease of cleaning and maintenance. Various concepts were generated for critical subsystems, such as storage and measurement methods. The final concept selection used a Pugh screening matrix and decision matrix, evaluating criteria like feasibility, safety, and aesthetics. This resulted in choosing specific mechanisms for ingredient storage, movement, measurement, sealing, and a user interface, with the complete design visualized in mock-ups and CAD drawings.

5.0 Detailed Design

5.1 Engineering Analyses

5.1.1 Heating Test

There were multiple tests performed on the heat sealing subsystem.

The first test we conducted was on the first heating strips we received from Amazon (*Figure 5.1*). Our testing was designed to better understand how the heating strips behaved and if they would work for our product. In order to be a good fit, the heating strips would have to be able to reach 140 degrees Fahrenheit to melt the low-density polyethylene the pouches were made of to form the heat seal. Because we had initially allocated 12 W for our heat sealing subsystem, we wanted to test with that amount of power. However, the heat strips we purchased were not able to reach 12 W. When connected to the power supply, the max we could supply was 24 V and 0.375 Amps to get around 9 W. We decided to still test on these heating strips to see how long they would take to heat up.

Figure 5.1. Initial heating strips purchased from amazon. These heating strips were used for our initial prototype. They took 40 seconds to heat up to 140 degrees Fahrenheit when 9 W (24 V and 0.375 Amps) were supplied to them. They took around 30 seconds to cool down.

The setup of the testing involved the power supply from Techspark supplying 9 W of power to the heating strips, a meat thermometer, a temperature gun, and a stopwatch. We first measured the temperature of the heating strips before power was supplied and then turned on the power and the stopwatch at the same time. Periodically (in our case every 20 seconds) we would use the meat thermometer and temperature gun to find the temperature and the center and the edges. We continued this process until the heating strips reached a constant temperature, which is when we decided to stop. We used the data we conducted to create a graph (*Figure 5.2*).

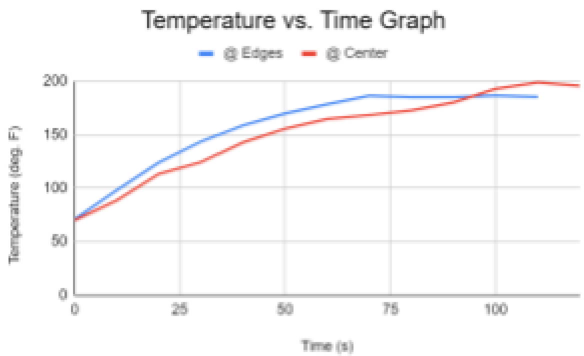


Figure 5.2. Graph of Temperature (deg. F) vs. Time (seconds) of initial heating strips at the edges and center. The heating strips were supplied with 9 W from the power supply. From this data we were able to conclude that these heating strips could be used for the initial prototype.

After determining that these heat strips could reach the 140 degrees we needed to achieve a good seal, we decided to test the cool down time, since time was a very important factor for our product. The setup is similar to the one used for the first test conducted, with the power supply supplying 9 W of power to the heating strips, a meat thermometer, a temperature gun, and a stopwatch. However, the process was different. We measured the initial temperature before the power supply was turned on, then turned on the supply and the stopwatch at the same time. We waited until the thermometer reached 140 degrees and recorded the time it took in seconds from the stopwatch, we would then turn off the power supply in order to let the heating strips cool down. We waited until the final temperature went down to less than 75 degrees and recorded the time that took. We repeated this 10 times. The results of our testing for heat up and cool down time is recorded in the table below (*Table 5.1*).

Table 5.1. Summary of Heat up and Cooldown Testing.

Trial #	Initial Temp (F)	Heat up (s)	Cooldown(s)	Final Temp(F)
1	66.6	36.81	29.29	74.8
2	68.5	31.03	31.59	74.6
3	69.1	38.23	26	74.5
4	67.6	33.87	30.05	74.8
5	67.3	35.12	30.55	74.7
6	68.5	32.19	37.67	74.8
7	67.8	36.43	27.88	74.5
8	69.4	38.56	29.87	74.6
9	68.8	31.34	39.23	74.3
10	69.1	37.65	29.61	74.8
	Avg:	35.12	31.17	
	Std. Dev:	2.86	4.14	

After concluding our testing on these heating strips, we determined that they would be okay for our initial prototype. The next testing we had to do for heat sealing was to determine if the design we had for our heat seal, the gears controlled by a servo motor, would provide enough force between the two arms to effectively seal the pouches. Because we knew that the servo motor in our configuration could supply approximately 1 kg-m torque, we wanted to test if that would be enough. The set up for this test was the two heating strips on pads, similar to how the final design had them interacting, with a pressure sensor on one of them that would return how many kg of force we were applying, and a pouch containing water was placed between the two heating strips.The pressure sensor was set up on an arduino and was configured to return what the estimated force was. The setup is depicted in *Figure 5.3*. A screenshot of the data we received from the pressure sensor is shown below (*Figure 5.4*). What we were able to conclude from this is that the servo would provide enough force to form a seal. We held the two plates for different time intervals until it could no longer provide a good seal, which we tested by turning the pouch over and seeing if it would leak. The data from the test is in *Table 5.2*.

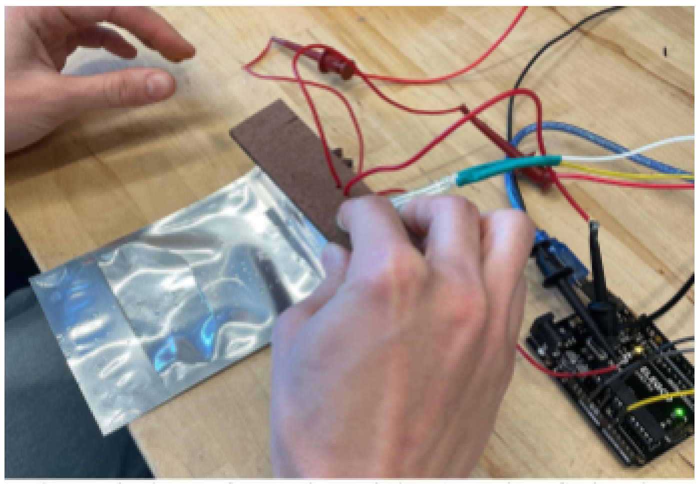


Figure 5.3. Picture of Force (kg) and Time (seconds) to Seal Testing. The pouch full of water was placed between the two heating strips. The two heating strips were connected to the power supply and receiving 9W of power. There was a pressure sensor connected to the arduino that was used to find what the force being apple to the heating strips was. Stopwatch was not pictured, but it was used to measure the time to seal.

```
13:43:38.329 -> ADC Value: 867  Voltage: 4.24 V FSR Resistance: 899.65 ohms     Estimated Force: 1.11 kg
13:43:38.865 -> ADC Value: 869  Voltage: 4.25 V FSR Resistance: 886.08 ohms     Estimated Force: 1.13 kg
13:43:39.405 -> ADC Value: 869  Voltage: 4.25 V FSR Resistance: 886.08 ohms     Estimated Force: 1.13 kg
13:43:39.911 -> ADC Value: 870  Voltage: 4.25 V FSR Resistance: 879.31 ohms     Estimated Force: 1.14 kg
13:43:40.418 -> ADC Value: 872  Voltage: 4.26 V FSR Resistance: 865.83 ohms     Estimated Force: 1.15 kg
13:43:40.966 -> ADC Value: 868  Voltage: 4.24 V FSR Resistance: 892.86 ohms     Estimated Force: 1.12 kg
13:43:41.474 -> ADC Value: 869  Voltage: 4.25 V FSR Resistance: 886.08 ohms     Estimated Force: 1.13 kg
13:43:42.082 -> ADC Value: 868  Voltage: 4.24 V FSR Resistance: 892.86 ohms     Estimated Force: 1.12 kg
13:43:42.532 -> ADC Value: 869  Voltage: 4.25 V FSR Resistance: 886.08 ohms     Estimated Force: 1.13 kg
13:43:43.057 -> ADC Value: 867  Voltage: 4.24 V FSR Resistance: 899.65 ohms     Estimated Force: 1.11 kg
```

Figure 5.4. Screenshot of Arduino Outputs of the Pressure Sensor During Time and Force to Seal Testing. We were appling 1 kg of force to the heating strips since that was the force that the servo motor would be able to apply.

Table 5.2. Results of Different Sealing Times

Force (kg)	Time (sec)	Success
1	6	Y
1	4	Y
1	2	N

Once we got the results, we decided that to be on the safe side, we would have the time to seal be around 5 seconds. We then tested the repeatability of the sealing mechanism. To do this, we used the laser cut gears, heating strips, a power supply, a 3D printed mount, a servo motor, a stopwatch, and pouches with water in them. A picture of the setup is shown in *Figure 5.5.* We connected the servo to an arduino and programmed it to wait for 40 seconds while the heating strips heated up, close to 0 degrees, wait for 5 seconds (in order to seal the pouch), and then reopen. We then turned the pouch upside down and provided force to see if a good seal had formed. We observed that 10/10 times, the combination of the heating strips and the gear mechanism were able to form a good seal. The results we got are presented in the table below (*Table 5.3*).

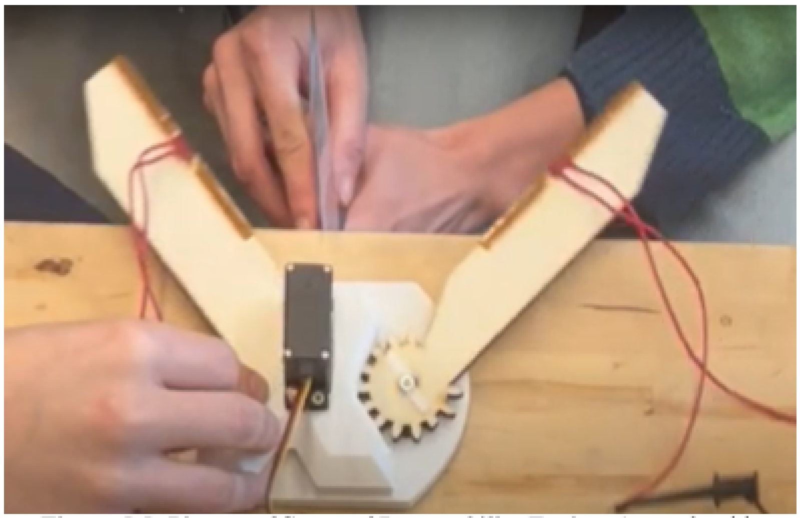


Figure 5.5. Picture of Setup of Repeatability Testing. A pouch with water was placed between the two gears. The gears were laser cut from ¼ inch plywood. They were housed in a 3D printed base and controlled by a servo motor that was powered and controlled by an Arduino. At the end of the gear arms there were two heating strips that were powered by 9W from the power supply.

Table 5.3. Results of the Repeatability Testing

Trial	Success?
1	Y
2	Y
3	Y
4	Y
5	Y
6	Y
7	Y
8	Y
9	Y
10	Y

While we determined that these heating strips would be okay for the initial prototype, since using the power supply would not be an inconvenience, we ultimately decided to get new heating strips that needed less power supplied to them (*Figure 5.6*).

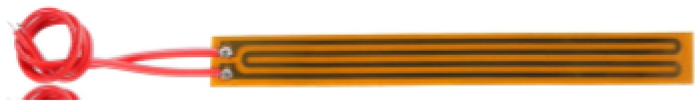


Figure 5.6. Image of Testing Strips Used for the Final Prototype. These heating strips ran on 12V and 1 Amp of power. They heated up to 140 degrees in about 25 seconds and still took 30 seconds to cold down.

Once we got the new heating strips, we performed the first and second tests on them to see what temperature they would reach with 9 W and 12 W of power supplied and to see if it provided any improvements to the heat up and cool down times.

The set up for this test was the same as the first test. We used a power supply supplying 9 W or 12 W of power to the heating strips, a meat thermometer, a temperature gun, and a stopwatch. The procedure was the same. We recorded the initial temperature, then supplied power and turned on the stopwatch at the same time and used the meat thermometer to record the temperature of the heating strips every 20 seconds. We performed this test with 9 W and 12 W and recorded both of the results on the graph below (*Figure 5.7*).

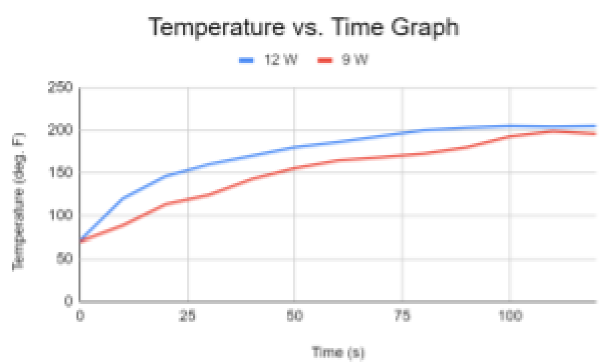


Figure 5.7. Graph of Temperature (deg. F) vs. Time (seconds) of New Heating Strips at 12W and 9W. The heating sttrips were supplied with either 12 W or 9W of power from the power supply.

We then repeated the same cool down experiment on the new strips and got the results listed in *Table 5.4*. We found that the heat up time was half the heating time found for the original heating strips! We also found that the cooldown time did not change, which made sense, since both these strips and the old strips were both being cooled by the environment.

Table 5.4. Results of Heat Up and Cooldown Testing on New Heating Strips.

Trial #	Heat up (s)	Cooldown(s)
1	21.81	28.12
2	20.06	32.37
3	23.23	29.81
4	18.87	27.46
5	20.12	30.68
6	18.19	31.49
7	21.43	33.59
8	23.56	28.93
9	19.34	31.76
10	22.65	29.61
Average	20.93	30.38
Stan.Dev	1.88	1.95

We ended up using these heating strips for our final design.

5.1.2 Liquid Flow Test

The goal for this analysis was to find out whether the peristaltic pumps provided a steady flow over time and whether timing the pumps alone was sufficient enough to estimate the amount of liquid poured. In this test, a pump was connected to a relay, which in turn was connected to an Arduino and a 12V power supply. The Arduino was programmed so that it would turn on the relay for 10 seconds and then turn off for 5. The amount of liquid dispensed in 10 seconds was measured using a scale. The results of this test are shown in Table 5.5. This test was done with two kinds of liquid: first with water and then orange juice.

Table 5.5: Results of Pump Flow Test

Tries:	Weight (water)	Weight (orange juice)
1	23.5g	23.9
2	23.7	24.1
3	23.9	24.0
4	23.5	24.1
5	23.6	24.0
6	23.8	23.9

7	23.4	24
8	23.5	24.1
9	23.8	23.8
10	23.4	23.5
Average:	23.61	23.94
Standard dev	0.17	0.18

The results of the water test showed that the pumps provide an average flow rate of 2.36 gr/s, and there isn't much variation in the flow rate as the standard deviation over 10 tries was only 0.17gr. Despite these findings timing the pumps alone is not sufficient to accurately measure the amount of liquid dispensed as at any given moment, there is no way of knowing whether the pipes are filled with liquid or not which will affect the time it takes to dispense a certain amount of liquid. This experiment also showed that the flow rate from the pumps depends on two other factors: the height of the pump relative to the liquid reservoir and the temperature of the liquid. Cold fluids cause the silicon tubing to stiffen which decreases the flow rate of the peristaltic pump, between cold and room temperature water a difference of about 1 gram was observed over a period of 10 seconds.

As a result of this analysis a weight sensor was used to measure the amount of liquid dispensed from each pump. The weight sensor used was a load cell with four wires with a rating of 1kg. It was placed under the pouch, and each pump was run sequentially as opposed to concurrently.

The aim of the orange juice experiment was to see how the pumps handle pulpy liquids and liquids of different density. For the orange juice the pumps demonstrated an average flow rate of 2.39 gr/s, slightly higher than the flow rate observed with water. The standard deviation over 10 trials remained low at 0.18 gr, indicating consistent performance.

However, the flow rate variation between testing of water and orange juice was very small and negligible in this testing. The viscosity of the orange juice led to slight variations in the dispensing process, highlighting the importance of considering the characteristics of the specific liquid being handled.

5.1.3 Testing Summary

In summary 2 subsystems of the drink maker were analyzed. Heat sealing and liquid flow. Heat sealing test showed the amount of time heat strips take to reach 140F which was an average of 21 seconds with the 12V heat strips. The test also showed the amount of time it takes for the pouches to be sealed which was 5 seconds. The liquid flow tests showed the average flow rate of the pumps which was 2.3 gr/s with water. The tests also showed that timing the pumps alone was not a good method of determining how much fluid has been dispensed from each pump, so as a result of this test a weight sensor was installed to the prototype.

5.2 FMEA

The failure modes & effects analysis (FMEA) conducted on the product focused on three key functions: Liquid Dispensing, Heat Sealing, and UI.

For Liquid Dispensing, potential failure modes such as overfill, underfill, and variations in drink strength were identified. The effects of these failures included inaccurate measuring and identification. The effects of these failures included inaccurate measuring and user dissatisfaction. The team implemented controls such as a drip tray with a moisture sensor and a weight sensor to mitigate these issues.

In the Heat Sealing function, failure modes like incomplete seal, improper pouch placement/timing, exposed heated pads, overseal, and their respective effects were analyzed. Controls such as user instructions, LED lights indicating heat status and timing adjustments were implemented to address these failure modes.

Lastly, for the UI function, potential failure modes included touch base malfunction and sending commands out of order, leading to inoperability and improper drink preparation. Controls such as algorithm adjustments were applied to prevent electronic and software failures, ensuring a more reliable and user-friendly product.

The Risk Priority Numbers (RPN) were calculated for each identified failure mode, providing a comprehensive assessment of potential risks and guiding further improvements in product design and manufacturing processes.

Function	Failure Modes	Effects	S	Cause	O	Controls	D	RPN
Liquid Dispensing	Overfill	Overflow	4	Inaccurate Measuring	2	Drip Tray + Moisture Sensor	4	32
	Underfill	Small Drinks	3	Inaccurate Measuring	2	weight sensor	4	24
	Strong/Weak Drinks	Unhappy user	3	Inaccurate Measuring	2	weight sensor	4	24
Heat Sealing	Incomplete Seal	Leaking	2	Improper Pouch Placement/ timing issue	3	User	5	30
	Exposed Heated Pads	Harm/unhappy user	7	User Error	1	led lights to indicate heat turned on.	1	7
	Overseal	Melt Plastic	6	timing issues/ friction	1	User	1	6
UI	Touch Base Malfunction	Inoperable	5	Electronic Failure	2	Algorithm	3	30
	Sending Commands out of order	improper drink/ more time	5	Software Failure	2	Algorithm	3	30

Table 5.7: FMEA Analysis Table

5.3 Manufacturing and Assembly Techniques

5.3.1 Bill Of Materials

The below table shows a bill of materials (BOM) of the final prototype. The list of components only shows the ones included in the final prototype and not all of the components that were bought during the duration of this project. Similarly the “Total” column shows the price of the components that were used in the prototype and not the overall price spent on each part. For example, the relays come in a pack of 8 but only 7 were used.

Subsystem	Component	Price Per Part	Qty.	Total
Sealing	Heating Strips	$1.89	2	$3.78
Sealing	LED Indicator	$4.99	1	$4.99
Sealing	Relay	$1.75	1	$1.75
Sealing	HS-422 Servo Motor	15.99	1	$15.99
Liquid movement	Load Cell (1kg)	$7.99	1	$7.99
Liquid movement	Pitchers/Liquid Storage	$4.95	6	$29.7
Liquid movement	Water Sensor	$6.88	1	$6.88
Liquid movement	Pumps	$16.69	6	$100.14
Liquid movement	Silicone Tubing	$2.66/m	5.5m	$14.63
Liquid movement	Relays	$1.75	6	$10.5
User Interface	Raspberry Pi 4	$55	1	$55
User Interface	5" touch screen	$45	1	$45
General	Brackets	$0.175	40	$6.99
General	Power Supply	$20.99	1	$20.99
General	Hardboard	$4.00	9	$36.00
General	Contact Paper	7.49	1	$7.49
General	Small Breadboard	$6.75	2	13.5
General	Jumper wires	$7.40	-	$7.40
			Total	**$388.72**

Table 5.8: Bill of Materials

5.3.2 Design For Manufacturing

To adopt the design to mass production implementing design for manufacturing (DFM) techniques is essential. This involves changes in materials and assembly techniques that were used in the initial prototype to make the product suitable for mass manufacturing.

The final prototype was designed to be assembled from laser-cut pieces. As such the frame design features lots of flat walls that are perpendicular to each other. To construct the prototype the laser-cut hardboard pieces were joint together using 90-degree brackets, nuts and bolts. All of the electronic components such as the load cell, heat strips, pumps etc are off the shelf parts and are connected to the wooden frame by nuts and bolts of various sizes. For example to join the wooden walls 4mm bolts were used whereas installing the pumps required 5/64" bolts. The screw holes for all of the assembly components were drilled with a hand drill and the nuts and bolts were again installed manually. In addition the final design contains 2 breadboards and jumper wires to connect all of the electronic components. All of the wires in the final assembly were either connected or soldered manually.

First design change would be to use a material that is more suitable for mass production compared to hardboard. A good option would be injection molded ABS. ABS is suited for high-volume production, durable and waterproof. Not only would this improve the products quality it would also streamline the manufacturing process as injection molding allows fast production of parts. Along with this material change, design simplification is also essential. While the current design is good for hand-assembly, it would need to be changed to be manufactured with ABS plastic.

In the prototype there was little to no thought given to tolerances or standardization of parts, however this would need to be considered in DFM. Standardizing components, for example using same bolt sizes for the electronics would reduce manufacturing complexity and cost through economies of scale, easier inventory management and reduced variety in tools.

The wiring should be replaced with a PCB to transition to a consumer product. While the breadboards and jumper cables are handy for quick prototyping and troubleshooting they lack the durability that is needed in a consumer product. Changing to a PCB would also require a change in the design but it would enable a more compact, reliable and safe electronics assembly. Automated soldering on to the PCB can be used instead of manual soldering of wires, increasing the rate of manufacturing.

For the initial stages of production most of the assembly would need to be done by hand as the volume of order would not justify a fully automated assembly process. It is likely that various parts from various sellers would arrive at one facility to be assembled. This brings various challenges such as setting up an appropriate facility with machinery, training and managing workers, controlling salaries, scheduling shifts, and most importantly setting up a safe work environment in accordance with the law.

There are also various logistic challenges that need to be overcome. Such as ensuring that the suppliers produce consistently high quality products, making sure the orders are placed on time and they arrive on time, managing the inventory which includes storign unassembled parts but also storing the final product.

6.0 Final Prototype Description

6.1 Design Problem Context

6.1.1 DfX Factors

To ensure the success of this device, multiple Design for X (DfX) guidelines were applied. These are the core guidelines that control the final characteristics of the device.

DfX Factor	**Approach**
Design for Cleanliness	As this is a home appliance device with various forms of sugary liquids running through it, the device is modular and allows for easy cleaning.
Design for Cost-effectiveness	The design uses simplistic mechanisms and inexpensive materials to keep the cost of manufacturing low.
Design for Assembly	The product is designed to be easy to assemble and disassemble. As such, screws and nuts were used in place of adhesive.

Table 6.1: DfX Factors

6.1.2 Human Factors

The device will be used by a person, therefore, operator safety must be taken into account. The device should be easy to understand and keep user safety at a priority. Alongside the easy-to-use UI, indicating the users of heating is a key component to ensuring no accidental contact with the heated elements is made.

6.1.3 Economic Impact

Targeting initially college students, the product has the potential to appeal to a wider market, including home users and commercial establishments like cafes and bars. Seal and Serve stands out against existing market players like Barsys, Bartesian, and Black&Decker, offering unique features such as enhanced customizability and features. The project proposes various potential revenue streams, including direct sales and partnerships with beverage companies. Its cost-effective and modular design not only simplifies manufacturing and assembly but also suggests a scalable and economically viable product for mass production. The introduction of Seal and Serve could create new jobs in manufacturing, distribution, and retail, as well as in customer service and maintenance, although it faces challenges such as continuous R&D investment and competition from established brands.

6.1.4 Service Environment

This device is intended to be used in a kitchen, preferably placed on a countertop. Therefore, the design was both compact and aesthetically pleasing so as to not be an eyesore for the owner. The design was made with impact on the environment in mind, and as such the use of plastic and acrylic materials was limited.

6.1.5 Societal Impact

This product addresses a gap in the beverage market by offering enhanced customization and convenience in drink preparation. The device's emphasis on safety, through tamper-proof packaging, resonates with public concerns about beverage integrity, especially in communal settings. Additionally, Seal and Serve's ease of use and quick preparation align with the fast-paced lifestyle of modern society, offering a convenient solution for both social and individual settings.

6.2 Demonstration of the Design

6.2.1 UI

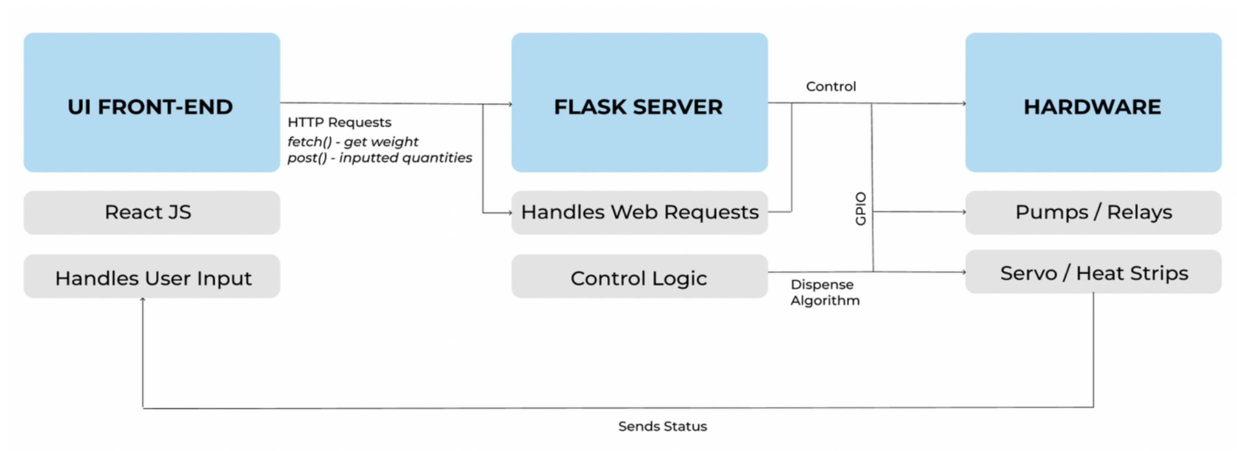


Figure 6.1: Seal and Serve Home Screen

The touch-screen user interface was developed using React JS, chosen for its component-based architecture that allows for a modular and easily maintainable UI. React's efficient update and rendering capabilities also ensured a responsive and user-friendly experience, essential for the interactive nature of the drink maker. The schematic in Figure 6.1 outlines a system architecture where the React-based UI front-end interacts with a Flask server, which in turn controls various hardware components. The UI front-end handles user input and sends HTTP requests to the Flask server to fetch weight data and post inputted quantities. The Flask server processes these requests, executing control logic and a dispense algorithm, and then sends commands to the hardware—such as pumps, relays, servo motors, and heat strips—to perform actions. For instance, the front-end constantly fetches weight values from the load cell. The server also sends status updates back to the UI to reflect the system state. The UI begins by displaying the logo, and allowing the user to choose between three options:

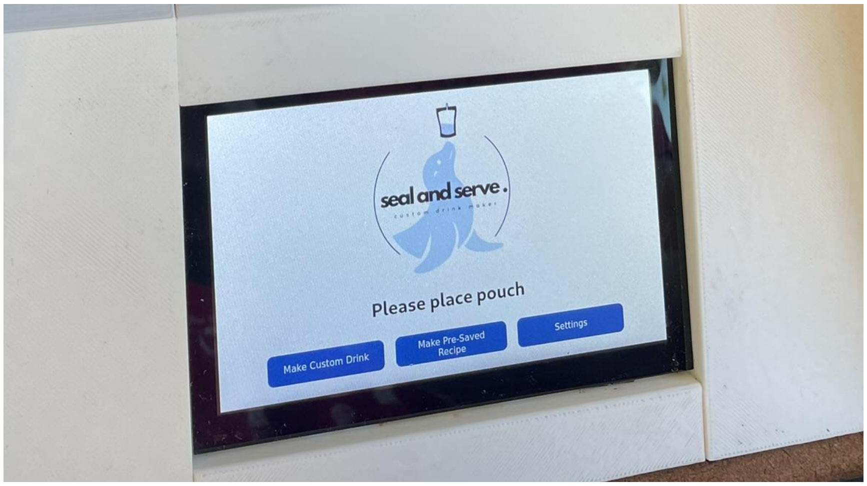


Figure 6.2: Seal and Serve Home Screen

Make Custom Drink: This option gives the user slider bars to select the number of shots they'd want in each drink, with increments of half a shot, or 15mL. This amount is limited to 6 shots, or 180mL, through a software lock, while the display also informs the user of this limit.

$$\#\ of\ Combinations\ =\ C(n+k-1,k)\ =\ C(6\ ingredients\ +\ \frac{180mL}{15mL}-1,\frac{180mL}{15mL})\ =\ C(17,12)$$

$$C(n,k)\ =\frac{n!}{k!(n-k)!}$$

$$C(17,12)\ =\frac{17!}{12!(17-12)!}=\frac{742{,}560}{120}=6,188\ Combinations$$

Given 6 ingredients with multiples of 15mL each, there are 6,188 different combinations to create a 180mL drink, which reinforces the customizability of the drink maker. Once the user has designed their customized drink, they hit the "Done" button and are informed that their drink is being made.

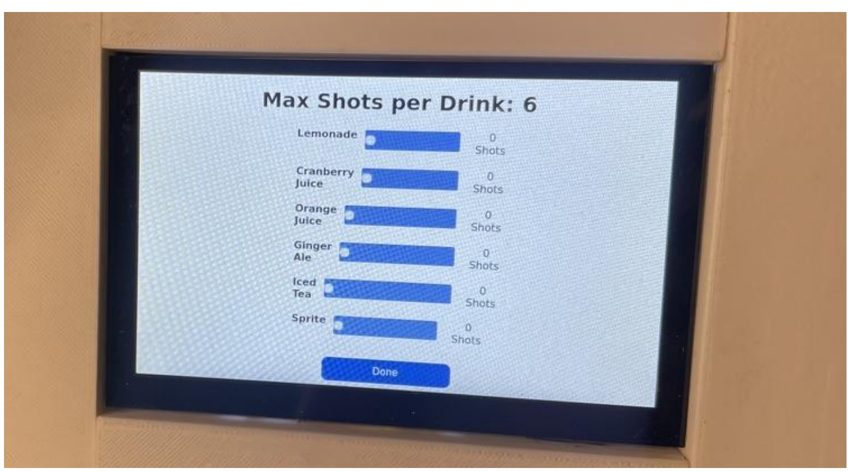


Figure 6.3: Make Custom Drink

Make Pre-Saved Recipe: This option allows the user to both select from pre-saved recipes, and also create their own recipes, using a slider bar setup similar to that found within the "Make Custom Drink" option.

Figure 6.3: Make Pre-Saved Recipe

Settings: This is where the user can adjust the liquid parameters, inputting the name of the liquid in each tank, allowing for easy swapping of ingredients. The codebase has a list of common ingredients with their mapped densities. If the user wishes to add an ingredient unavailable in the options, they can manually input a name and the density value will default to 1 g/mL.

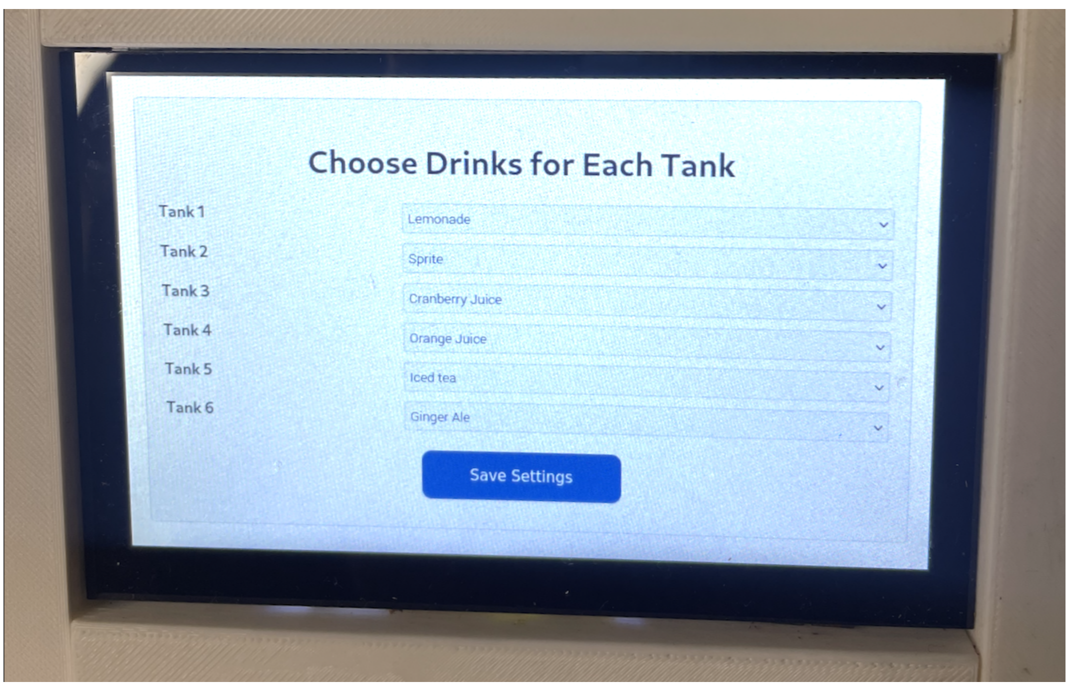


Figure 6.4: Settings

6.2.2 Liquid Dispensal

After the user selects the drink they'd like to make, the UI communicates the various drink parameters to the backend code which then begins instructing the pumps to turn on or off through their respective relays, depending on the weight read by the load cell. The closed-loop flow control begins by taring the load cell when the pouch is empty, as there is no liquid inside. As the pumps flow, the load cell continuously communicates the weight of the pouch to the Pi which uses the following formula to calculate the amount of liquid from each container:

$$mass = \# \, of \, shots * \frac{30 \, mL}{1 \, shot} * density$$

Once the weight read by the load cell reaches the desired value, the Pi instructs the pump to turn off, and then turn on the next pump. Once the entire drink has been dispensed, all pumps turn off and the sealing process begins.

6.2.3 Package Sealing

The sealing process starts by turning on the relays that control the adhesive heating pads. Once the pads, which operate on 12V/1A/12W, are supplied with power, they begin to heat up, and the device waits for 25 seconds for them to reach the required temperature. Any time that the sealing pads are supplied with power, the indicator light "Heat On" on the left front panel illuminates. This bright red light leverages universal signaling, where the color red is globally understood to denote caution, effectively alerting users to the risk of burns or heat-related hazards. This feature not only enhances safety but also boosts user confidence, as it clearly communicates when a potentially hazardous component is active, fostering a sense of security during the appliance's use.

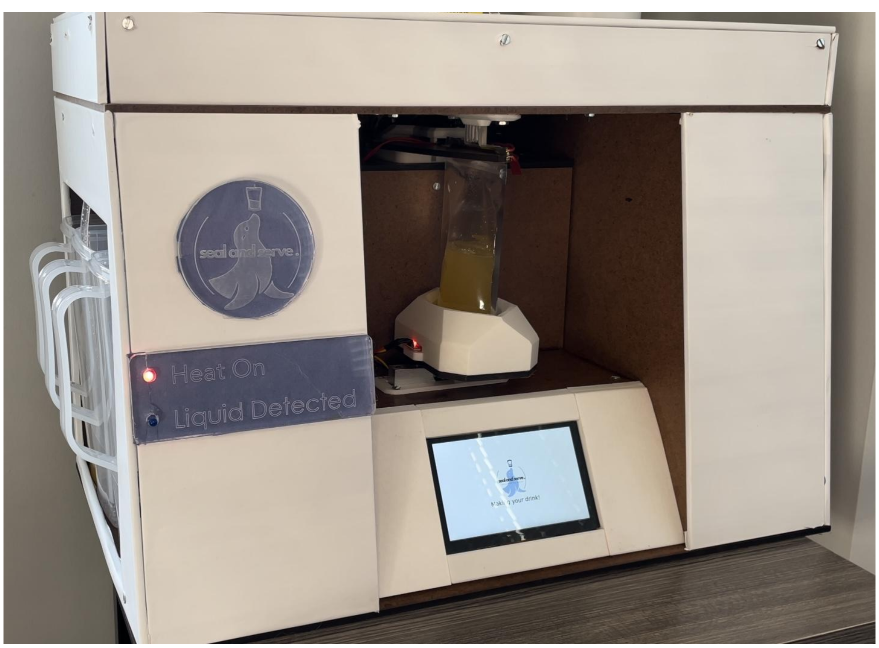


Figure 6.5: Heating Indicator Light Active

6.2.4 Enclosure

Figure 6.6: Pouch Base

This is the final design, which features panels made of hardboard, some of which are wrapped with white contact paper. This design features sloped panels on the side with a touch screen near the bottom for the User Interface. The logo of the device can be seen on the left panel, above 2 indicator lights, one to caution the user that the heating elements have been turned on, and another to inform the user that the water sensor detects liquid. The touch screen is slanted to allow for direct viewing and use from an elevated angle. Any specialized parts for the device were printed from white PLA, including the following: Pouch Base, Cup Base, Screen Bracket, Spout Bracket, Load Cell Bracket, Drip Tray/Base, Servo Motor Bracket. In the center of the design, the user can place their pouch or cup, each of which has their own base, as can be seen in Figures 6.7 and 6.8, respectively.

Figure 6.7: Pouch Base

Figure 6.8: Cup Base

To account for leaks that can occur in the device, a moisture sensor within each base was used, which can be seen in Figure 6.8, and below the load cell, a removable drip tray is installed. This drip tray is accessible from behind Tank 4, the container closest to the front on the left side.

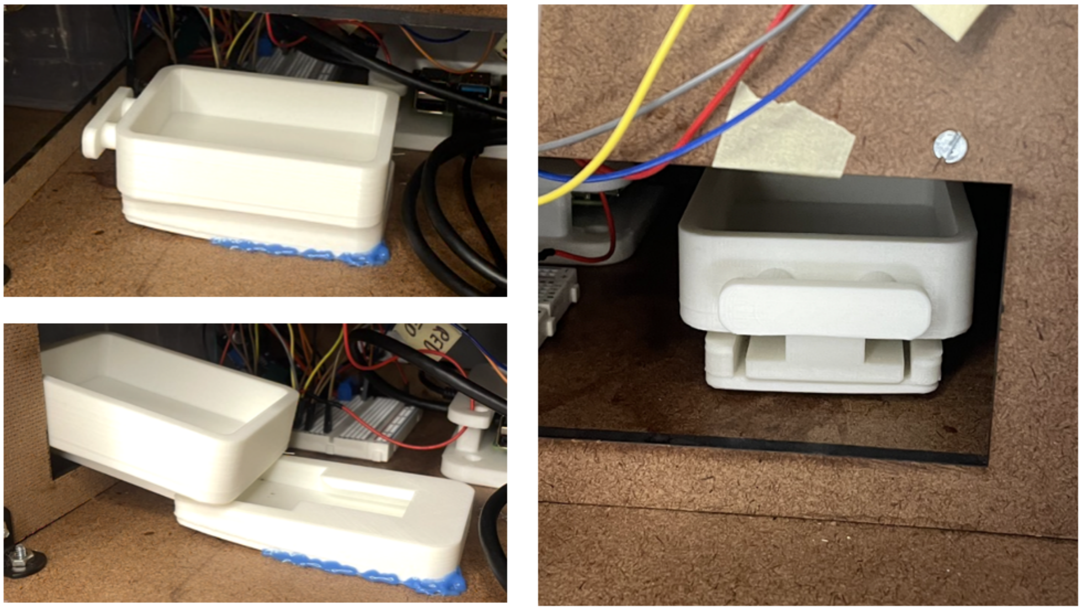


Figure 6.9: Drip Tray Setup

6.2.5 Wiring & Electronics

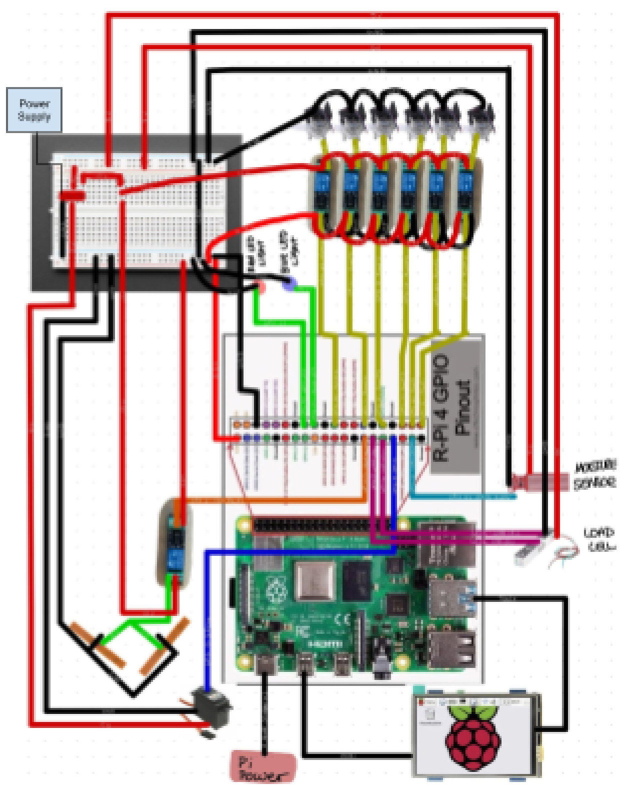


Figure 6.10: Full System Wiring Schematic. Simplified for space and understanding.

As can be seen in the wiring schematic in Figure 6.10, the wiring of the device all stems from the Raspberry Pi, which follows the following GPIO pin configuration:

- **Pump 1 Relay:** Pin 21
- **Pump 2 Relay:** Pin 20
- **Pump 3 Relay:** Pin 16
- **Pump 4 Relay:** Pin 12
- **Pump 5 Relay:** Pin 1
- **Pump 6 Relay:** Pin 25
- **Load Cell:** Pins 5&6
- **Liquid Indicator LED:** Pin 24
- **Heating Element Relay:** Pin 0
- **Servo Logic (PWM):** Pin 13
- **Heat Indicator LED:** Pin 23

The Pi also supplies the relays with power from the 3.3V output. Since the Pi cannot supply more, a 12V/5V voltage divider was used to separate the power supply into 2 circuits: one 12V circuit to power the heating pads and the pumps through their respective relays, and a 5V circuit to provide power to the water sensor, load cell, and the Servo Motor. This voltage divider can be seen in Figure 6.11, connected to the breadboard on the lower level using screw connectors.

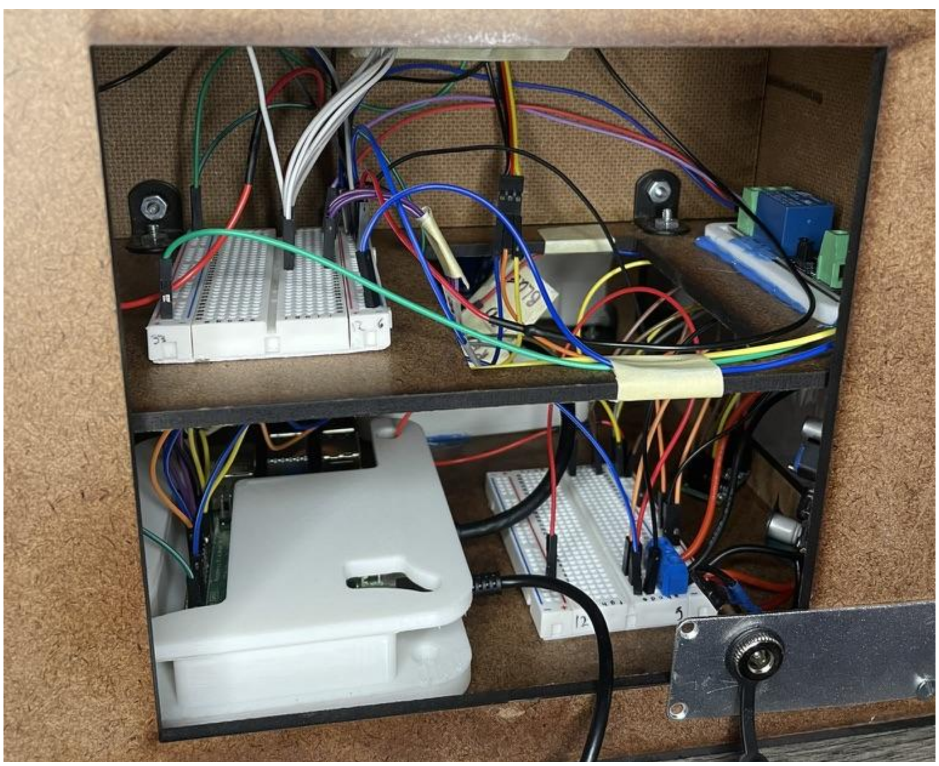


Figure 6.11: Dual Floor Breadboard Set-Up

Due to complications during the prototyping process, our Raspberry Pi ended up frying, and as such, a protective shell was designed to avoid any future potential contact with hazardous materials. A mount for the heat sealing relay was also designed, which can be seen on the upper level in Figure 6.11.

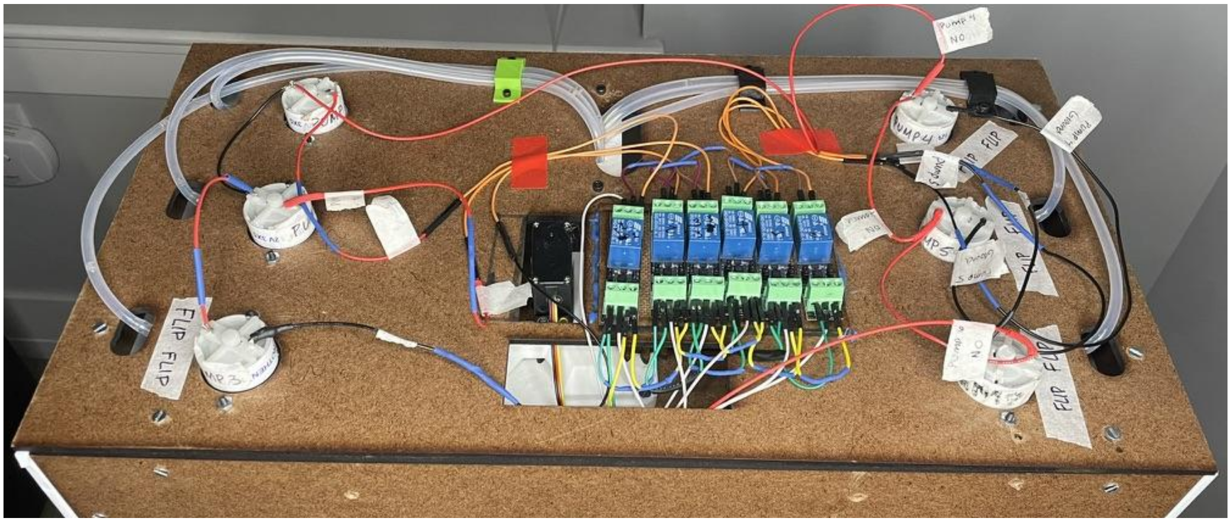


Figure 6.12: Roof Wiring

Below the removable roof, the pump along with their relays and wiring can be seen. As shown in Figure 6.12, multiple daisy chains were used to reduce the number of wires, for the pumps' and relays' power and ground.

6.2.6 Video Demonstration

[Video 6.1: Seal and Serve - UI Demonstration]

Video 6.1 shows users selecting the various amounts of each ingredient they'd like in the drink. This follows the process described in section 6.2.1, where the selected option is "Make Custom Drink".

[Video 6.2: Seal and Serve - Pouch Demonstration]

Video 6.2 shows a demonstration of Seal and Serve filling up a pouch and then sealing it. The three ingredients used in this demo were selected to test a variety of fluid properties. These ingredients were Gin, Sprite Zero, and Simply Peach juice. Gin was used to test the machine's ability to handle alcohol, an important function to customers. Sprite Zero was used to demonstrate the machine's ability to handle carbonated beverages, and Simply Peach juice was used to show that the machine can handle sugary liquids. The video ends with the pouch being sealed, and as can be seen below in Video 6.3, the seal was uniform.

[Video 6.3: Seal and Serve - Seal Quality Test]

In this short video, the quality of the seal can be seen. The seal is completely uniform, with no gaps for liquid to get through.

[Video 6.4: Seal and Serve - Cup Demonstration]

Video 6.4 shows another functionality of Seal and Serve: the ability to bypass all heat sealing and fill up regular drinks. As seen earlier in Figure 6.8, a cup base can be mounted onto the device similarly to the pouch base. The cup is then placed on the base, and the drink fills up similarly to that of the pouch, but no sealing is employed.

6.3 Full System Testing and Results

6.3.1 Testing Set-up & Procedure

Throughout the system testing, multiple functionality tests were performed. Edge cases, such as 0 mL shot values for different ingredients, as well as 0 shots overall in case a user wants to seal a pre-filled pouch. Additionally, various tests were done on the load cell to ensure proper calibration, such as weighing the filled pouch and comparing the value against the desired amount. Each of these tests were either successful, or had their failure accounted for in the final design and were tested until successful.

To perform a full system cycle test, a full 180 mL pouch was made, using 30 mL of each ingredient. The load cell weight was measured, as was the temperature of the heating elements. The procedure of the test went as follows:

- Begin by selecting “Make Custom Drink”
- Select 1 shot of each ingredient, totalling the 6 shot limit.
- Each ingredient is then dispensed into the pouch, and the weight of the pouch is measured.
- Once the 6th shot is dispensed, the heating starts, and the system waits 25 seconds.
- The servo motor closes the gear, and the pouch is sealed. The heating pads are then left to cool.

6.3.2 Results

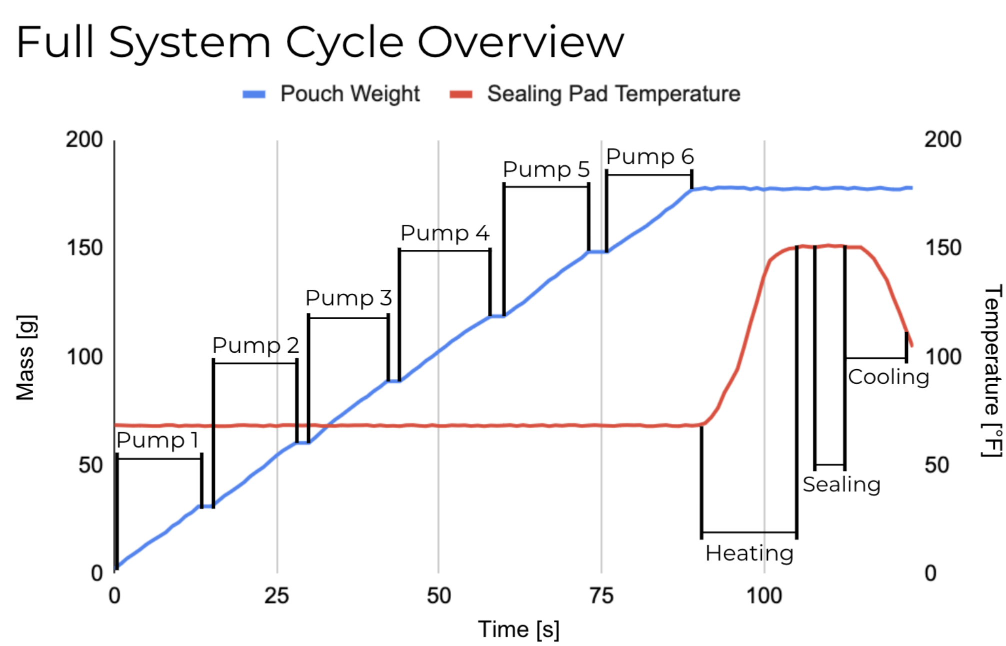


Figure 6.13: Full System Test Results

Figure 6.13 shows the results of the full system test. This cycle shows that the pumps are outputting liquid at an overall average of approximately 2.3 mL per second, similarly to what was found during the initial pump testing. The heating times also line up with the results of the heat sealing testing, with approximately 25 seconds needed to reach the required temperature.

6.3.3 User Feedback

On the day of the design expo, many aspects of the product were commented on. The contact paper-wrapped hardboard was a big talking point, as people were pleasantly surprised by the decision to not use acrylic, due to its wasteful production process. Additionally, various aesthetics of the design were commented on, including the sloped front panel and the user friendly interface. Many users appreciated the inclusion of indicator lights, which, as mentioned earlier, allowed them to be aware any time the heating element was on, or if there was an overfill.

Many users implored about the possibility of making the pouches more environmentally friendly, which the team has looked into since. While the use of biodegradable pouches were not originally conceived of during the design process, it presents a great opportunity to reduce the waste caused by the single use pouches. Biodegradable pouches do exist, and for further use of Seal and Serve, these pouches will be procured and used. [5] There were leaks in the design, and while the pumps do turn off as soon as one is detected, oftentimes there was already some liquid leaking through the pouch base. As such, a drip tray below the pouch base and load cell was installed for future use, as was seen in figure 6.9.

7.0 Conclusion

Seal and Serve is a successful product and was received very well by users. It met all its functional requirements in terms of dispensing ingredients, sealing pouches, modular design, and incorporated a custom user interface. However, there always exists an opportunity for improvement throughout the design process which can be incorporated in the future. Some of these include:

- For more streamlined and efficient project planning, parts should just be purchased as soon as they're wanted, rather than waiting to do a comprehensive mass order. Additionally, surplus components that are critical to the design should be ordered in the case of failure and unexpected circumstances.

- More emphasis should be given to material selection earlier on in the design process. For instance, waterproofing was only considered once the wooden enclosure was made and assembled.

- User testing should be done throughout the design process and not only at the final stage. This would inform certain pain points in the design (such as ergonomics) earlier on.

- More exhaustive analysis on the pumps would've helped better define the capabilities of the hardware, allowing a potential increase in the variety of ingredients used.

- As discussed in Section 6.3.3, user feedback from the design expo also drives the opportunity for improvements, such as using biodegradable pouches, which will be used in the future.

References:

[1] Bartesian (2023). *The Bartesian Cocktail Maker*. [online] Bartesian. Available at: https://bartesian.com/products/cocktail-maker [Accessed Sep. 10, 2023].

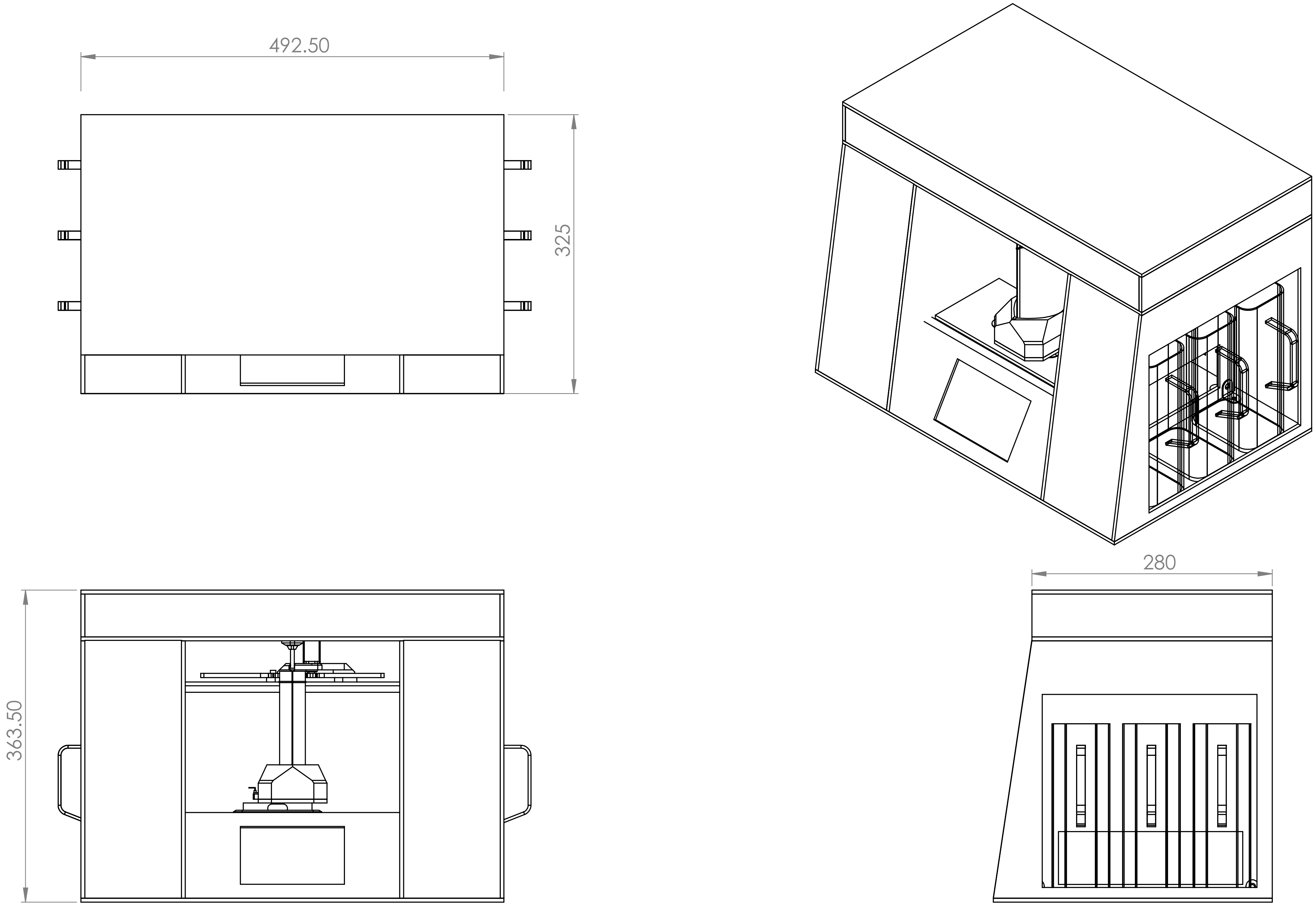
[2] Barsys (2023). *Barsys 2.0+*. [online] Barsys. Available at: https://thebarsys.com/products/barsys-2-0 [Accessed Sep. 10, 2023].

[3] Barsys (2023). *Barsys 360*. [online] Barsys. Available at: https://thebarsys.com/products/barsys-360?variant=45227392270582 [Accessed Sep. 10, 2023].

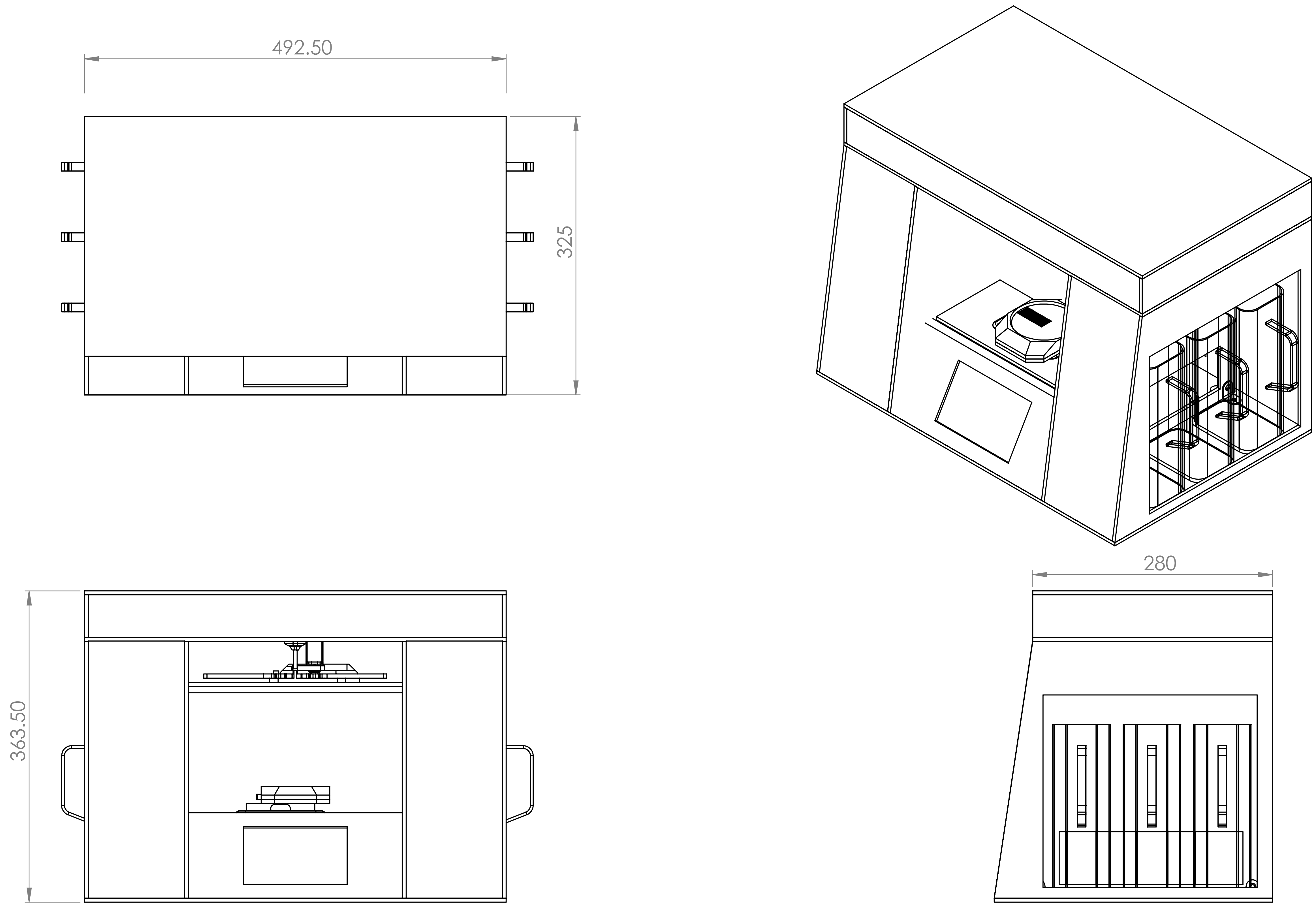
[4] "Ready to drink cocktails market size & share report, 2030," Ready To Drink Cocktails Market Size & Share Report, 2030, https://www.grandviewresearch.com/industry-analysis/ready-to-drink-cocktails-market [Accessed Oct. 13, 2023].

[5] "Stand-Up Pouches," Elevate Packaging, https://elevatepackaging.com/compostable-bags/pouches/ [Accessed Dec. 14, 2023].

Appendix A: CAD Drawings



AUTHOR: Sebastian Levy	CLASS: 24-671 Team # Team 2	PREPARED FOR: Final Report
STUDENT ID. slevy2	TITLE: Seal and Serve	
DATE: 2023-12-15		
MATERIAL: MATERIAL	PART DESC. POUCH BASE	REV. 1
UNLESS OTHERWISE SPECIFIED, UNITS: MM, DEGREE	SCALE:1:5	SHEET 1 OF 1

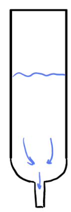


AUTHOR: Sebastian Levy	CLASS: 24-671	Team # Team 2	PREPARED FOR: Final Report
STUDENT ID. slevy2	TITLE: Seal and Serve		
DATE: 2023-12-15			
MATERIAL: MATERIAL	PART DESC. CUP BASE		REV. 1
UNLESS OTHERWISE SPECIFIED, UNITS: MM, DEGREE	SCALE:1:5		SHEET 1 OF 1

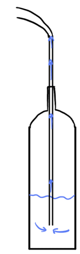
Appendix B: Concept Sketches, Lists

1. **Store Materials**

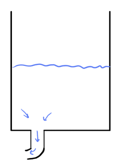
1.1. Upside down drink Bottles



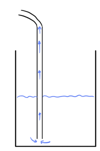
1.2. Right side up drink Bottles



1.3. Upside down tank



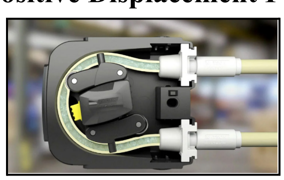
1.4. Right side up tank



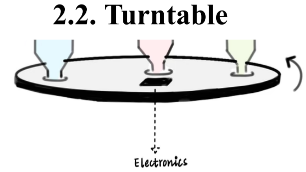
1.5. Wooden Barrels

2. Move Materials

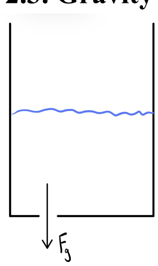
2.1. Positive Displacement Pumps



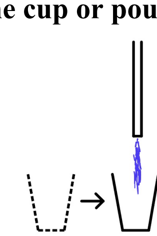
2.2. Turntable



2.3. Gravity

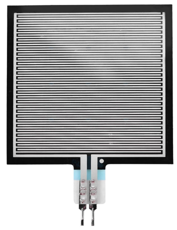


2.4. Moving the cup or pouch under nozzle

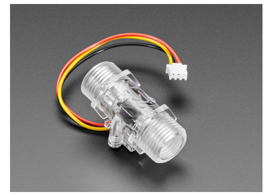


3. Measure Materials

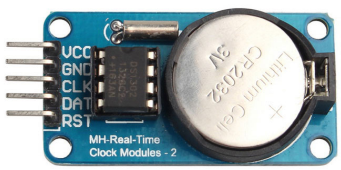
3.1. Force Sensor



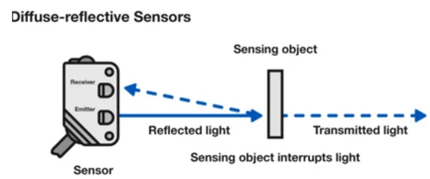
3.2. Flow Sensor



3.3. Time Sensor

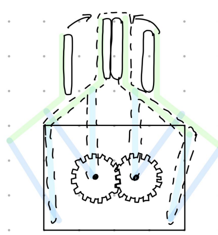


3.4. Diffuse-Reflective Sensor

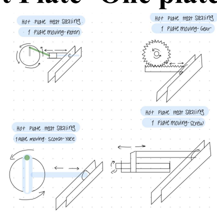


4. Seal Pouch

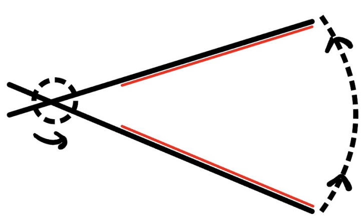
4.1. Hot Plate - Both Plates Moving



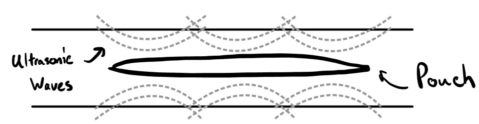
4.2. Hot Plate- One plate moving



4.3. Hot Plate - Scissor Movement

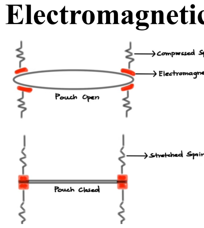


4.4. Ultrasonic Sealing



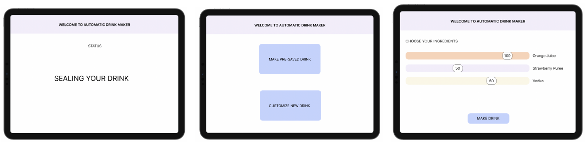
4.5. Lead-Screw Mechanism

4.6. Electromagnetic Press

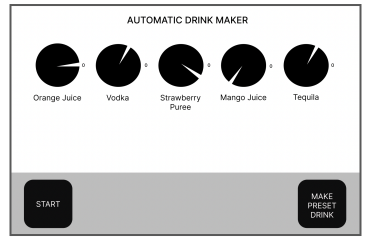


5. User Interface

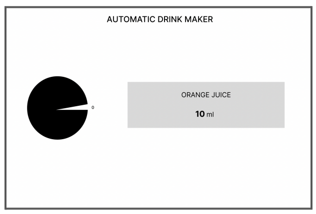
5.1. Touch Screen



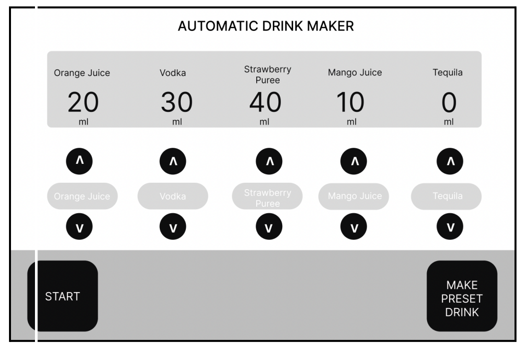
5.2. Knobs



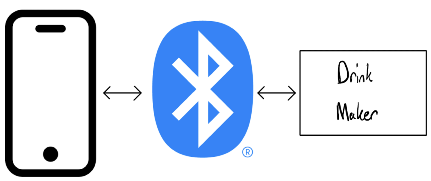
5.3. Combination of Knobs and Touch Screen



5.4. Buttons



5.5. Bluetooth Connectivity



Appendix C: Code

Link to GitHub

Appendix D: Off-Shelf Components

Component	**Price**
Raspberry Pi 4	$63.24
ELECROW 5 inch Touchscreen Monitor	$49.99
Fridge Door Plastic Pitcher with Lid	$13.89
AuBreey Digital Load Cell	$7.99
12V/0.5A Peristaltic Pumps	$15.27
Silicon Tubing	$15.99
Songhe Rain Water Level Sensor	$6.88
HS422 Servo Motor	$15.99
12V/1A Film Heater Plate Adhesive Pad	$15.99
Stand Up Clear Front Zipper Lock Pouches	$15.52
Single Channel 3.3V Relay	$13.99

Appendix E: Work Distribution

Team Member	Design Contributions	Report Contributions
Anaya Bhammar	• UI • Logo • Indicator Light System	• Conclusion • Demonstration of Design: UI
Denis Alpay	• Installation of Pumps • Wiring and Soldering of Pumps & Relays	• Problem Definition • Liquid Flow Test • Testing Summary • Manufacturing and Assembly Techniques
Helen Wang	• Gen1 & 2 Rough CAD Design • Pump Relay Holder • Tube Fixture	• FMEA • Liquid Flow Test
Laura Reichard	• Heat Sealing Mechanism • Full System Wiring Design & Schematic	• Heat Testing • Demonstration of Design: Wiring and Electronics
Sebastian Levy	• Final Full System Design • Pouch & Cup Base • Heat Relay, Load Cell, Tubing Spout, and Raspberry Pi Brackets • Drip Tray	• Executive Summary • Sections 1-4 Summaries • Final Prototype Description