Kansas State University

Electrical and Computer Engineering

Senior Design II

ECE591

Team 8 - Final Report

Healthy Hands

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Executive Summary

After experiencing day to day life during the COVID-19 global pandemic, our team decided to create a sanitary-based design to help prevent the spread of the coronavirus. Our project stemmed from the idea that although there are similar models in existence today, none have the option of dispensing a variety of sanitizing liquids, helpful to those who may be hypoallergenic, in which allows everyone a germ-free opportunity in any public environment. Our team has determined that it is feasible to create a multi-dispensing sanitary system with the use of touch controls and a motion sensor to trigger a dispensing output. This design allows user-friendly use in a modern and unique way, and can also be used for a variety of substances, such as sunscreen, condiments, etc.

In this report, our design of a multi-liquid dispensing system for any public space is explained. Furthermore, we discuss a project description, the technical design, design solutions and alternatives, global issues and perspectives, and our development plan. Our report begins with a detailed explanation of the background and inspiration of our project and proceeds to discuss the project goal, project requirements, and required testing in bringing this sanitary system to life. We then move into the technical design of the project by considering the possible design alternatives of the dispenser, and the system-level overviews of the software and hardware. Next, we consider global issues and perspectives that impact our project and its design throughout the global pandemic. Finally, we discuss the work plan which demonstrates the breakdown of work for our project and how we planned to meet our goals in an organized and timely manner. Our report also includes anticipated budget and displays our research into the feasibility of our design. This report ensures that our team was able to successfully design a multi-liquid dispensing station that can help all individuals live in a bacteria-free environment during the global pandemic.

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1. Project Description

1.1. Background and Motivation

Since March of 2020, according to CDC.gov, there's been a report of 32.8 million cases and over 582,000 confirmed individuals who have died due to the COVID-19 pandemic. Immediately following the outbreak, people quickly realized how important it is to keep themselves and the area around them clean. Soon after, people found that the easiest way to do so would be to use sanitizing products as much as possible. Hand sanitizer specifically became high in demand, and scarce in grocery markets as people raced to purchase ensuring the wellbeing of their families. While supply of sanitizing products has begun to return, the utilization of these products efficiently has become a necessity to everyday life.

For most people, using hand sanitizer is easy. Simply apply any kind to their hands until dry. However, this can be an entirely different situation for people who may be allergic or develop rashes after using certain types of hand sanitizer. This puts these people at a certain kind of risk that can be avoided entirely if they had the option to choose a sanitization product that worked for them. In addition, designs for hand sanitizer dispensers are usually manual. Manual dispensers pose the problem of lingering germs after use due to the individual's hands not being clean before using the dispenser. The multi-dispensing sanitizing station can build upon current sanitizing stations to create a safe and easy way to prevent the future spread of COVID-19. We believe that we have a simple and effective solution to reduce exposure and incorporate product variety to satisfy the users' health needs; thus, potentially saving countless lives being lost to COVID-19.

1.2. Project Goal

The goal for our project is to develop a multi-liquid dispensing station which will provide multiple sanitizing products to individuals who may prefer a different brand or type of product. The station will be designed to have little to no exposure to outside germs/bacteria while the chosen product is being dispensed.

1.3. Project Requirements

ID	Project Requirement	Description
1.0	Device needs to be portable	**Constraint:** The unit should be light enough to be carried by one person and simple to set up for any environment.
2.0	Maintain space standards for public use.	**Constraint:** Overall size needs to be small enough to not impede pedestrian traffic in public areas and restrooms.
3.0	Maintain a cost below ~$550.	**Constraint:** Cost needs to be minimal enough to reproduce cheaply. Lower cost will allow a budget for higher-end liquid products.
4.0	Unit shall track liquid level.	**Primary Functional Requirement:** The unit shall have a pressure/weight system that accounts for the weight calibration before use and the weight throughout the chosen product's life cycle in the system.
5.0	Unit shall have the ability to calibrate specific liquid levels.	**Primary Functional Requirement:** The unit shall have four buttons inside the device to calibrate each liquid once a liquid is replaced.
6.0	Unit shall have both touch screen controls and motion-based dispensing of a selected product.	**Primary Functional Requirement:** The unit shall be designed so that once a product has been selected, the user has the option to dispense via touch screen controls, or motion sensing so that the dispenser will wait until a hand has been placed below output before dispensing the product.
7.0	Unit shall have no cross contamination between products.	**Primary Functional Requirement:** The unit shall have separate tubes leading from the pumps to prevent liquid cross-contamination and buildup inside the tube.
8.0	Unit shall be powered efficiently.	**Objective:** Minimize power consumption when the device is off.
9.0	Unit shall have the ability to present information to the user.	**Primary Functional Requirement:** The unit shall have an LED screen that will display product information and fluid level.
10.0	Unit shall dispense liquids.	**Primary Functional Requirement:** The unit shall contain multiple pumps that will pump multiple variants of liquid. Liquid amounts dispensed will vary based upon their initial calibrated weight.

Table 1: Project Requirements for Multi-Liquid Dispenser

1.4. Validation and Acceptance Tests

1.4.1. Liquid Weight Testing:

- Weight tracking of each of the 4 liquid's levels from the load cells.

1.4.2. Timing and Dispense:

- Test accurate timing and dispensing amount amongst each 4 liquids.

1.4.3. Security:

- Calibration for a secure touch screen login interface.

1.4.4. Zeroing Process:

- Provide a zeroing process for accurate readings from the load cells.

1.5. Validation and Acceptance Test Summary

For validating and checking for acceptance with our design, we required a liquid weight test, ensuring the volume displayed on the screen is what is measured in the system. This was done by putting various amounts of liquid in our system checking to see if the value is correctly displayed on the UI screen. Once that was confirmed, we moved forward testing our timing and dispensing of each of the 4 liquids. To begin testing, we placed 4 unique liquids per each of the 4 bottles, all containing its own density. One at a time, we dispensed each liquid, seeing how quickly and how much is dispensed. For this to pass testing, it should only output a certain amount of liquid. This ensures saving as much liquid inserted in the system and getting the perfect amount for max efficiency. We then tested our implementation for security, to prevent any tampering from nonproduct users. We created a login interface to our UI for product owners to create their own username and password, keeping the mechanism safe. We also added a lock and key to the outside of the enclosure so no one can break into the station. Finally, our last testing criteria was the zeroing process. The zeroing process occurs when our enclosure is opened, providing recorded readings from each of the 4 load cells to be stored in a data file, ensuring the correct weight level of each bottle displayed.

1.5.1 Verification Matrix

Requirement ID	Requirement	Requirement Verification Method			
		Similarity	Review Of Design	Analysis	Test
1	Device Needs to be portable		X		
2	Maintain space standards for public use		X		
3	Maintain reasonable cost		X		
4	Unit shall track liquid level				X
5	Unit shall have the ability to calibrate specific liquid levels				X
6	Unit shall have gesture based product selection				X
7	Unit shall have motion based dispensing of chosen product				X
8	Unit shall have no cross contanimation between products		X		
9	Unit shall be powered efficiently				X
10	Unit shall have the ability to present information to the user				X
11	Unit shall dispense liquids				X

Table 2: Verification Matrix for Multi-Liquid Dispenser

2. Technical Design

2.1. Solutions and Design Alternatives

There are various structures to take into mind when creating our Sanitary Station design. Our mission was to develop a design that would bring separation amongst the varying sanitizers and lotion without cross contamination. To do this, we created individual tubes per substance container that flow each product through one main output. This ensured the safety for hypoallergenic individuals without concern of skin irritation.

2.1.1. Power Solutions:

The question of whether to have a stand-alone build or wall plug-in based mechanism for power was questioned and tested. The ideal goal for a stand-alone build would be utilizing a 12v battery to provide stand-alone power without the use of wall plugins, allowing our device to be used in any environment. In order to do this, we would need powerful enough motors, so instead we chose a wall plug-in, making our project less portable but more secure while in use.

2.1.2. Dispensing Mechanics:

Our design utilizes multiple pumps connected to each of the liquid containers. Each pump has separate tubes from the others that allow dispensing of a configurable amount of liquid. A gravity-based approach is used for accurate dispensing.

2.1.3. Output Tubes:

Our four output tubes allow for both the sanitizers and lotions to be dispensed individually without combining substances. This ensures every individual gets the designated liquid chosen without the concern of hypoallergenic tendencies. We contemplated implementing a one-tube system to ease our workload, however it would defeat the purpose of preventing cross contamination amongst each of the products. The only solution to this would be creating a flushing mechanism before initial power up to clear out the tubes. But instead, we decided upon prioritizing a multi-tube design, as the flushing system required much more maintenance.

2.1.4. Touchscreen Buttons and Motion Sensing:

Our design is being controlled by touch screen buttons and a motion sensor. Sensor based dispensing allows for a healthier interaction after repeated use by the public. Although the user still has to use the touchscreen to select a product, there is minimal interaction when using the dispensing motion sensor. Unfortunately, our motion sensors we purchased weren't of great quality, leading to false positives and random dispenses. Overall, the product still works perfectly if we overlook that issue.

2.1.5. Liquid Level Detection:

Liquid level detection is shown by the amount of substance weight balanced per bottle. This is done with a pressure sensor (load cell) built into the device. We implemented three load cells into the system because our fourth load cell died two days before presentation.

2.1.6. Display:

The dispenser has a small LED readout screen that displays product information, liquid level, and the date/time. This screen is a resolution of about 480p and 7 inches. Another option besides the use of the LED screen was to use an LCD screen that could pose to be more compatible with modern technology. But the LED screen proved to be the best for our project.

2.2. System-Level Overview

2.2.1. Hardware:

For the hardware, a Raspberry Pi is used to control the system. The system is composed of PIR motion sensors, load cells, buttons, fluid pumps, AC to DC converter, and an LED touch screen. The Pi controls the signal to the relays for each corresponding fluid pump, as well as records/calculates/calibrates corresponding fluid levels. Touch screen controls allow an individual to select a specific liquid of their choosing through the UI via left/right buttons, as well as a dispense button for optional dispensing. There is one motion sensor implemented in the design. This motion sensor is used solely to dispense a chosen liquid. Once motion has been detected to dispense liquid, the Pi sends the signal to the chosen liquid's relay and begins pumping the fluid. Post-liquid dispensing leads to the next stage of liquid level recording. Load cells record the dispensed liquid level after each dispensing process. When a fluid runs out, the fluid will be replaced, and the calibration process will begin. There is a button for each of the four liquids in the system. Pressing the calibration button records the weight of each liquid, utilizing its load cell. Our LED screen displays the product information. The system's components are powered by multiple voltage regulators.

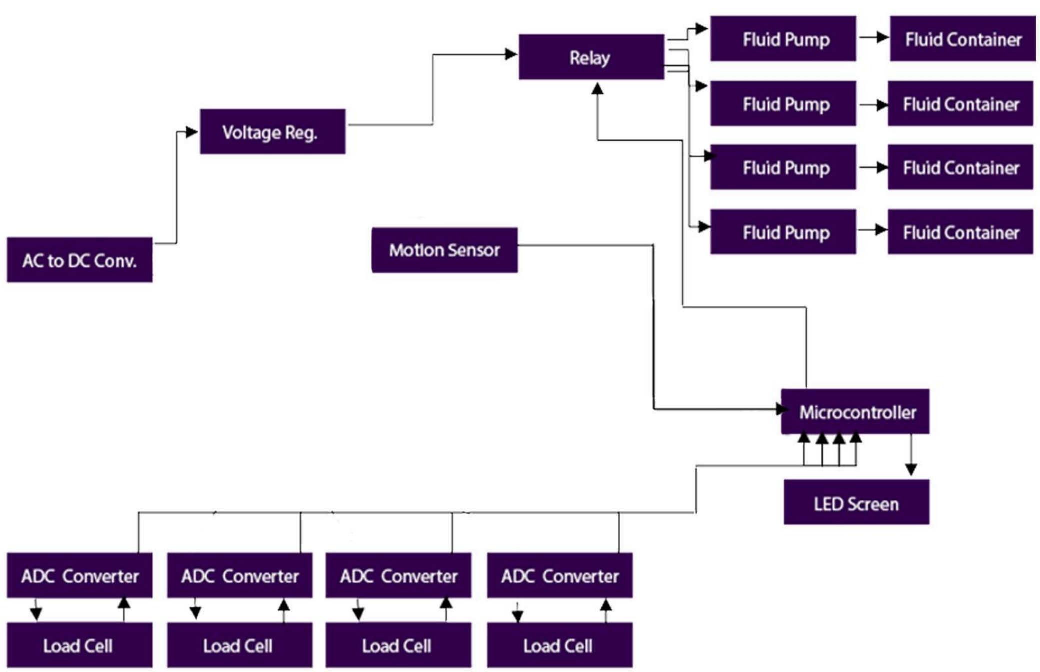


Figure 1: Liquid Dispensing Station Hardware Block Diagram

2.2.2. Software:

The software for the system is built using Python language. The system records fluid level upon dispensing and calibration. Additionally, fluid pump states and motion sensor outputs are recorded. The LED output displays the product information and calculated fluid level. The system has a low-level fluid blocker that prevents further pumping once a fluid level has reached a certain threshold of 5%.

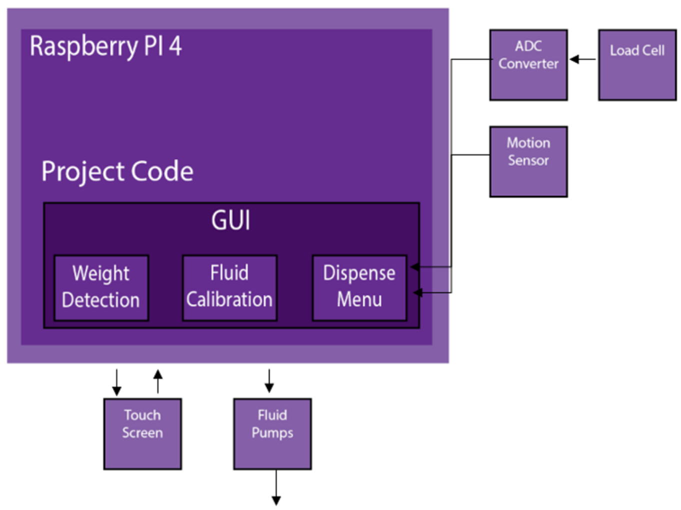


Figure 2: Liquid Dispensing Station Software Block Diagram

2.3. Module-Level Descriptions

As shown in Figure 1, we based our entire system around the Raspberry Pi. Stemming off that, we included everything needed to run our dispenser. Starting with motion detection, we have one sensor with a voltage regulator which inputs a dispensing action by the user. Selecting of each liquid is supplemented by touch screen buttons displayed on the UI. Each of our four liquids contains a container, a pump, and a load cell. Each of these liquids are placed in four separate units to allow easy removal when needed for refill. An AC to DC power converter is used for powering the system. The last few components we utilize are the LED screen, a motion sensor for dispensing, and left / right buttons for liquid selection used to calibrate each load cell.

In Figure 2, we divided our system into three components: Weight Detection, Fluid Calibration, and Dispense Sensing, all controlled by a Raspberry Pi. The LED screen displays liquid level, liquid descriptions, and the date and time. To calculate the liquid level, we use load cells that depict weight detection in order to compare each of the four liquid's weights and their differing levels, all of which are then displayed on the LED screen. We implemented touch screen controls for selecting a desired liquid, as well as a dispense button on the UI for dispensing. Finally, there is also a motion sensor built into the pi that detects motion for dispensing as well. This is triggered when a hand is positioned below the point of dispensing.

2.3. Applicable Standards

While we did not explicitly follow specific standards during the production of our project, we're sure that along the way we followed OSHA standards when in the ECE woodshop and also IEEE standards when completing the hardware for our project.

2.4. Detailed Design Descriptions

We used the Raspberry Pi 4 4GB to control everything in our system. Pin 22 is used for controlling the motion dispensing part of our system. Pins 26/14/15/18 is used to control the relays in our system. Pins 4/17/22 are set up in case we had ever decided to implement our original gesture based sensing into our system. Finally, pins 23/24/25/8/7/20/12/16 are set up for our four HX711's in our system to convert analog data to digital data for weight reading. Both the 5V pins are used for powering the four ADC's, the 5V relay, and the system fan. In total we used 19 of the available pins on the Pi. Below is the pinout diagram for our system in Figure 3. The green dots next to each pin shows they are being used in our system. The relays are set in a normally-closed state and given 12V 500mA when each is opened to provide power to the specified fluid pump. The 12V 500mA is provided by the 12V 500mA voltage regulator being powered by the 12V 3A AC to DC converter.

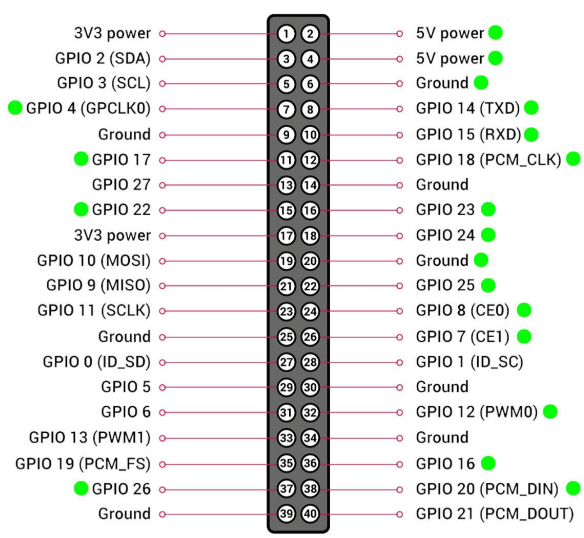


Figure 3: Pinout Diagram for Raspberry Pi 4 4GB

2.5. Validation and Acceptance Test Results

Testing of our design required liquid weight tracking, timing and dispense, security, and a zeroing process. In testing our liquid weight tracking, we ensured each of the four load cells accurately recorded each of the four liquid's weight levels. We created a calibration screen that states each of the liquid's weight levels, as well as had each level displayed on the UI. Each time we dispensed a certain liquid, we checked the liquid calibration recording to ensure that the percentage was exact after dispensing. We also tested the low-level fluid blocker implemented to prevent further pumping of empty liquid bottles below 5% to ensure no further pumping would happen. To do this, we tested a liquid bottle that contained less than 5% of liquid. When testing to dispense, it would stop.

In testing our timing and dispense of each of the four liquids, we simply took into mind the viscosity of each of our four substances used. In our design, we used 3 hand sanitizers, one of which being more viscous, we also used a lotion based substance, much thicker than the rest. For our most viscous substance, in ensuring the proper amount would be dispensed, we created a timing method that would only activate the pump for a certain amount of time. This time could be altered for each liquid in accordance with its viscosity. Also, each liquid could have a separate timer to combat the vacuum effect of the fluid going back up the tube. This would counteract the vacuum effect and allow the liquid to come out even if it had crept up the tube.

In testing the security of our design, we tested our login screen on the UI to make sure that the user had to enter a correct username and password combination in order to get to the calibration screen. In tandem with this, the exterior of the enclosure has a lock that requires a key to be opened. These two security factors will help deter others from tampering with the device.

In testing our zeroing process, we made sure that each of the four liquids could be zeroed out to ensure accurate load cell readings of each of the four bottles. Without a zeroing process, our load cells values could be inconsistent. We also have our values being saved in a file. This way when powering down the system, all liquid weight levels stayed saved accurate readings of all four levels. We also implemented a calibration screen, a screen in which a product owner sets each liquid level state via buttons correlating to each of the four liquids, as well as four additional four buttons to reset each of the four liquids.

3. Other Issues

Affordability of the Multi-Liquid Dispensing Station

Summary:

Our goal is to make the Multi-Liquid Dispensing Station theoretically commercially available. We would also like our project to be mass produced. The commercial cost needs to be considered because many businesses or individuals may not be able to afford such an expensive product. Affordability must be considered because COVID-19 has made a great impact on the global economy.

Resolution:

The components we decided to construct our project with were chosen for our desired design goal while fitting within our estimated budget. Unfortunately, many websites were out of stock until further notice for many of the parts we were wanting, so we found parts on other websites at a more premium price. The project will be able to be built at a much affordable price once stock is built up. Theoretically, if the product were to be commercialized, then the costs to manufacture this project will be drastically lowered utilizing mass production. Bulk part ordering will lower the unit total cost of parts as the cost per part will be cheaper.

4. Work Plan

4.1. Work Breakdown Structure and Gantt Chart

Task #	Task	Jack	Cody	Lawson	Taylor
1	**Hardware Validation**				
1.1	Load Cell		A	R	A
1.2	Fluid Pumps	A	R		
1.3	LED Screen	R		A	
1.4	Motion Sensors	A	R		
1.5	Power System			A	R
2	**Software Design**				
2.1	Proper Fluid Output		R		A
2.2	Motion Sensing	A	R		
2.3	Motion Gestures	R		A	
2.4	Screen Output	R		A	
2.5	Liquid Weight Level		A		R
2.6	Liquid Calibration			R	A
3	**Physical Layout**				
3.1	Interior Pump Layout	A	R		
3.2	External Design			A	R
3.3	Optimal Internal Routing	R			A
3.4	Component Protection		A	R	
4	**Software Validation**				
4.1	Software Reliabilty	R	R	R	R

Table 3: Work Breakdown Structure for Multi-Liquid Dispenser
(R = Responsible, A = Assisting)

Gantt Chart is included as Appendix A at the end of this document.

4.2. Proposed Budget and Final Expenditures

Our financial plan aimed to keep the cost of production down, while still being of high quality. We originally aimed to have a total estimated budget of around $550. The Raspberry Pi, Pi power supply, and LED touch screen was supplied by K-State. Excluding those supplied parts, the total amounts to approximately $275. Our overall total cost amounted to $490, which consists of a Raspberry Pi 4, the pumps and containers, the AC/DC converter, the LED screen, the enclosure materials, and lastly small parts such as relays, sensors, resistors, etc. On the following page is our updated budget table.

Desription	Price	Qty	Shipping	Item Total
Fluid Pump (12V DC 500A)	$15.75	4	$ -	$ 63.00
siny ID 9mm / OD 13mm 3 Ft 1 Meter PVC Clear Hose Tubing	$ 8.99	1	$ -	$ 8.99
1/4" ID Silicon Tubing, JoyTube Food Grade Silicon Tubing 1/4" ID x 3/8" OD 10 Feet High Temp Pure Silicone Hose T	$ 8.99	1	$ -	$ 8.99
Official Raspberry Pi 7" Touchscreen Display	$60	1	$ -	$ 60.00
12V 5A Power Supply Adapter Converter	$11.99	1	$ -	$ 11.99
Pololu 12V, 500mA Step-Down Voltage Regulator	$ 4.95	1	$ 9.45	$ 14.40
6V, 500mA Step-Down Voltage Regulator	$ 4.95	1	$ 9.45	$ 14.40
Pololu 5V, 500mA Step-Down Voltage Regulator	$ 4.95	1	$ 9.45	$ 14.40
FX1900-0000-0025-L Load Cell	$15.54	4	$ 9.99	$ 72.15
PIR Motion Sensors	$ 9.99	1	$ -	$ 9.99
JBtek 4 Channel DC 5V Relay Module for Arduino Raspberry Pi DSP AVR PIC ARM	$ 7.99	1	$ -	$ 7.99
Raspberry Pi 4 4Gb	$55.00	1	$ 8.95	$ 63.95
Pi Power Supply	$ 8.00	1	$ 10.84	$ 18.84
16 Oz Plastic Bottles with Caps	$15.49	1	$ -	$ 15.49
5PCS HX711 Load Cell Amplifier Breakout Weight Weighing Sensors Ad Module Analog to Digital Converter, for Ardui	$ 8.99	1	$ -	$ 8.99
Raspberry Pi 4 Case, iUniker Raspberry Pi 4 Fan ABS Case with Cooling Fan, Raspberry Pi 4 Heatsink, Simpl	#####	1	$ -	$ 10.99
Tulead 10PCS PCB Board Perfboard Prototype Board Circuit Breadboard 6"x3.5"(LW)	$10.59	1	$ -	$ 10.59
Menards Building Materials	$62.72	1	$ -	$ 62.72
Faracent USB Type C Extension Cable (3.3Ft/1m)	$12.99	1	$ -	$ 12.99
		Tota	**$ 58.13**	**$ 490.86**

Table 4: Budget Table for Multi-Liquid Dispenser

4.3. Feasibility Assessment

4.3.1. Ease-of-Use

Our design provides easy use with its ability to be portable and well intact. Touch screen controls allow individuals to make quick interactions with our build without a worry of any faulty error. This provides a hassle free and user-friendly mechanism for any environment. Our project also provides multiple substance selection to cater to any individual.

4.3.2. Battery vs Direct Wall Input

Risks involve power shortage around battery life if chosen to have a stand-alone build. The required voltage for self-sustaining power had to be around 12V. It was best to have a wall-plug build to ensure power without complications.

4.3.3. Build Time

Our build time took about three months during our Senior Design II class to complete. Our team confidently completed the project within the desired time span and kept the price below $500 for all supplies needed. This project was a great opportunity for all four of our members to take part in constructing the Dispensing Station design. We used applications such as Discord and Google Docs to keep all members updated and task efficient.

4.4. Lessons Learned and Recommendations for Feasibility and Risk Mitigation

One major lesson we learned during this project was to more carefully choose parts to use in the creation of the design. We chose our parts based on their reviews rather than our specific needs and ended up buying parts that were difficult to work with. This also hurt feasibility because some of the parts ended up being more expensive than we expected. Another risk to feasibility would be the fact that we used lots of hot glue to secure things in place, which would not be realistic in a finished product.

5. Conclusion

In this document, we explained how our design can provide any consumer with a reliable, efficient, and effective Multi-Liquid Dispensing Station. We hope that our passion in this report is seen, and why we are excited to have created such a health efficient system for the public to use during this global pandemic. In our report, we have outlined our build and design strategies and implementation plans. In addition, we laid out our testing and verification methods. All of which shows how our project was able to meet and exceed the requirements we had laid out for ourselves. We explain both our hardware and software subsystems. In explaining our time management for creating this system, we have provided a Work Breakdown Structure as well as a Gantt Chart showing our detailed time analysis. As for financials, we have broken down our budget by part, showing why we requested our specific amount and what it came out to be. Finally, we assessed the feasibility of our design. For this, we outlined potential risks regarding the ease-of-use of the dispenser, our power implementation, and again the time it took in creating the dispenser. After all our research and findings, our hard work and dedication amongst each of the four of us, we believe that we have developed a substantial Multi-Liquid Dispensing Station.

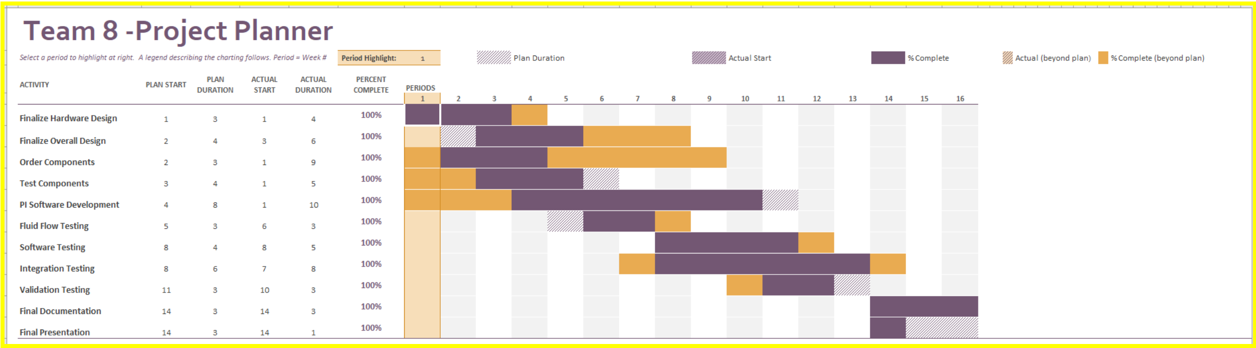
6. References

"CDC COVID Data Tracker," Centers for Disease Control and Prevention. [Online]. Available: https://covid.cdc.gov/covid-data-tracker/#cases_casesinlast7days [Accessed: 15 Oct. 2020].

"Skin reactions related to hand hygiene," *WHO Guidelines on Hand Hygiene in Health Care: First Global Patient Safety Challenge Clean Care Is Safer Care.*, 01-Jan-1970. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK144008/ [Accessed: 20 Oct. 2020].

7. Appendices

Appendix A: Gantt Chart



Appendix B: Base Code GitHub Link

https://github.com/cody598/SeniorDesign