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All-In-One Hand Washing System

A Major Qualifying Project

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Abstract

Washing your hands is the most effective way to prevent the spread of germs; however, individuals do not always comply with established standards. Our design project goal was to design a more consistent and clean way to wash hands. The device needed to be easy to use and comparable, if not better than washing hands with soap and water according to the CDC's guidelines. This technology will get rid of grime, kill germs, and dry hands all in less than 20 seconds. Our design stabilizes soap, water, and energy costs and has a unit cost comparable to current public facilities components.

We created a prototype with an electrical control circuit and viable mechanical design to prove the validity of our idea. Our prototype was meant to replicate a countertop unit that washed a user's hands in a consistent manner. The prototype used simpler, less expensive components to dispense soap, wash the hands, and dry the hands of the user. Due to a lack of custom parts, the prototype required the user to rub their hands together to work the soap into their hands and allow the water to fully rinse the soap off. Our prototype functioned without requiring the user to touch anything to operate the device. This touch free operation was accomplished with an infrared sensor and LED that began the process of washing hands once the beam was interrupted. This caused a microcontroller to iterate through a predefined set of tasks, and used transistors to control the various functions of the device. The entire device was fully functional by the end of testing and allowed us to provide evidence of the viability of our design.

We utilized this prototype to create a completed design. Our solution is the design of an all in one unit that takes the place of current sinks, soap dispensers, and drying technology. Our unit fits on the existing countertop and is plumbed into the current drain and water intake lines. This touch free unit utilizes IR sensors and an MCU to control each function of the hand washing process. The process begins once the sensors inside the unit recognize the user's hands. Upon recognition, the soap is sprayed from the wrist to the fingers in 3 seconds; a short pause then allows the user to scrub their hands to remove grime. Water then sprays from the user's wrist to their fingers in another 3 seconds. Finally air is blown out of the top and bottom of the entrance of the machine, allowing the user to dry their hands as they remove them from the machine. This process is completely touch free and resource conscious.

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CHAPTER 1- MOTIVATION FOR PROJECT

1. Introduction

With over 1 million germs on the average bathroom faucet and not to mention the multitude of germs found along the way to the bathroom, something needs to be done to stop the spread of these germs. If humans washed their hands multiple times a day the number of sick days a year, as well as the number of illnesses, would decrease dramatically. In general, there needs to be more of an emphasis placed on the ideology behind washing hands in order to motivate more people to do so and reduce the number of germs instead of skipping such a simple act. One way of achieving this is to develop a more convenient, time effective method, that not only encourages people to wash their hands but also provides them with a means to do so that fits in with the simplicity and speed of today. Technology today is coming up with anti-bacterial soaps, waterless hand sanitizers, and even UV light sanitation systems to kill off germs. However, one of the best methods of sanitation is still by traditional means, soap, water and fully drying hands. With this knowledge we can simply utilize current principles and package them in an improved manner that attracts and promotes the consumer to use the device. The engineering capabilities and tools necessary to develop this product are already available and simply just need to be combined.

The goal for this project is to continue the advanced technology theme of today's era and develop a new and improved means for hand washing, based upon the initial research and design work from the IQP "Replacement Hand Washing System". The objectives for the device are as follows; create a device that sits in the wall like current hot air hand dryers, allow users to soap, wash and dry their hands without a single touch from the user, and reduce the length of time necessary for a single hand washing cycle. The projected new technology will aim for a wash and dry cycle of approximately 15 seconds, far less than the average wash and dry cycle of currently available technology. The user will place their hands into the device and in so doing will trigger the system to start, the first step will soap the users hands from the wrist to the finger tips in 3-4 seconds, allow a short pause to scrub hands, and then rinses the soap off starting again from the wrist in roughly 3-4 seconds, and finally the system will start the air dryer and trigger the user to slowly remove their hands from the device. This will allow people to wash and dry

their hands significantly faster, so there will be no more waiting in lines for a sink and dryer because this device will do it all, quicker and more effectively and all in one cycle. Another objective of this project is to use a filtration system within the device. Utilizing a filter makes it possible to clean the water before and after use in order to conserve energy and save water! The device will be far more convenient, and will have an increase in the efficiency and sanitation potential over current methods and will have a competitive cost to top it off. This projects overall intentions are to replace the need for sinks, paper towels, and hot air dryers by providing a one-step device that saves time, is cost effective and can allow humans to wash their hands more often where ever they go.

Chapter 2 of this report is a literature review of work performed in the IQP “Replacement Hand Washing System”, which went into different types of germs in different environments, different kinds of sanitation techniques and their effectiveness and UV light sanitation devices including costs of each. This chapter will include additional research, design modifications, and options for materials and components. Chapter 3 of this report involves the building of the prototype. Here the final design choice, a full bill of materials, complete operational schematics, as well as the steps taken for the full prototype build and testing procedure that will be used to assess the prototypes success. Finally, the report is concluded with Chapter 4 which looks into the testing results, improvements made, and the overall final assembly. This chapter will end with a finalized look back at the project and possible future improvements that can help reach deeper into the goals.

CHAPTER 2 HAND WASHING

2. Introduction

In this section the group takes a look into the research and efforts of the previous IQP group (Replacement Hand Washing System). Here we focus on the background research involved with hand washing that was previously conducted and more or less condense what was researched. This section of the chapter will focus mainly on summarizing the findings that the IQP group was able to accomplish; such as what current methods of hand washing exist, if there are any systems that already meet some or all of the design parameters, and what alternative methods are used to sanitize hands. At a later point in the chapter we show our expansion to this previous research and begin to generalize it more to the project goal. We mainly focus on taking a deeper look into current patents that could be related or associated with our design goals and see how those designs can be applied to what we would like to accomplish. With this research we prioritized and applied major finds related to the design of the hand washing systems known today in order to focus on what our requirements would need to be.

The main priority behind the design goal is the necessity for a proper method of hand washing to be established that fits in with today's user. Hand sanitation is one of the most important and effective ways to help prevent the spread of diseases. The ultimate purpose of hand washing is to eliminate as many germs as possible before contaminating other people or objects with them.

This process is necessary for limiting the spread of germs which are essentially on everything. These germs that are on everything are associated with either bacteria or viruses, both of which can make one sick. Bacteria germs can cause illness but are easily treatable with antibiotics, whereas viral germs are much harder and need vaccines to treat them. Since we cannot distinguish between the two without the use of microscopes we must do our best to prevent the spread of them.

2.1 Recapping the work of IQP (Replacement Hand Washing System)

The IQP group primarily focused on different methods that are currently available and suitable to hand washing. This focus led to choosing a method that works the best for everyday hand washing, as well as a soap that could be used for general purposes as well. This research and findings conducted by the IQP group set a foundation for the research and design work that the MQP group performed. With the best soap and method for hand washing on a general scale the MQP group was able to focus primarily on the design and implementation aspect of the project. In the following section, 2.1.1, we focus on recapping the preliminary research conducted by the IQP group which ultimately played a pivotal role in the design and implementation of the all-in-one hand washing system.

2.1.1 Methods Currently in Use

According to the Center of Disease Control (CDC), there are five important steps that should be followed with hand washing. These five steps are as follows:

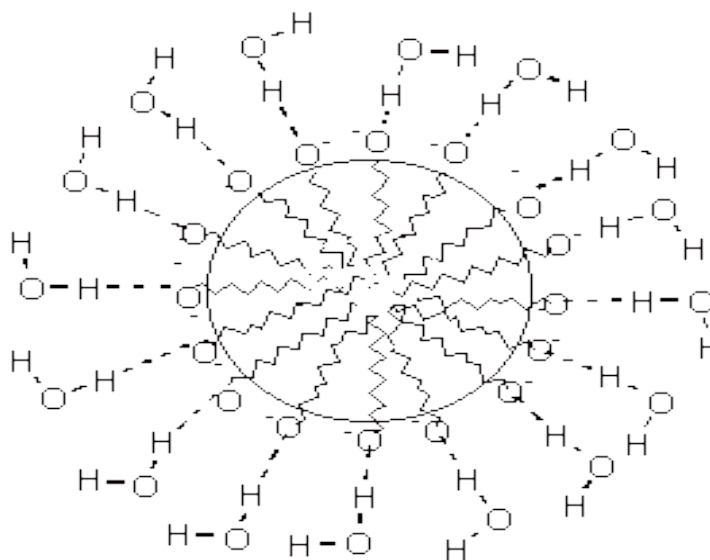
1. Hands are to be washed with soap and warm running water.
2. Hands are to be rubbed together for at least 20 seconds and should be thoroughly cleaned from wrists to finger tips.
3. Hands should be rinsed with running water.
4. While water is still running the hands should be dried thoroughly with a single use towel.
5. The faucet should be turned off using the single use towel to prevent re-contamination.

The fact of the matter is that not all places have the same means of hand washing and drying and so this technique cannot always be followed. So, the main points to get across are that you need to use soap and warm water, rub your hands together and clean from wrists to finger tips, rinse under warm water, and dry thoroughly. The last part is one of the most important to help prevent the re-colonization of the microorganisms called germs because they grow and spread much more rapidly in damp environments (Rybicki, [38]).

The standard protocol for washing hands usually follows approximately five simple steps; wet with water, dispense soap, rub to remove grime, rinse off all soap and grime, then dry

thoroughly. By following this protocol, the average person should wash and dry their hands anywhere from 30 seconds to one minute depending on drying technique used. One of the biggest proponents of clean hands is in fact the soap that is applied during step two. The reason that it is suggested to follow the above stated order is so the user can disperse or use a small amount of the soap across the entire area of their hands, since soap on its own does not naturally like to spread, in small quantities, without the assistance of water. This section takes a look at the many different types of soap available and what exactly each of them does to purify the hands.

Standard hand soap found in use in public restrooms generally consists of fats and alkali metals. The alkali metals found in these are usually sodium hydroxide found in solid soaps, and potassium hydroxide found in liquid soaps. The combination of alkali metal to fat creates fatty acid chains which then produces glycerol. This reaction can be seen in the following figure, Figure 1. This reaction is what makes soap possible since the dirt and germs that are to be removed from the hands become chemically inclined to bind to this new non-polar substance.



A Soap Micelle

Figure 1 Soap Micelle Created

As can be seen from Figure 1, the illustration of the chemical property of soap, the soap micelle is what is formed and what is removed by water after frictional forces upon rubbing

together of the hands have clearly uplifted this aggregate. This process is what common commercial grade soap uses. Figure 2 is an illustration of two varying types of common public soaps in their common commercially available forms.



Figure 2 common liquid hand soap, Softsoap (left), and common solid bar soap, Dial (right)

The common liquid hand soap and bar soap that are found in almost every bathroom in public have very simple make-ups and processes in cleansing as previously mentioned. Both types of the basic hand soap shown above work well for day-to-day use, however they are not the best cleansers out there today.

Surgical scrubs are intended for exactly what their name infers surgery. This particular form of soap is used by doctors prior to surgery to ensure the utmost sterility so that they do not contaminate the patient. The particular surgical scrub that was looked into goes by the name of *N*-Duopropenide (NDP), and according to an article within (Puente, [36]), by Herruzo-Cabrera this scrub works better and over longer periods of time than many other alternative forms of hand washing techniques.

N-Duopropenide is a compound made from ammonium iodides and formaldehyde (Zentralbl, [45]) this dynamic duo that forms the compound aid in both killing off bacteria and viruses as well as also preventing new bacteria and viruses from growing on the applied area. The ammonium iodides are quaternary, and the ones used are:

benzyltrimethyldecylammonium, benzyltrimethyltetradecylammonium, and benzyltrimethylhexadecylammonium (Puate, [36]). This scrub also contains 60% isopropyl alcohol, as commonly found in the liquid hand sanitizers seen everywhere these days. The dehydration effect on anything it comes into contact with destroys bacterial cell membranes and virus capsules. This effect can be quantified up to 99.9% of germs being killed with each use. Although the dehydrating of the germs is necessary, it also causes dryness of the skin which can create cracks where any contagions can thrive. This is where the third proponent of this solution comes into play. The emollients used in the solution moisturize the skin, which in turn prevents the skin from painfully cracking. So, in other words not only will this scrub kill off the same amount of germs as regular hand sanitizers, it has emollients to keep the hands moist, and it has formaldehyde to prevent more contagions from returning and growing on the skin after the hand washing.



Figure 3 illustration of common surgical scrubs, NDP (left) mentioned above, and Chlorhexidine (right).

In Table 1 and Figure 4 and 5 taken from R. Herruzo-Cabrera's paper titled: Usefulness of an Alcohol Solution of *N*-Duopropenide for the Surgical Antisepsis of the Hands Compared with Hand washing with Iodine-Povidone and Chlorhexidine: Clinical Essay, we can see clear indications of the effectiveness of the NDP scrub.

Table 1: Study of the Efficiency of Surgical Scrubbing Up.

Study of the Efficiency of Surgical Scrubbing Up with Three Products on Cutaneous Germs ($n = 15$ healthy volunteers), Expressed as Log CFU/5 Fingertips^a

| Time | 4% Chlorhexidine | | 7.5% I-pov | | 2.3% NDP-alc | |
|----------------|------------------|-----|------------|-----|--------------|-----|
| | \bar{X} | SD | \bar{X} | SD | \bar{X} | SD |
| Before washing | 4 | 0.5 | 4 | 0.4 | 3.9 | 0.4 |
| After washing | <1 | — | 3.1 | 0.2 | <1 | — |
| +1 h | 2 | 0.3 | 4.3 | 0.9 | <1 | — |
| +3 h | 2.7 | 0.6 | 4.5 | 1.2 | <1 | — |

Bivariant analysis

1. Time

"Before" $P > 0.05$ (NS)
 "After" I-pov > (**) chlorhexidine (NS) NDP-alc
 + 1 h I-pov > (**) chlorhexidine > (**) NDP-alc
 + 3 h I-pov > (**) chlorhexidine > (**) NDP-alc

2. Products

I-pov Before > (**) after
 + 3 h > (*) after
 + 1 h > (*) after
 Chlorhexidine Before (NS) + 1 h (NS) + 3 h
 NDP-alc Before > (**) + 3 h > (**) + 1 h > (**) after
 Before > (**) + 3 h (NS) + 1 h (NS) after

^a I-pov, iodine-povidone; NDP-alc, *N*-duopropenide in alcohol; NS, no significant differences.

* $P < 0.05$.

** $P < 0.01$.

The above table shows how the three surgical scrubs compared to each other after the in vivo tests against cutaneous germs. The following two figures, Figure 4 and 5 show the test results. After analyzing both the table and figures we can clearly see that the NDP scrub is the best scrub of those that were analyzed. In comparison to the other scrubs the NDP killed off the germs and kept them off hour after hour, whereas the other scrubs, especially the 7.5% I-POV saw returns of the germs in the first time frame and actually some saw increases in the return from the original state.

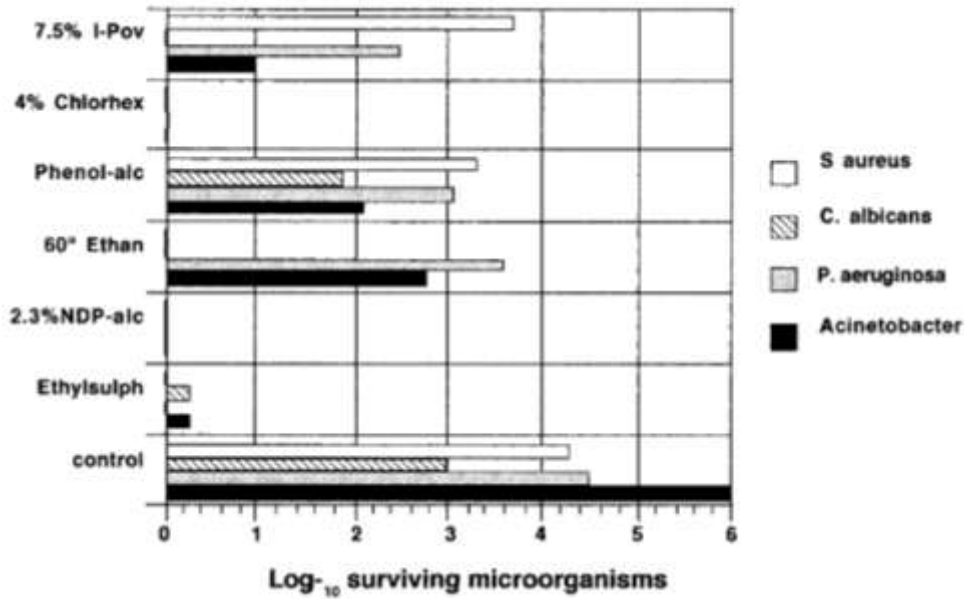


Figure 4 illustrated In vitro germicide effect of six products

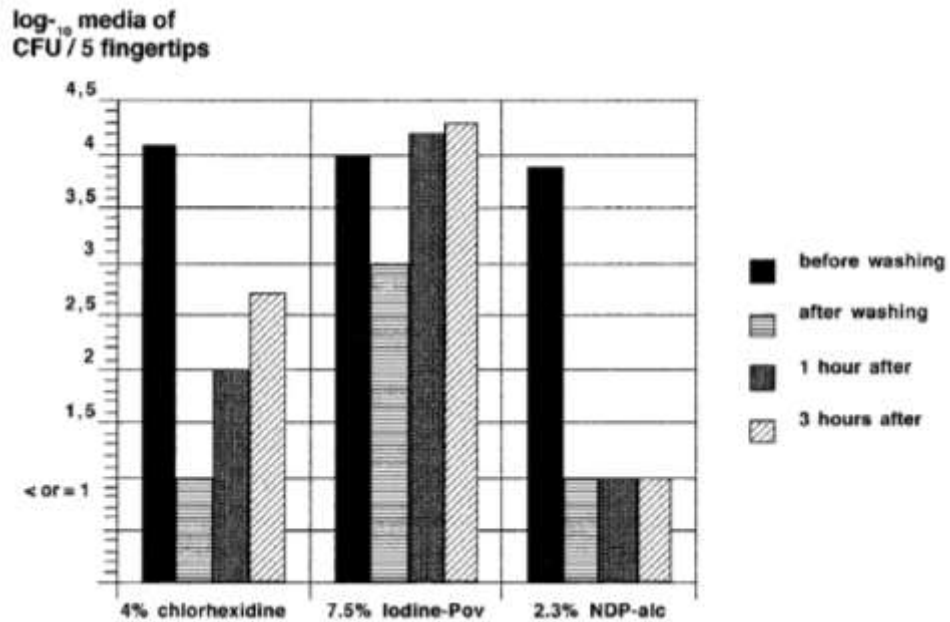


Figure 5 Study of the efficiency of surgical scrubbing on cutaneous germs

Figure 4 is an illustration of the killing capabilities of six cleansers in the test against common germs found on hands. As can be seen the *N*-Duopropenide solution has little to no logarithmic growth, indicating the best killing. In Figure 5, the same *N*-Duopropenide solution is compared to the other two cleansing solutions found in Table 1 by growth of CFU (colony

forming units) over time and again the NDP reiterates the fact that it is a better cleansing solution. For these reasons and those previously mentioned about this scrub, hospitals and doctors chose this scrub because they need the best when it comes to protecting their patients.

Although they may not be on the same level of germ killing as the previously discussed soaps, gentle soaps are necessary for certain age groups, such as very young and the elderly. The gentle soaps provide a degree of cleansing while also ensuring that it moisturizes and nourishes the delicate skin of the young and old alike. The benefits behind this particular soap are that it is for the most part all natural and chemical free. An illustration of common organic baby soap can be seen in Figure 6.



Figure 6 shows bare organics, organic baby soap with no scent.

Some of these natural oils that have immune supporting properties as well as moisturizing properties would be: vitamin E, jojoba oil, castor oil, lavender oil, almond oil, shea butter, olive oil, and coconut oil (Todar, [42]). Since they are all-natural, one does not need to be concerned with harsh chemicals affecting the baby's sensitive skin, or causing tear production in their eyes.

As initially stated, gentle soap is not the best at cleaning hard grime and dirt off skin, however that is not the intention of this particular soap. Its main purpose is to gently dislodge the particles of dirt, dead skin, and excrement from the healthy skin, and wash it away while

moisturizing. This sort of cleaning would not work well for the everyday user given its lack of germ killing and grime removal capabilities; however the moisturizing characteristics of this particular soap would be beneficial.

In general all of the previously mentioned soaps have been intended for primarily germ killing purposes and not really intended for grime removal. There are occasions and occupations where this particular type of soap is extremely necessary, such as mechanics and construction workers. In these occupations, the workers usually end up with grease, oil, dirt, and all sorts of other grime worked into their hands that a normal everyday soap would take hours of scrubbing to remove. The grime soap however is made for this purpose. It contains a small, gritty substance, usually a type of pumice that helps to remove the deep worked in grime in one use, instead of multiple uses like the other soaps would need.



Figure 7 is a common heavy-duty scrubs; Gojo (left), Fast Orange (right)

Two products that work well and cover all the bases for the grime removal issue are the Go-Jo Cherry Gel Pumice Hand Cleaner (left), and the Fast Orange (right). The Go-Jo is described as a gel that contains tiny pumice scrubbers in it to scrub away the tough dirt particles

that gets lodged in skin crevices (Permatex, [35]). These gels also have the ability to remove grease, which means it contains certain fats to remove it, and it also conditions the skin with moisturizers to keep it healthy and refreshed. Also, in addition to the pumice scrubbers imbedded in the soap, the company, Fast Orange, also provides a small scrubber that can be used in addition to the product to help ease the really tough ground in stains from ones hands and fingernails. The benefit of this soap would be its increased grime removal capabilities; however it does not compete with the germ killing capabilities of the surgical scrub category.

A modified pair-wise chart taken from the IQP (Replacement Hand Washing System) can be seen below. In this chart the group took a look at the previously mentioned types of soaps and compared them in five different categories in order to choose the best soap for an all-around good cleaner. The modifications that were made were combining the elderly soap and the baby soap into one category that is now title gentle soap. This chart is based on a one to ten scale, where one is the best and ten is the worst.

Table 2: Comparison of the current varieties of soap (Scale 1-most effective -> 10 least effective)

| | Cost | Killing Germs Ability | Time Kill Germs | Accessibility | Effects On Skin | Totals |
|---------------------------|------|-----------------------|-----------------|---------------|-----------------|--------|
| Regular Soap | 3 | 7 | 5 | 2 | 3 | 20 |
| Surgical Scrub | 9 | 1 | 2 | 8 | 2 | 22 |
| Gentle Soap | 4 | 7 | 6 | 3 | 2 | 22 |
| Hardcore Dirt Soap | 6 | 5 | 5 | 4 | 5 | 25 |

As one can see in Table 2 the regular hand soap has the lowest total from the soap subcategories listed in the table, therefore being the best current commercially available contender for use in the general hand washing system, however depending upon the intended location for this machine different soaps can be purchased and used. This was expected since it works decently well in an equally average amount of time for a low cost. If cost were eliminated from the table as a deciding factor, the surgical scrub would be the best choice since it works the best and it would not be too difficult to manufacture and/or order. In addition, if we were able to obtain a slightly modified version of the NDP surgical scrub that would perhaps be ‘watered down’ and commercially available, while still maintaining its amazing germ fighting abilities, then that would be our optimal solution to the soap choice dilemma.

Hand Sanitizers are the alternative to the traditional soap and water technique for hands cleansing. This method is usually more intended for the on-the-go person where they are able to quickly squirt a little in their hands and rub it together in order to kill off the germs, when there are no restrooms available. This method is an extremely simple idea that functions very well. It is relatively cost effective since only around a 2.5mL squirt on a hand is enough to rub around to remove 99.9% of germs from ones hands (Brassard, et al, [9]). The only thing to consider is the extended continuous use of this method versus the traditional soap and water technique, as well as the idea of children having access to this. It is speculated that children could possibly ingest this product and become very ill due to the main ingredient of the product being isopropyl alcohol. The main usage for isopropyl alcohol is killing germs in a short period of time as well as evaporating once rubbed into the skin. These two properties of isopropyl alcohol are the sole reasons hand sanitizers work. Figure 8 shows the common brand and form of hand sanitizers, Purell.



Figure 8 is a common hand sanitizer, Purell with aloe.

When comparing 40% alcohol solutions to the 60% alcohol solutions, the difference was so noticeable that the CDC posted a statement concerning hand sanitizers and their formulas (Brassard, et al, [9]). Now most if not all hand sanitizers must contain between 60% and 92% of ethanol or isopropyl alcohol. Increasing the concentration of alcohol in hand sanitizers is great to clean ones hands, but it also has its dangers when used around children. As mentioned before, young children always seem to be putting things in their mouths. If they ingest enough hand sanitizer, they could become very ill and show the appearance and signs of being intoxicated, and like alcohol, if enough is consumed fatalities can occur.

A secondary issue with having a higher alcohol content in hand sanitizers is the alcohol's dehydration effects on the skin. In order to keep hand sanitizers functions the same, one cannot exclude the alcohol portion since it actually does the killing of the germs. So it is necessary to add vitamins and moisturizers to the product in order to cancel out the dehydrating effects of the alcohol.

UV light, also known as Ultra Violet Light, is outside of the visible spectrum. There are three ranges of ultra violet light; A, B, C. UV-C light is the most common range. It is a short wave spectrum from 280nm – 200nm. This wave length is generally produced by the sun; however modern advancements have shown to be able to replicate this wave length and produce a light bulb that can mimic the sanitation properties of the suns radiation.

Ultra Violet light emits radiation and is extremely harmful against microorganisms. UV-C is a germicidal wavelength at 253.7nm. It can disinfect air, water, and other surfaces against germs. It is used in sanitation by breaking down germs molecular bonds destroying their nucleic acids. This disinfection is a photochemical process where the germ's cell membrane and DNA are broken down upon exposure. The germ's molecular bonds are ultimately destroyed rendering the germs sterile because the germs can no longer reproduce (Brassard, et al, [9]).

Direct exposure to Ultra Violet light is extremely dangerous. It can cause burns on the skin. Table 4 shows the different characteristics of UV-A, UV-B, and UV-C light.

Table 3: Chart of the different UV ranges.

| Region | Also known as | *Range in nm | Hazard Potential | Damage Mechanism (High Exposures) |
|--------|---------------|--------------|------------------|-----------------------------------|
| UV-A | near UV | 320-400 | lowest | cataracts |
| UV-B | mid UV | 290-320 | mid to high | **skin or eye burns |
| UV-C | far UV | 190-290 | highest | skin or eye burns |

*Early "black lights" emitted in the range of 360-390 nm.

** Increased risk of some types of skin cancer.

Long term exposure can lead to ulceration and skin cancer. If UV light enters the eyes it can burn the epithelial tissue. Many sources have said that UV-C cannot cause cancer or cataracts but it is still not clearly proven and universally accepted. Another danger in using Ultra Violet light lies within their bulbs; UV bulbs contain mercury (Brassard, et al, [9]).

The three different methods to killing germs all have advantages and disadvantages. Table 4 is the pair-wise comparison chart comparing the effectiveness of each method established by the IQP group of the Replacement Hand Washing System (Brassard, et al, [9]). It can be seen that hand soaps and sanitizers are close in effectiveness. An important objective to point out it that soap have a much better ability to clean grime and for the purposes of this project are more significant. This chart is based on a one to ten scale with one being the best and 10 being the worst per category.

Table 4: Pair-Wise Comparison of Sanitation Methods

| Methods/ Objectives | Safety | Ability Kill Germs | Cost | Availability | Water Usage | Energy Usage | Clean Grime | Totals |
|--------------------------------|---------------|-----------------------------------|-------------|---------------------|------------------------|-------------------------|--------------------|---------------|
| UV Sanitation | 8 | 3 | 5 | 4 | 1 | 7 | 9 | 37 |
| Soap | 3 | 7 | 3 | 3 | 5 | 4 | 2 | 27 |
| Hand Sanitizers | 4 | 5 | 3 | 3 | 1 | 2 | 8 | 26 |

2.1.2 Current Technology

Every bathroom is equipped with a sink for hand sanitization purposes. While shape, size, location, and other characteristics vary, all sinks provide the opportunity for hand-washing. While sinks have been used for centuries, there are several key flaws with the current sink design, particularly when it comes to public places. As illustrated below, many of today's sinks have handles in order to turn the water on and off. Also to be noted is the fact that the soap and hand-drying apparatuses are separate from the sink itself.



Figure 9 Common Sink

Most sinks must be manually turned on and off, requiring the user to touch the sink in order to utilize its function. This flaw can allow for significant bacteria accumulation and can, in turn, defeat the purpose of the sanitization in the process. Some motion sensor technology has been implemented in public bathrooms around the world. Unfortunately, it is rare that one does not have to touch anything (i.e. soap dispenser, paper towel dispenser, or the sink itself) in the hand sanitization process. Water conservation can also become a problem with many sinks today, due to leaks or lack of motion sensor efficiency. Generally, the motion sensor is placed below the sink head, portrayed in Figure 10. Problems can arise with the sensor's range capabilities and time can be wasted due to sensor lag.



Figure 10 Motion Sensor Faucet Head

Current soap dispensing technology is similar to that of modern day sinks. While some must be mechanically operated to dispense the soap or sanitizing agent, others are motion sensor operated to provide a predetermined amount of soap. Figure 11 is a patented design for a simple, push-operated soap dispenser. Once pressure is applied to the bar, a roller inside the apparatus is triggered, releasing a pre-proportioned amount of soap from inside. The roller rolls over this tube and extracts the soap by means of forcing it to the nozzle end at the base of the device, and once the pressure is enough the soap will be dispensed (Maddison and Dawson [30]).

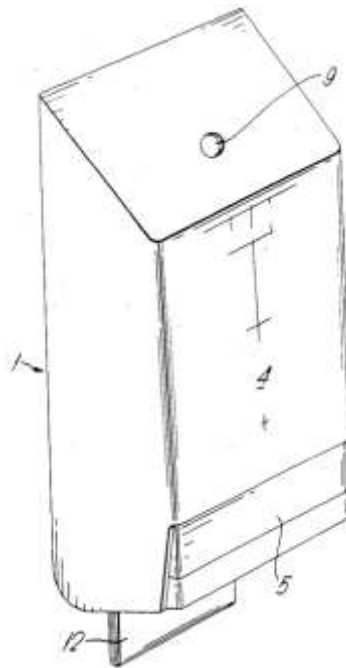


Figure 11 Patented Soap Dispenser

There are also many other patented, more complex soap dispensers, the majority of which are found in hospitals with the surgical scrubs. These devices use electromagnetic energy in the form of infrared light in order to operate, as well as just involve more of a process for the dispersal of the liquid soap. Externally, the device looks extremely simple but on the inside all the mechanisms behind its operation, from the rollers and base pad to the batteries that power the electromagnetic energy, are much more complex than the simple push-operated dispenser. Two images of this patented device are shown in Figure 12. The image on the right is the interior components of the device and the image on the left is an exterior image of the device as a whole (Albert and Thomas [4]).

The infrared light is refracted off the object placed in front of the sensor, triggering the device to begin dispensing the sanitizing fluid inside. The soap being used inside these different designs can be adapted based on the location of the dispenser. For example, different sanitizing fluid would be used for an elementary school than would be utilized in a hospital.

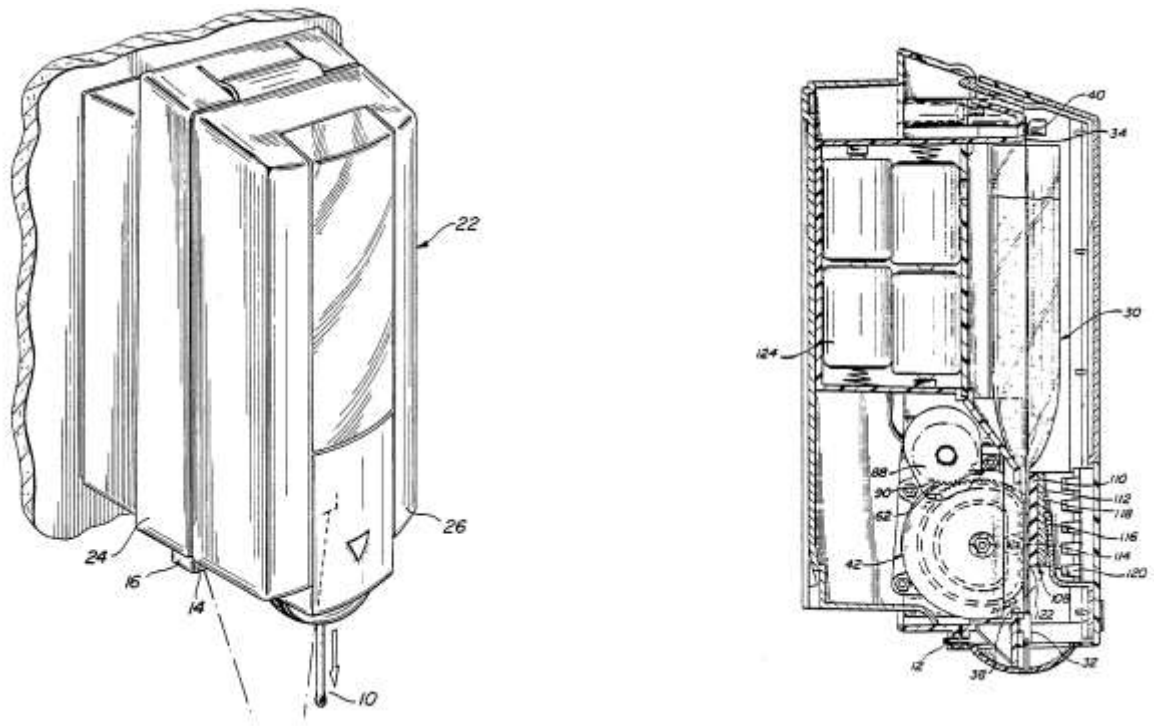


Figure 12 Patented Infrared Soap Dispenser

There is a wide variety of hand-drying mechanisms already in today's market. While some simply dispense paper towels to dry hands, others blow air on the user's hands in order to remove excess water. Many attempts have been made to improve efficiency and cleanliness of hand-drying devices, but there are still enhancements to still be made.

The most basic hand-drying mechanism is the push-operated paper towel dispenser. This has been in use for the longest period of time and is one of the most unsanitary because the user must push a lever to dispense the paper towels. This also brings waste into the equation. The user has the ability to dispense as much paper as desired, making this method of hand-drying inefficient and terrible for the environment. Illustrated in the Figure 13 below is an example of a current push-operated paper towel dispenser and its general specifications.

GP Push Paddle Roll Paper Towel Dispenser



| Product Details | |
|-------------------------|-----------------------------|
| Brand Owner | Georgia-Pacific |
| Brand | GP |
| MFG Item# | 54338 |
| Color | Translucent Smoke |
| UP - UPC | 073310543383 |
| Each Per Ship Unit | 1 Each |
| Items Per Each | 0 Each |
| Case Total | 1 Each |
| Dispenser (WxDxH) | 12.750" x 10.500" x 14.250" |
| UNSPSC | 47131701 |
| Replaces Item | 58553, 58353 |
| Buy Multiple | 1 EA |
| Case Shipping Info | |
| Case GTIN | 10073310543380 |
| Case Gross Wgt | 8.000 lbs |
| Case Net Wgt | 7.380 lbs |
| Case Dimensions (LxWxH) | 13.000" x 10.500" x 14.250" |
| Case Volume | 1.130 CFT |
| Unit Shipping Info | |
| TI-Qty/Layer | 14 |
| HI-Layers/Unit | 3 |
| Unit Qty | 42 |
| Unit Dimensions (LxWxH) | 45.500" x 40.500" x 40.880" |

Figure 13 Push Paddle Paper Towel Dispenser

While most paper products can be recycled, the towels used in hand-drying situations cannot, because of their likeliness of carrying bacteria or other contaminants associated with trash and other fecal matter. Other disadvantages include transportation of paper products, as well as producing and storing them in mass quantities. Taking these factors into consideration, it is clear that the waste produced by paper-drying products have a much greater negative effect on the environment than they are worth. Unfortunately, these are still the most commonly used hand-drying mechanism today.

Other hand-drying methods include simple air-blowers. There are hundreds of different air-drying mechanisms on the market today, some more efficient and sanitary than others. Several of these air-driers are displayed in Figure 14 below. Some of these driers are triggered by the push of a button (middle) while others are activated by motion sensors (right and left). Obviously, the push-button hand driers are becoming obsolete because the user must touch the drier to activate the fan. Any contact with the cleaning or drying apparatuses is detrimental to hand sanitization. Regardless of the triggering mechanism, all of these hand driers lack several

sanitary aspects because they simply blow the air in the bathroom onto the user's hands without cleaning or filtering it at all.



Figure 14 Types of Hot Air Hand Dryers

Another problem posed by these blow driers is their efficiency. Not only do they take an extensive amount of time to dry off the users hands, but they can also waste a significant amount of energy by running long after the user is finished. Whether pushed or sensed, these driers can run for ten to twenty seconds longer than necessary, wasting a large amount of energy that could easily be saved. Many of these hand driers require the user to stay and dry for up to thirty seconds, a significant deterrent to anyone in a rush.

In recent years, even more advancements have been made to these blow-drying methods. Dyson, a leader in air-blowing and vacuum technology, has created a more efficient, sanitary, and faster way to dry ones hands. The Dyson AirBlade utilizes Dysons patented technology in order to peel away water from the user's hands as they remove them from the unit. This device uses motion sensors to trigger operation, as well as a timer to cut off the cycle in the appropriate amount of time specified by Dyson, which is roughly about 12 seconds (Dyson [17]). The device is an extremely efficient product both in cost and energy, being up to 80% more efficient than traditional warm air hand dryers and being up to 97% more cost effective then using paper towels (Dyson [17]).

Once triggering the device to turn on, a digital motor inside starts to work and spin at about 81,000 times a minute and moves the air through a heap filter which removes 99.9% of bacteria from the air, and then proceeds to force it out of two apertures at approximately 400mph (Dyson [17]). This device also utilizes anti-microbial additives that are used in the exterior surfaces of the unit itself. Dyson was also the first hand dryer ever to be approved for the food

industry by the HACCP. An example of the AirBlade, displaying the interior components as well as exterior components can be seen in Figure 15 (Dyson [17]).

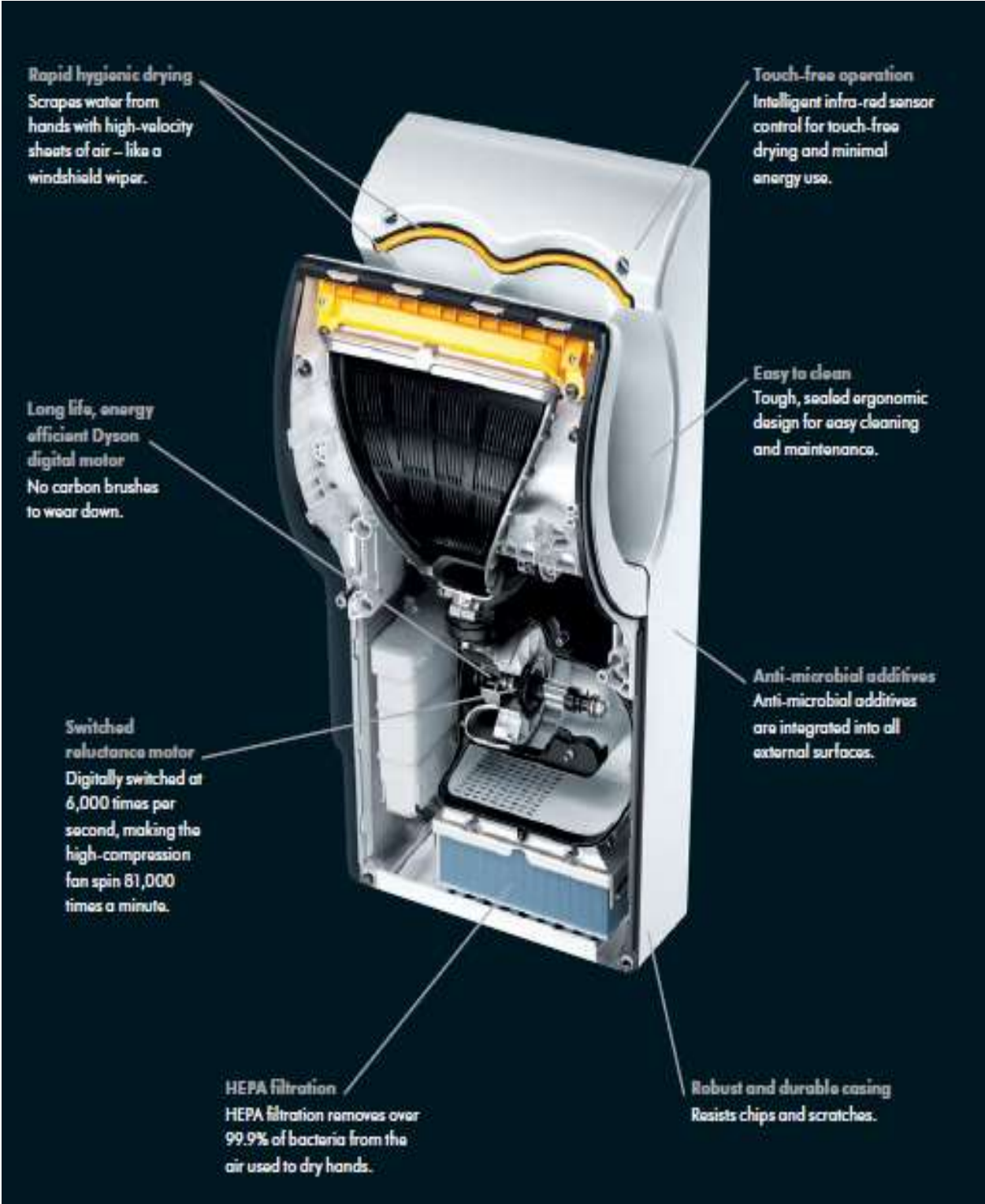


Figure 15 Dyson AirBlade

Hand sanitizer is perfect for on-the-go cleaning. When a sink and soap is unavailable, people can use this simple product to kill over ninety nine percent of germs in a matter of seconds. There are many different methods to store and dispense hand sanitizer that vary depending on the location and given situation. Although commonly used in large public places like stadiums, arenas, or parks, hand sanitizer dispensers can be adapted to fit anywhere. These are particularly important in crowded places, where diseases can be spread easily.

There are countless designs for these wall-mount sanitizer dispensers. Some distribute a liquid sanitizer while others dispense disinfectant foam. Similar to wall-mount soap dispensers, these hand sanitizing mechanisms can be triggered by simply pushing a lever or button. One of these push-operated dispensers is illustrated in Figure 16, along with some of its general specifications.


| Description | Features | Specs | Images | More In This Line | More Info | MSDS | Reviews |
|---|----------|-------|--------|-------------------|-----------|------|---------|
| <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;">  <p style="margin-top: 5px;">02211 - Foaming Hand Sanitizer Dispenser</p> </div> <div style="width: 65%;"> <p>Foaming Hand Sanitizer Wall Dispenser</p> <ul style="list-style-type: none"> ● Wall mounted design allows easy access and frees counter space ● Pump dispenses anti-bacterial foam hand sanitizer at the push of the dispenser bar ● Holds 1 liter containers of foaming hand sanitizer ● Manufactured of ABS plastic in white ● Dispenser dimensions are 9.5" x 5" x 4" (HxWxD) ● Integrated key and lock allows the user to stock product easily ● Features a one year warranty ● Proudly Made In USA <p>02110 Foaming Hand Sanitizer</p> <ul style="list-style-type: none"> ● Kills 99.9 percent of common germs in 30 seconds ● Effective against E. coli, salmonella, staph, and strep and C. difficile bacteria ● Foaming hand sanitizers yield approximately 3-4 times more applications than gels ● Alcohol-free ● Aloe vera to prevent drying out of hands ● Available in single 1 liter bottle or case of 6 <p>02201 Alcohol Foaming Hand Sanitizer</p> <ul style="list-style-type: none"> ● Kills 99.9 percent of common germs in 15 seconds ● Hypoallergenic formula to minimize risk of allergic reactions ● Quick-drying alcohol based formula ● Built-in skin conditioners ● Available in single 1 liter bottle or case of 6 </div> </div> | | | | | | | |

Figure 16 Foaming Hand Sanitizer Dispenser

Some more advanced sanitizer dispensers have been adapted to become non-touch, just like the motion sensor soap distributing apparatuses. Once again, the motion sensor further prevents the spread of germs and other bacteria because the user does not need to touch the machine in order to extrude sanitizer. An example of a motion-sensor sanitizer distributor is

illustrated in Figure 17. Generally, these mechanisms are more expensive than the push-operated ones because they require electrical components to compliment the mechanical aspects of the machine.



Figure 17 Motion Sensing Hand Sanitizer Dispenser

Overall, these wall mount sanitizer dispensers are simple to use and maintain. Generally, they can be obtained at a relatively low price and are easy to refill. These characteristics make hand sanitizer dispensers a popular means of disinfecting ones hands.

Figure 18 portrays a UV-C germicidal wand. This wand is used to help eliminate bacteria and germs in many different environments. The wand uses UV-C light to breakdown germs and bacteria at their molecular level by breaking down their DNA, therefore rendering them unable to reproduce. This particular device allows the user to sterilize areas such as countertops, doorknobs, and other heavy traffic areas where contact is necessary. The wand can be run via battery pack and contains a UV-C light bulb that is enclosed on the top side, protecting the user from the light's radiation. This allows it to be a portable bacteria destroyer with increased functionality (Lyon [29]).

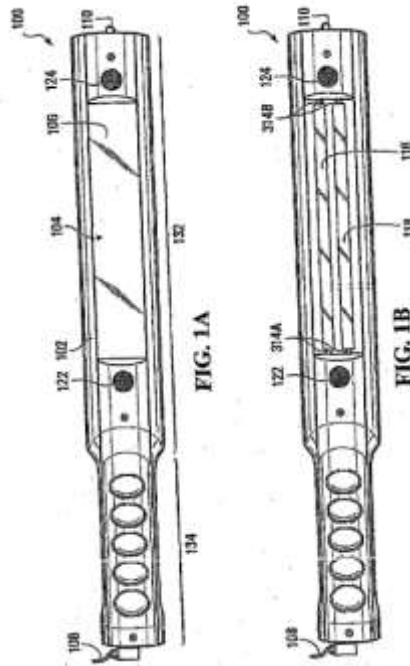
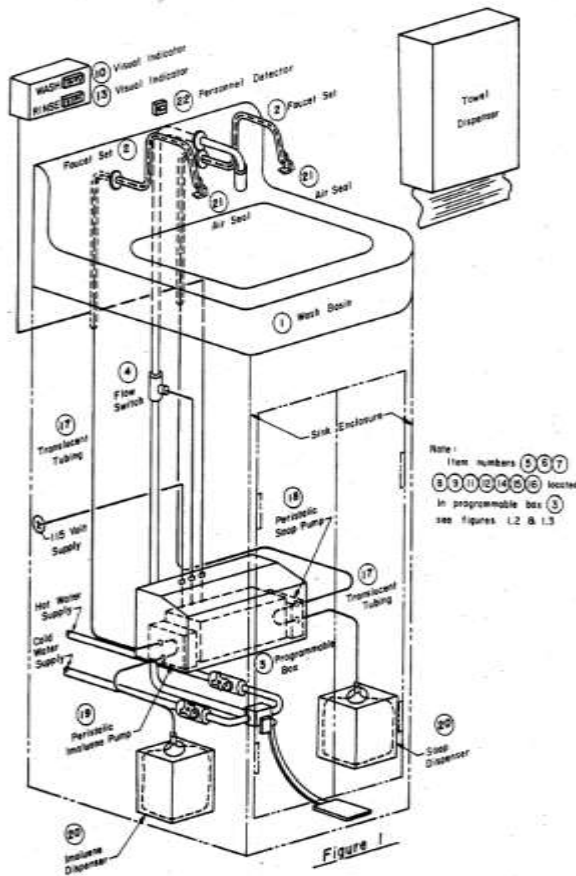


Figure 18 UV-C Wand

2.1.3 Patents and Potential Resource Management Techniques

Many engineering innovations are discovered and designed off previously existing products. In this section, previously existing hand-washing apparatuses are observed and discussed. Different aspects of these existing designs can be incorporated into the All-In-One Hand-Washing Station.

Figure 19 illustrates a slightly altered version of a traditional sink-drier combination. This product is specifically designed with visual and audio aids to alert the user when they have properly completed the hand washing and drying processes. This is a product that could be used in a restaurant setting, alerting the employees when they have appropriately completed their hand sanitization. Another important aspect of this design is its automatic functions, preventing the user from having to touch the machine to begin or end washing. This prevents obvious spread of bacteria (Davies [13]).



Equipment List

- 1 Wash Basin
- 2 Faucet Set
- 3 Programmable Control Box
- 4 Flow Switch (normally open)
- 5 Line Fuse (120VAC)
- 6 Step-down Transformer (120-24VAC)
- 7 Voltage Switch
- 8 Programmable, two-cycle repeating timer (adjustable)
- 9 Wash Timer (timed open timer, adjustable)
- 10 Visual Indicator "Wash" Cycle
- 11 Soap Timer (timed open timer, adjustable) optional
- 12 Rinse Timer (timed open timer, adjustable)
- 13 Visual Indicator "Rinse" Cycle
- 14 Reset Timer (timed closed timer, adjustable)
- 15 Audible (Buzzer) Indicator
- 16 Imolue Timer (timed closed timer, adjustable) optional
- 17 Translucent Tubing (disposable type)
- 18 Soap Pump (optional)
- 19 Imolue Pump (optional)
- 20 Soap, Imolue Dispenser (disposable type)
- 21 Air Seal (disposable type)
- 22 Personnel Detector (by customer)
- 23 Buzzer Timer (timed open timer, adjustable)
- 24 Master Relay
- 8A Nand Gate (Multiple)

Figure 19 Patented Modified Sink

Figure 20 depicts another fully automated hand washing and drying device. This design would be more suitable in hospitals, laboratories, or other medical facilities. By dispensing a cleaning solution on the user's hands, spraying water to rinse, and finally air drying the user's hands, this mechanism can do all three required sanitation steps.

This device is significant to the group's needs because it incorporates all aspects of washing and drying without requiring the user to touch anything. This machine can be used for a myriad of different applications because of its adaptability. It is also in compliance with legal and social standards in terms of cleanliness. The enclosed design prevents any spillage of water or sanitizing agent, reducing health risks. Although designed for medical facilities, this design could be easily adapted to fit into a plethora of places, including schools, restrooms, malls, or restaurants (Chardack, [10]).

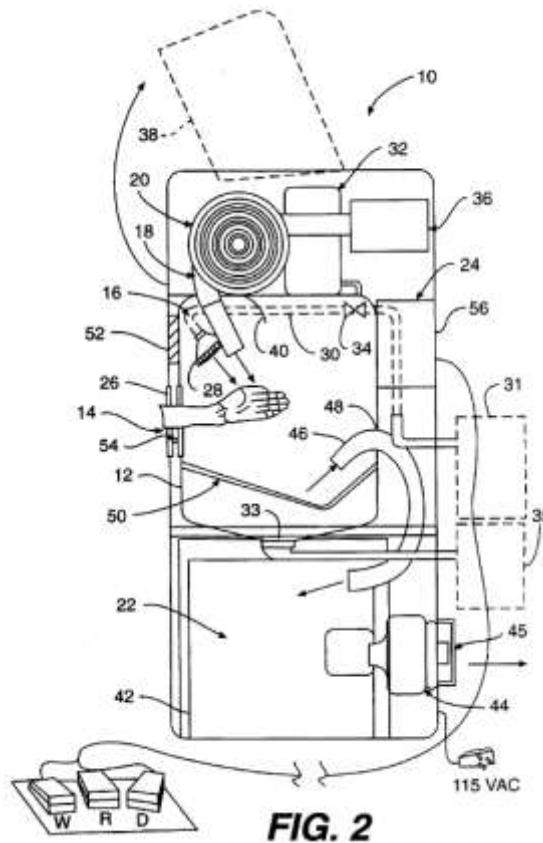


Figure 20 Patented Hand Washing System

The following design, shown in Figure 21, is similar to the one illustrated in Figure 20. They share common functions in that they both clean and dry one's hands without the user having to touch the machine to activate cleaning. This device involves multiple ports for water, air, and sanitizing solution, which are injected above a basin where the user would insert their hands. A motion sensor is location inside the machine in order to detect when the user has inserted their hands. It also utilizes a timing system to control how long each step of the sanitization process will take, preventing time from being wasted. Although this mechanism is not as adaptable as the previously discussed apparatus, it is smaller and therefore can be used in a different range of applications (Stanley E. Flowers, [39]).

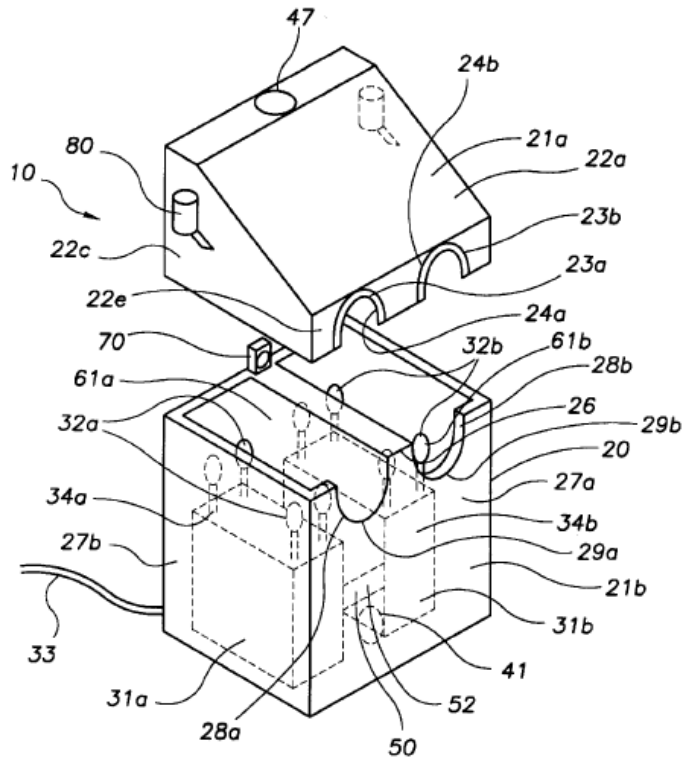


Figure 21 Patented Hand Washing Station

A more electrically involved design is illustrated in Figure 21. Here, a wall mounted cabinet, proximity sensor, and extensive processing circuitry is used to control the sanitization and drying of the user's hands. The cabinet's purpose is to house the soap dispenser and water lines while protecting the electrical components from being ruined by water or sanitizing liquid. What makes this apparatus unique is its ability to keep track of hand washing counts and times, and allowing the statistics to be downloaded for analysis. This component of the machine is interesting because it gives the owner the ability to study hand washing habits. This data could potentially be used to monitor whether or not employees are washing their hands, and if implemented, could improve the overall cleanliness and health of the general population because it would force people to wash their hands for fear of being caught (Foster, [20]).

An important factor in hand sanitation is the use of water itself. Millions of gallons of water are constantly being used for sanitization purposes. In order for hand sanitization to be possible, the water itself must be clean. If the filtration techniques used to clean water used in sinks and other water-dispensing apparatuses could be harnessed to recycle the water being used to rinse one's hands, the positive effect on the environment would be enormous.

Figure 22 depicts a common household water filtration device. The design incorporates nine different filter elements to clean and purify the water being dispensed. These elements range from course filter fabrics that trap large debris to much finer filters capable of trapping tiny particles. Carbon is then used to remove further impurities. This concept provides an opportunity to recycle water being used in an All-In-One Hand Washing Station, reducing and potentially preventing the need for a plumbing hook-up (Thellmann, [41]).

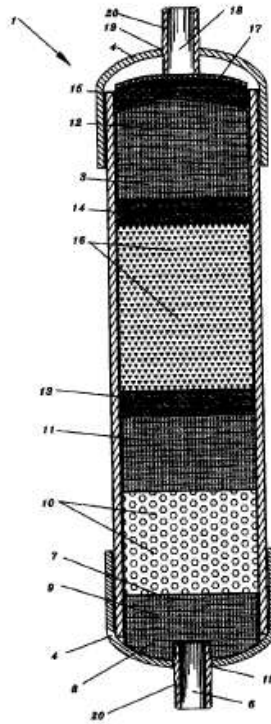


Figure 22 Water Filter Patent

Other water filtration devices include FiberFlo Hollow Fiber Cartridge Filters and Capsule Filters depicted in Figure 23. This technology is currently being implemented by MarCor Purification, a medical device company specifically geared towards water filtration for medical purposes. Because these filters are used in medical applications, their efficiency and sanitization capabilities are held to the highest of standards (MarCor, [31]).



FiberFlo Hollow Fiber Cartridge Filters
Proven technology for bacteria, endotoxin and particle control.



FiberFlo Hollow Fiber Cartridge Filters
Proven technology for bacteria, endotoxin and particle control.

Figure 23 FiberFlo Water Filter

“The unique membrane structure of FiberFlo HF Filters provides consistent and verifiable pyrogen removal that surpasses traditional, absolute-rated membrane filters. High-level endotoxin, bacteria, and spore removal make these point-of-use filters ideal for a variety of water purification or process fluid applications. This most advanced of filtration technologies also provide high flows with high filter efficiency for savings in system design.”

The design shown in Figure 24 is used in automated car washers in order to filter and reuse the water that drains into the trenches following every car wash. If built on a much smaller scale, this design could be incorporated into a wall-mounted hand washer in order to reuse the water that drains post-sanitization.

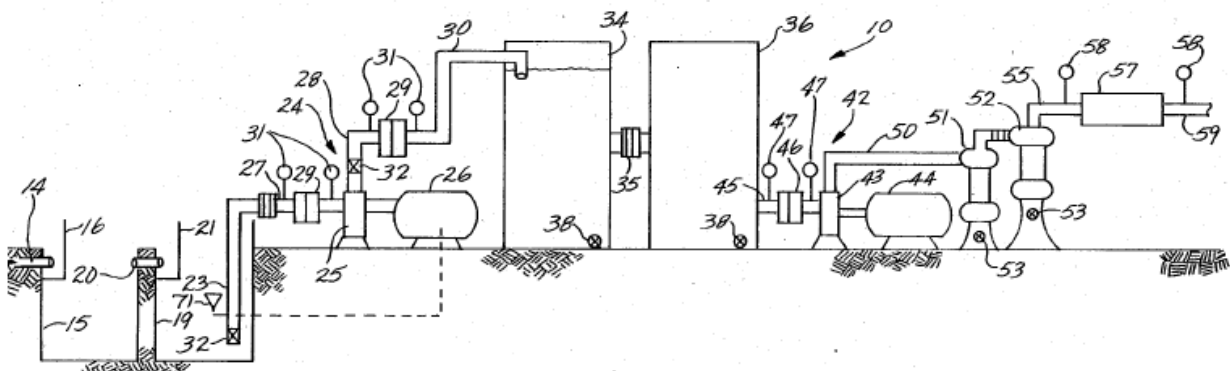


Figure 24 Car Wash Filtration System

Trench drains are incorporated in this design to collect the already used water for filtration. Following collection, the water continues through a process of coarse and fine strainers to remove debris and other contaminants. These finer filtration techniques include centrifugal separators. This design is relevant because it is made to filter out soap and other cleaning products so the water can be reintroduced to the system, similar to a hand sanitization station.

2.2 Extended Research

This section discusses current patents related to hand-washing systems. These designs are ones the group plans to utilize in the final prototype. Different aspects of each of these patents are crucial components of the final All-In-One Hand-Washing station model. The ability of the group to identify the functionality seen in each of the patents that follows was crucial for the success of the design that would be implemented. The group was able to look at these designs from both the consumer's aspect and the design engineers' aspect and brainstorm ideas based on our findings. Through this process the group was able to determine key features that inspired further design work to improve in our own design as well as features to clearly avoid.

2.2.1 Patents

The automated hand wash machine is a patented machine that has features which apply to our project. The device exists in order to create an automated hand-washing solution to ensure consistency and simplicity in the hand-washing process. The device draws on the fact that individuals may not always wash their hands in a consistent and sanitary manner. The device, therefore, is completely automated and requires no physical contact between the user and the device.

This device surpasses the scope of our original designs by evaluating the needs for different soaps and solutions to deal with various occupational hazards, such as the different needs of doctors, chefs, food servers, and other such positions.

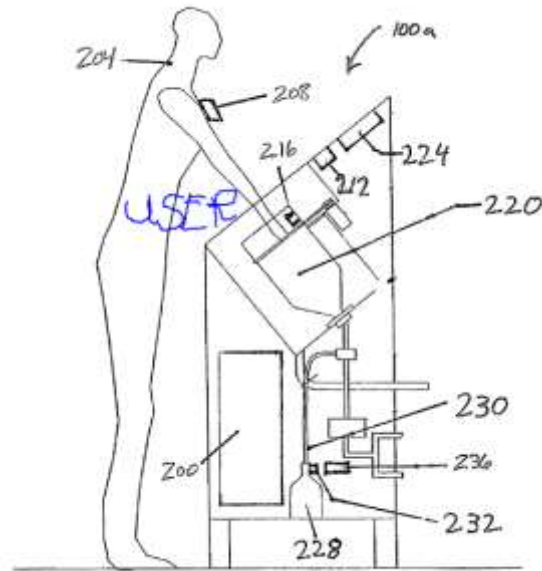


Figure 25 Automated Hand Wash Machine, (Barnhill, [8])

As we can see in Figure 25, the device is quite large and requires the users to keep their hands extended and down at an angle. This seems like it may be less-than-optimal for children or shorter individuals to utilize.

The target audience of this device is clearly in industrial and service-related industries. The bulk and height limitations of the device do not cater well to universal or even widespread adoption. This fact was accepted by the developers during their conceptualization, and that is evident because of their integration of compliance verification.

In many places where sanitation is government mandated, employers require their employees to wash their hands after use with a sign and some pre-employment training. This device was designed with a feature to enforce this policy of mandatory hand-washing. These systems can be linked to an administrative server in order to monitor the employee usage of the stations. The prototype described by this patent is simply connected to an RFID scanner, and an RFID is implanted in a bracelet or as keycard that the employee must wear at all times. The RFID scanner in the machine can then tell that an employee has successfully washed their hands. Another RFID scanner at the entry can be used to cross-check employee entries with hand-

washing, which can essentially ensure that each time the employee used the restroom; they also washed their hands in an appropriate manner.

CLEANING STATION-USE RECORD 336

| EMPLOYEE NAME | TIME STAMP | DURATION | DATE | COMPLIANCE |
|----------------|---------------|----------|-----------|------------|
| Janet Smith | 08:00:00 a.m. | 10 secs | 5/21/2006 | Y |
| Bill Powers | 09:00:23 a.m. | 5 secs | 5/21/2006 | N |
| Jason Williams | 10:07:40 a.m. | 12 secs | 5/21/2006 | Y |
| Judy Jones | 11:10:05 a.m. | 11 secs | 5/21/2006 | Y |
| Sandra Collins | 11:20:31 a.m. | 6 secs | 5/21/2006 | N |

Figure 26 Example Use Record

COMPLIANCE REPORT 640

| EMPLOYEE NAME | TIME | DATE | LOCATION | FULL CYCLE |
|----------------|------------|-----------|----------|------------|
| Janet Smith | 8:00 a.m. | 5/21/2006 | A | Y |
| Bill Powers | 9:00 a.m. | 5/21/2006 | A | N |
| Bill Forbes | 10:00 a.m. | 5/21/2006 | C | N |
| Jason Williams | 10:07 a.m. | 5/21/2006 | A | Y |
| Jane Givens | 10:30 a.m. | 5/21/2006 | D | N |
| Judy Jones | 11:10 a.m. | 5/21/2006 | A | Y |
| Sandra Collins | 11:20 a.m. | 5/21/2006 | A | Y |

Figure 27 Example Compliance Report

Above we can see some of the possible methods for data to be stored and displayed by an administrative server. The device would be able to store different data points and each unique RFID could be given to a single individual. His design is a prototype, and the patent's creator explained that they expected to pair the RFID with a video camera to ensure that the RFID tag has not been put on the wrong employee, thereby confirming compliance. The recording, RFID

data, and time would all be recorded and archived thereby allowing for batch checking of employee compliance. The RFID scanner will also check the soap containers to ensure that they are the proper detergents for the application at hand.

In all, this machine sacrifices sizing concerns in order to integrate government-mandated hand-washing standards into a functional and consistent unit for commercial uses. The other major issue is that the device only senses when an employee uses the station but does not complete a full cycle. If an employee does not use the station their presence is not recorded and the compliance tracking is therefore invalidated. This is a major design flaw. The device is helpful for understanding what markets are saturated and what particular design features we will need to focus on in order to differentiate our product.

The automated appendage cleaning apparatus with brush is another example of current patent. This device also focuses on hand cleaning. Due to the nature of non-automated processes, the efficacy of manual hand-washing is inconsistent at best. Thus the need for automated hand-washing systems is clearly established. Like most touch-free systems, this device strives to automate the entire hand-washing process into a simple task that only requires the user to place their hands in the proper place, and the device promises to do the actual cleansing for them. This system focuses not only on cleanliness of the hands on a microbial level, but it also strives to remove debris such as dirt and grime with a brush.

The system here introduces a potential issue: if the user touches anything inside the device it is no longer sterile. This is especially problematic on a portion that has a lot of surface area and that directly touches the skin. The brushing portion directly matches the previous description and thus causes the need for disinfectants to be used. RFIDs are also employed here to ensure that the brushes are replaced when they are no longer considered sanitary. The brushes are cylindrical so that the mechanics can be simplified.

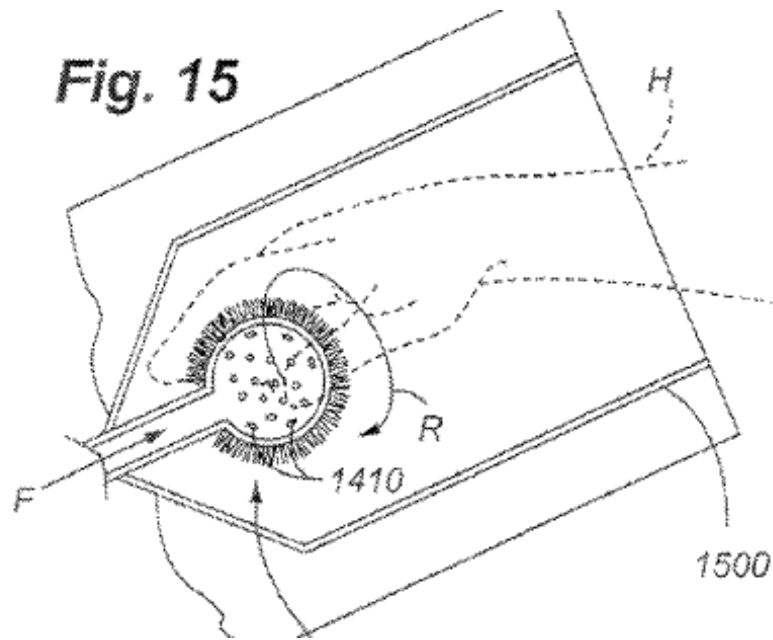


Figure 28 Patented Hand Scrubbing Device, (Barnhill, [7])

The user is supposed to move their hand in order to scrub all possible areas where debris has collected. In Figure 29 we see an image of the entire apparatus as it would look in real life.

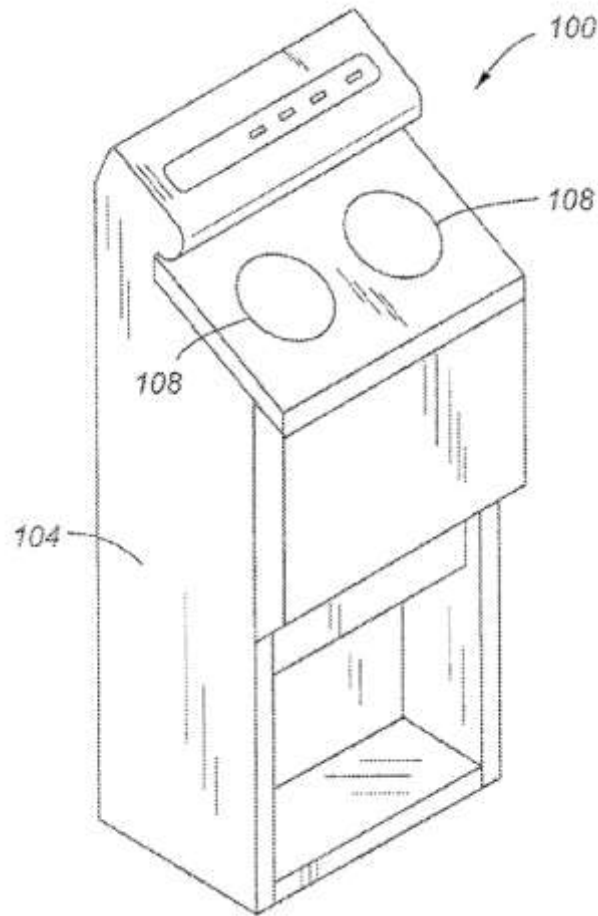


Figure 29 Hand Scrubbing Device Exterior View

As can be observed, this device is slightly less bulky than the previous one. This is a definite improvement, because bulk in these devices is something that should be avoided in order to ensure that they can be installed into existing settings.

Inside of the device is a cylinder for each hand with a brush at the ends, as well as abrasive pads and nozzles for soap, water, and disinfectants. The patent suggests that the cylinders may be fixed, and the nozzles, pads, and brushes may move, or that the entire cylinder could move and all the aforementioned components, being affixed to the cylinder, would move thusly.

The device would also include an RFID sensor for brush replacement as well as compliance verification. Below is a compliance report that uses unique RFIDs to identify what

employee used the device, when, which specific device, and if they complied with cleanliness regulations. Beside the compliance report is a brush replacement record, which allows the machine's owner to ensure that the device is operating as well as it is supposed to. If the brushes wear out, the device's efficacy drops substantially, because the brushed will not remove as much debris and may harbor microbes.

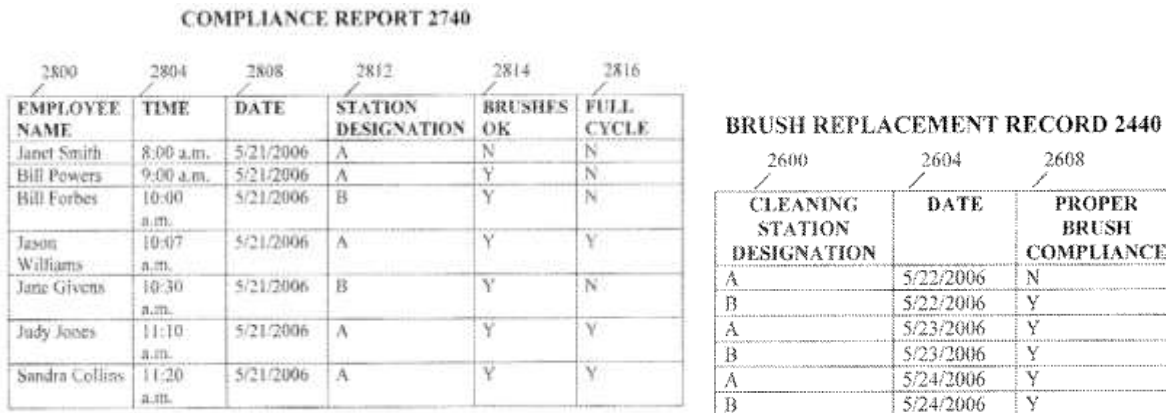


Figure 30 RFID Compliance Reports

In general, this device focuses on removal of grime above all other possible design foci. Although the cleaning solutions used may keep the device fairly clean, it is unlikely that the same level of sterility will be maintained in a system that touches the user compared to one that does not. This machine includes a lot of functional points that make it a good all-around choice, but it's large size and need for brush replacement are both hindrances in gaining acceptance in pre-existing locations. It is interesting to note the stress placed on RFID as a way to ensure that all devices are in working order as well as ensuring compliance.

The dispenser with palm reader device is a soap dispenser with the added ability of reading user biometrics. Just like the other devices that are being implemented in commercial applications to ensure employee compliance to regulations on sanitation. This device was created to counter individuals that trick machinery into recording their hand washing without actually washing their hands. These other dispensers record what users have utilized the machinery and when, but they do little to guarantee that the user has actually cleaned their hands in a satisfactory manner. They have different methods to confirm the ID of the user, including key card swipe systems and key code operated systems as well as fingerprint readers.

Aside from the fingerprint operated models, all these devices are prone to fraud. The fingerprint readers and key code bases systems bring the risk of cross-contamination because the users have to touch the device. The card readers are problematic because the user must have a card on them to operate the system. In many of these systems, the user can simply confirm their ID and then remove their hands and let the soap spill, but the records will indicate their compliance with hand washing mandates.

This specific dispenser uses a touch-free method for confirming user identities that is known as palm vein identification. This method is based on the fact that no two people have identical vein structures in their palms, and that these vein structures can be used in much the same way as a fingerprint. An infrared sensor is shined on the palm and the light passes through the veins differently than the rest of the flesh thereby producing an image that a sensor records and cross-checks with an employee database to ensure compliance. A simplified diagram of the veins in the hand can be seen in Figure 31:



Figure 31 Illustration of Unique Patterns on Palms, (Ophardt, [33])

In addition, this dispenser uses infrared thermometers to measure the user's temperature without actually touching the user. This is useful for determining the health of the user, as an elevated temperature would indicate a fever caused by some type of disease. This data can be used to separate healthy and sick individuals to prevent the spread of disease.

There is also a simple distance sensor that ensures that the hand is in a location that is suitable for scanning and soap dispensation. The sensor also triggers the thermometer and the palm vein reader systems to run, which ensures that they do not run all the time or try to poll for information when the hand is not close enough, which could cause functional errors. There is an image of the IR distance sensor below:

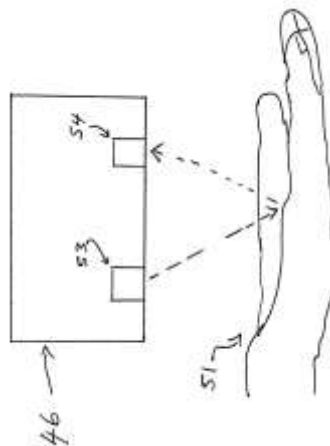


Figure 32 Schematic of Sensors Reading Palm

If the IR emitter is on and the hand is close enough, a certain amount of light will bounce back to the IR sensor and cause the device to begin polling for temperature and palm vein information. This ensures proper functionality and reduces the potential for mistakes.

Figure 33 depicts a diagram of the invention in question. The user simply places their hand in the correct location and the device identifies the user with the palm vein identification method, collects their temperature reading, and dispenses soap onto the hand. The device is very compact, and fits a similar form factor to modern soap dispensers that can be seen in the bathrooms of many businesses.

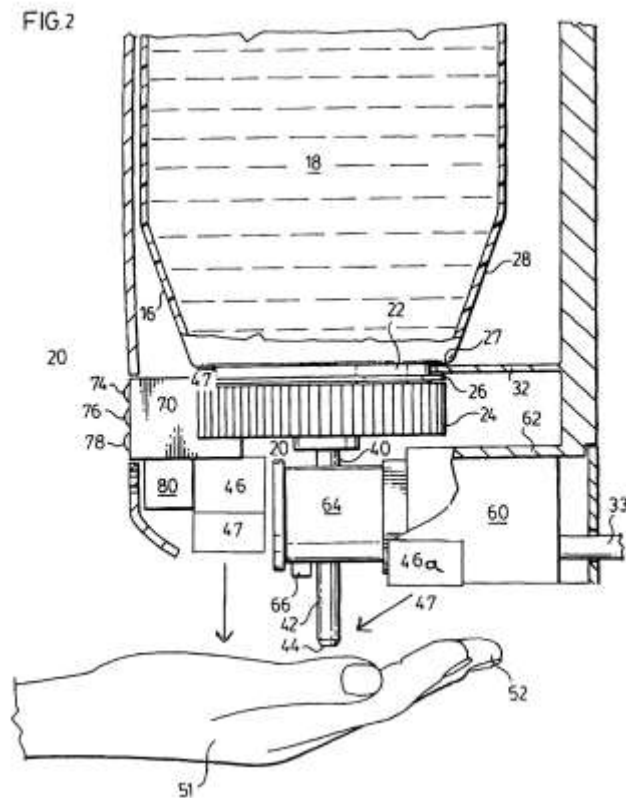


Figure 33 Palm Reading Dispenser Patent (Ophardt, [33])

This device is a great soap dispenser, but it lacks a lot of the functionality of the automated hand washers. It does not guarantee that the individual will wash their hands in an

adequate or reproducible way. The fact that it does not do these things will make the device less expensive, which was more likely taken to be a more important design feature than consistency.

The portable hand cleaner device is meant to be a hand washing device that can be installed in locations where there may not be easy access to water or electricity, as well as in applications where the device would need to be mobile. This device must, therefore, focus on efficiently using resources. Like all the other devices, the user just places their hands in the device and the procedure begins. The device works by sensing a user's hands and then beginning to spray them down with a cleaning solution that is stored inside the actual unit:

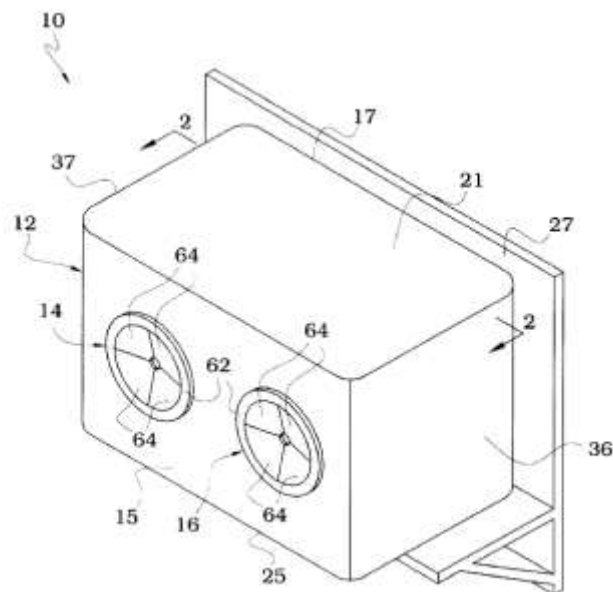


Figure 34 Portable Hand Cleaner Patent (Bargenquast, [6])

Figure 34 is a simple schematic of the outside of the device. It is small, as the two holes on the front are approximately the same diameter as the width of an adult's hand. The device has flaps (64) that are flexible in nature and that exist to isolate the hands and prevent splashing over. This is an interesting choice, because it also increases the user's exposure to contaminated surfaces. The material is not antimicrobial, so diseases can be transferred from the actual flaps. This could be mitigated by using an antimicrobial material or some type of sterilization technique like a UV flash, but that is not contained in this patents.

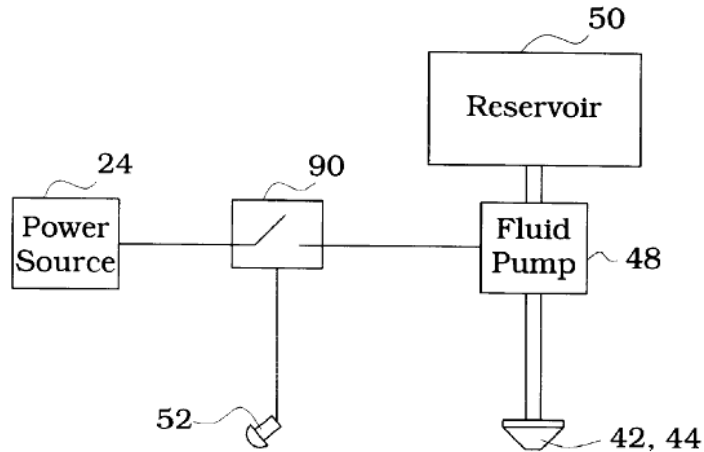


Figure 35 Schematic of Patent

In Figure 35 we see a simple schematic of the device. The power source can be a renewable source such as a battery with a solar cell, or more conventional wall power. The power then goes through a switch, which could be manually actuated or motion sensitive/touch free, as the optional part labeled 52 demonstrates. This switch activates a fluid pump which pushes a cleaning solution from the reservoir and into the nozzles, labeled 42 and 44 on this diagram. In all the functionality is rather simple.

This device is extremely simple in nature. It does not seek to perfect hand-washing, but only to allow users to maintain hygiene in situations and locations where that is not a typical option. This device is more similar in nature to our device, which is more focused on public use than on enforcing regulated practices in commercial applications. This device is a bit oversimplified though and could be improved. Its small size and versatility have been stressed in design over proper hand-washing techniques and this may be a key point for our device to differentiate from those that are currently on the market.

Many Business owners require their employees to wash their hands regularly to prevent the spread of harmful bacteria. This patent, monitoring device, depicted in Figure 36, is a great application for this. A way to monitor the use of hand washing stations would allow for a more sanitary and well controlled working environment. With the use of a simple sensor built into a

bracelet or watch would allow for this monitoring to occur. The business owner could install a sensor at the bathroom door that recorded when a user entered the restroom. This sensor could resemble one seen when entering most department stores that track when people try to steal items. The owner could then install a device like the one below seen installed above a sink. This would then force the user to register that they are washing their hands before leaving the bathroom and passing through the first sensor again. If the user was forced to enter their hands into a device like the one seen in the figure below before they could access the soap solution or even sink located within the bathroom. People could then better regulate when an employee washed their hands and could keep a more sanitary working environment.

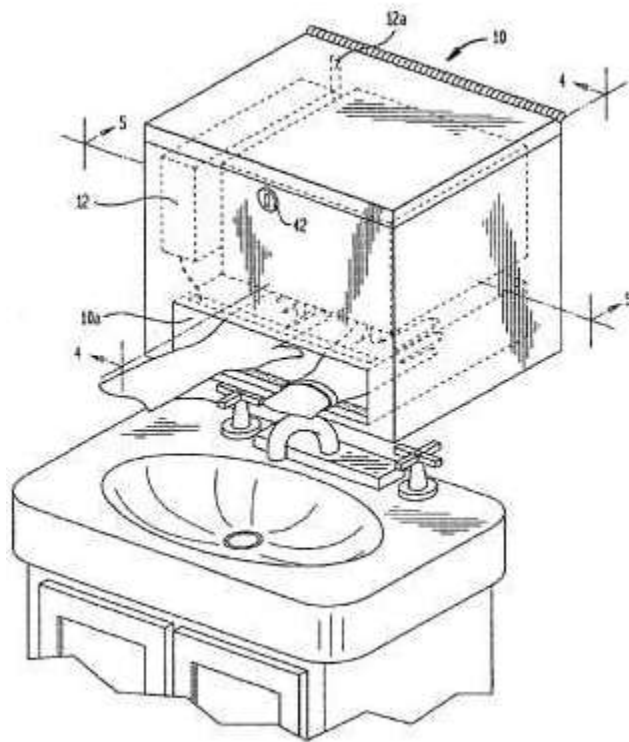


Figure 36 Monitoring Device Patent (Lewis et al., [1])

Figure 36 begins to encompass several aspects of the idea behind the All-In-One Hand-Washing station. First, the user can wash their hands in a sink. Then, without having to walk anywhere, the user can simply insert their hands into a box-like hand-drying system. This idea is specifically important because this prevents water from dripping all over the floor while the

person walks from the sink to the hand-drying apparatus. One flaw in this system is that the water still might be able to escape the hand-drying housing a leak all over the sink.

A way to wash and dry ones hands while not needing to move around or touch anything is a very achievable goal. The device seen below, the hand washing station patent, brings the washing and drying together into one device but requires an input on a keypad to select what you are trying to do i.e. does the user only want to wash? Does the user only want to dry? Or does the user want to do everything?

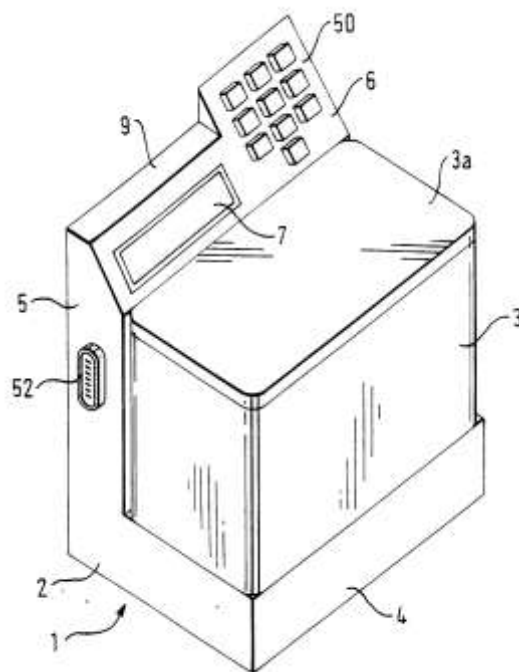


Figure 37 Hand Washing Station Patent (Foster, [20])

The device seen above can be located on almost any wall that would allow for a power supply, a water supply, and a drain hook up. It allows the user to input what wash they want and then waits until the user inserts their hands into the device. The device then recognizes the user is in the ready position by using an infrared sensor. This then tells the pump to spray a soap solution to have the user wash and then water solution onto the user's hands to rinse. Once the rinse cycle had been completed the system would then start a drying cycle which would dry the user's hands before they were removed from the device. Some problems could occur while using this device. One problem could be that the IR sensor gets dirty or blocked somehow and cannot

tell that the user is ready to have their hands washed. Another problem is that the machine is not totally hands free so prior to the hand washing, users could spread more germs onto the device which could then mean the spread of germs to other users by means of these hard surfaces.

2.3 Applications towards Design Goals

After reviewing the work completed by the IQP team as well as conducting further research on current patents, the group was able to gain a better understanding for the need for the device which greatly increased the design aspect. With ideas on how to modify or incorporate current technology into a new packaging, the group was then able to develop several design iterations for potential prototypes that could be used to test the functionality of all components and steps involved in the hand washing process for a single unit.

There are several different applications that the prototype design can be adapted to fulfill. The model the group created will be designed to fit commercial purposes. This model can be placed over a household or public restroom sink. The perks of this new design include reduced hand-washing time, a fully enclosed system, no-touch use, and space-saving potential. With the completely enclosed sanitization system, no water will be able to leak out, allowing for cleaner bathrooms. Another important aspect of the model is the reduction of material waste. Not only has paper been completely eliminated from the hand-washing process, but the other components will also be limited as the unit is set on a timer and will be able to control the distribution of the water and soap. Other potential applications include medical, food, commercial, and even public schools. The type of sanitary solution used in the system could be easily changed out with hospital-grade cleaning solution. An RFID could be added into the system in order to register if employees working in restaurants have properly washed their hands after using the lavatory. Finally, this unit could be placed in large commercial areas like shopping malls or professional sports stadiums in order to encourage hand-washing and reduce lavatory traffic.

CHAPTER 3 – DESIGN OF THE SYSTEM

3. Introduction

According to the previous research conducted by the IQP group and the extended research the MQP group conducted on this subject, hand washing is by far the most effective method used to stop the spread of germs (Brassard, et al, [9]). However, the challenge behind this is to get society to listen and follow the suggested and tested standards for this process. In order for society to comply with these standards we need a way to make it easier for them to follow. So, what better way to accomplish this than to have a system that will do up to 100% of the work for you and in a third of the time!

The design goal of the system is to not only improve the rate at which hand sanitation can be achieved, but to also make it substantially easier and with improved benefits over current methods. The goal was to drop the current rate from the 45 seconds to 1 minute mark down to 15 to 20 seconds, while making the process touch-free. The ideal system is designed to run thusly; user inserts hands into opening on housing which triggers motion sensors to start the process, the first response signals the soap sprayer to start spraying and also triggers a linear actuator to move the sprayer from the wrist to the finger tips, upon finishing this phase the system allows for a 2-3 second delay allowing the user to scrub their hands and remove any set in grime.

During this delay the sprayer assembly is returned to the start and upon return triggers the next phase to start, which starts the water spraying at the wrist and again like before moves from the wrist down to the finger tips, and in both cases has sprayers above and below the hands spraying. Upon shut off of water phase, the air dryer, located at the entrance/exit of the system, starts up and triggers the user to slowly begin to remove their hands from the system thus scraping the water off with high powered air streams. A good analogy of this process, which actually sparked the main idea behind the development of this system, is the touch-free car washes that are fully automated and run in a very similar manner as this system.

The optimal design for the system not only speeds up the hand washing process but is also far more sanitary due to the touch free nature, and much more environmentally friendly due to the reduced use of water, and reduced use of energy, along with no paper towel trash. Not

only does this improve the quality of hand washing but also increases the cleanliness and organization of the restrooms they are placed in. This is primarily due to all steps being housed in a single unit, as well as increasing the turnover rate at which users will be able to enter and exit the restroom.

The objectives of the systems design and operation are as follows:

- Maintain same level of cleanliness post wash and dry cycle as current method if not increased
- Increase cleanliness and organization of the restroom
- Reduce the time necessary for the process by a third of the current time
- Environmentally friendly
- SAFE
- Appropriate for all users
- Maintain similar cost to current methods, if not cheaper
- Easy, touch-free operation
- Easily maintainable
- Allow for use from all hand sizes
- Easily replaces current sinks
- Durable and long lasting
- High volume capability

The constraints or restrictions within this particular system that must be followed are as follows:

- SAFE for all users
- High volume capacity
- Easy to use (minimal user interaction)
- Sustainable
- Budget friendly
- Complete cycle in a third of the current time

The flow chart seen in Figure 38 shows a basic interpretation of both the activity of the washing system and the user interface over the course of one complete cycle. The chart shows what different components interact with as well as when they start their interactions:

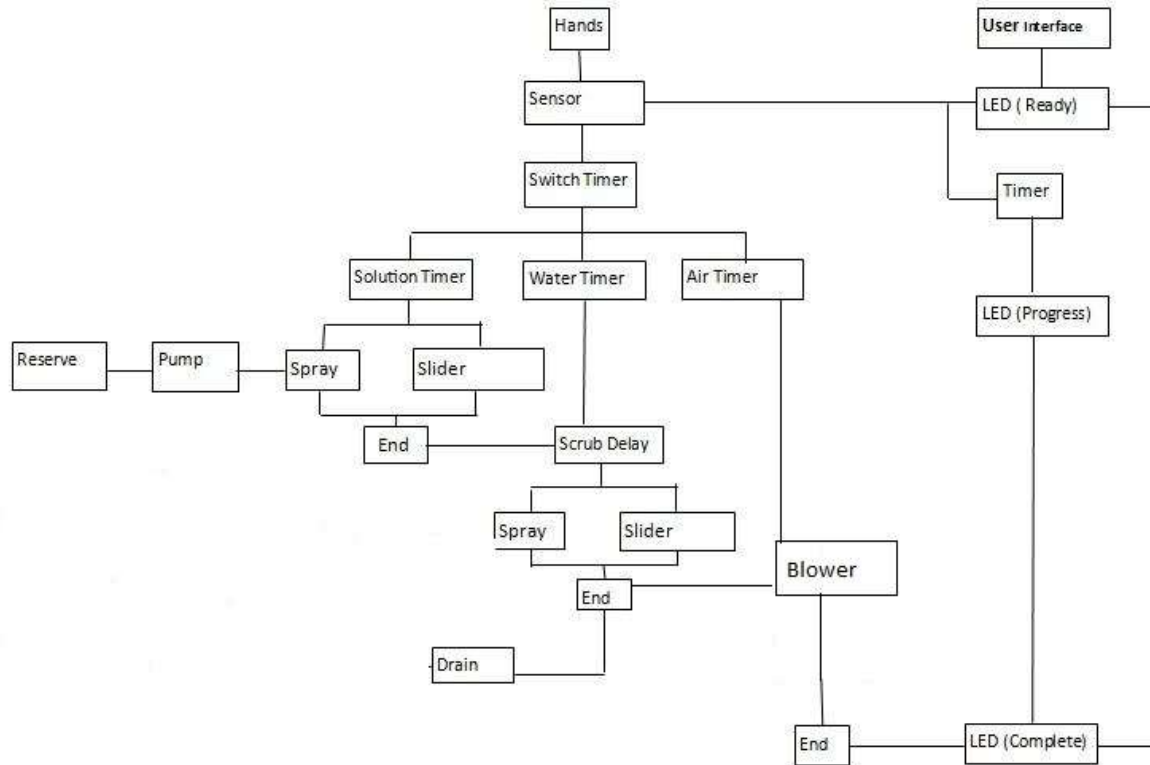


Figure 38 System Flow Chart

Further details of the system and its operation will follow throughout the course of the chapter. This basic flow chart was the basis for both the prototype design and the group's ideal design.

Considering the fact that the MQP group decided to follow the majority of the objectives and constraints laid out by the initial IQP group, the model drawings from SolidWorks were updated from the chosen method the IQP group decided upon. The updates that were made to the design were two fold based upon the added objectives and constraints by our MQP group. The first and most major modifications were made to adjust the system from a standalone model that would be placed on a wall to a model that could be inserted into the place of a current sink. Additional modifications included changing up materials and components to allow for increased

performance and ease of manufacturing. The final design that the IQP group chose can be seen in Figure 39.

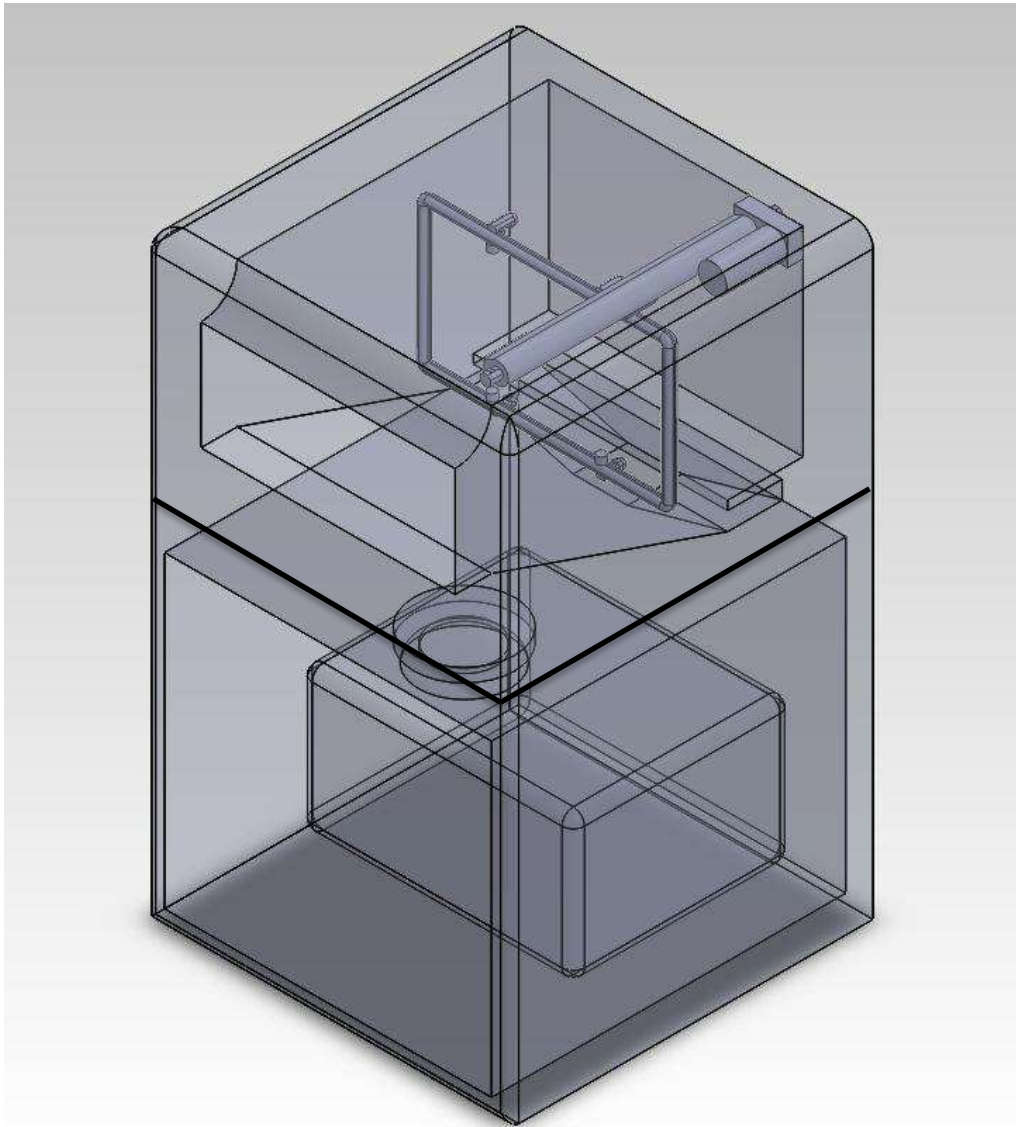


Figure 39 IQP Final Design

The modifications that the group made right off the start included the removal of the lower half, at the line division seen in figure 39, and only keeping the upper half of the model. From there we replaced the sloped drain with a standard restroom sink and drain configuration, thus making it much easier to replace and or incorporate into a current sink or current sink location. From there we expanded on the model which will be shown in the following section, both for the prototype and the ideal model, which varied primarily with material choice.

3.1 Prototype

In this section the group describes the designs of both the mechanical and electrical systems that were implemented in the prototype design. The group initially breaks this down into the two systems and then discusses the materials that were used in the building of the prototype. In addition the group discusses the testing that was achieved with the prototype and how those tests were able to lead to the future design points of the group's ideal design.

There were a few alterations the group had to make in order to be able to test the prototype in an appropriate setting. A water pump is used to simulate flow from a sink's plumbing and an air pump is used to imitate that of a common air dryer. Several alterations were made in the design in order to increase flow-rates to match ideal statistics. A cost analysis also had to be made in order to ensure all the components needed for the construction of the prototype were affordable.

3.1.1 Mechanical Prototype Design

Figure 40, Prototype Full Assembly, is the SolidWorks model of the prototype that the group actually built for testing purposes. The main differences between this particular model and the actual model, shown and described later on in this paper, are the materials that are used, aside from that the concept remains the same. Table 5 shows a list of the items in the model that are numbered to correlate with their respective image in the model:

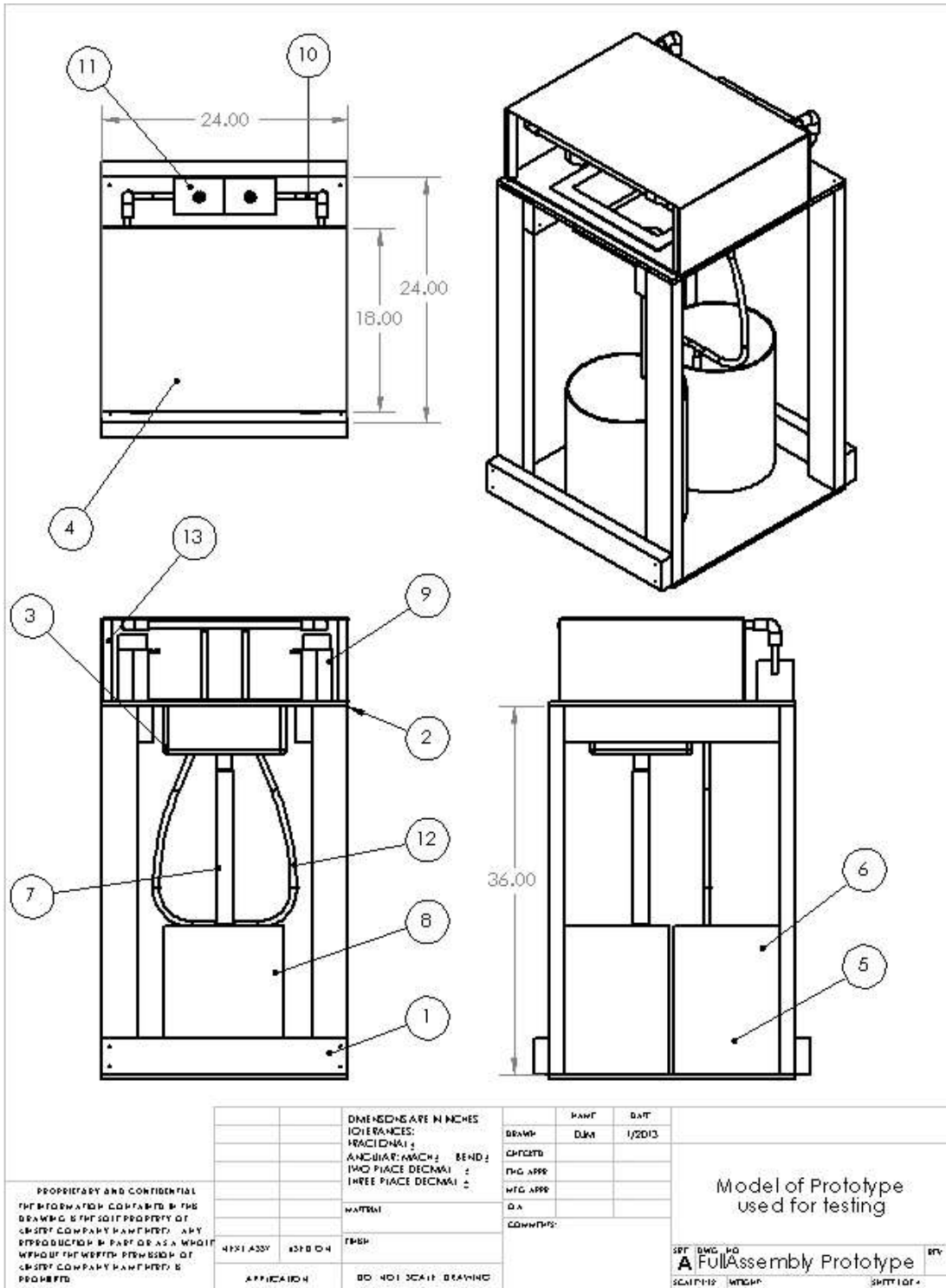


Figure 40 Prototype Full Assembly

As previously discussed the group decided to stray away from a standalone system due to our added objectives and constraints of being able to replace or expand a current sink configuration. However, as shown in the model the main assembly of the system is located on top of a frame made from 2" x 4" studs with 7/16" sheathing on top and bottom for support and shelving. This frame is used merely to represent a standard bathroom counter top as well as being functional for testing and as a displaying stand for the unit since we were unable to physically remove or expand onto a current sink for testing purposes. The upper sheathing has a cutout for the sink just like a normal counter top and a sink is mounted in the cutout in the same manner as would be in a traditional restroom. The main system is located on top of the frame and contains a sink and drain, a drain bucket, acrylic sheeting as a housing, flexible PVC as the water lines attached to a water pump, a water reservoir, touch free soap dispensers, and PVC air duct connected to air pumps located in the rear of the machine. A full list of materials, aside from connectors and hardware can be seen here in Table 5 and will be described in more detail later in the chapter.

Table 5: Items Used

| # on Model | Item |
|------------|------------------|
| 1 | Frame |
| 2 | Frame |
| 3 | Sink |
| 4 | Housing |
| 5 | Water Pump |
| 6 | Water Bucket |
| 7 | Drain |
| 8 | Drain Bucket |
| 9 | Soap Dispensers |
| 10 | Air Duct |
| 11 | Air Pump |
| 12 | Water Lines |
| 13 | Housing Supports |

For the prototype the goal of the group was to test the theory and functionality behind the actual model we designed for. In order to accomplish this we had to have certain items stand in for others we were unable to use. In the case of our prototype we used a drain pipe connected into a large bucket to simulate the standard sink drain since we did not have the option of tapping into a wall or actually replacing a sink unit. Another stand in material we used was the water

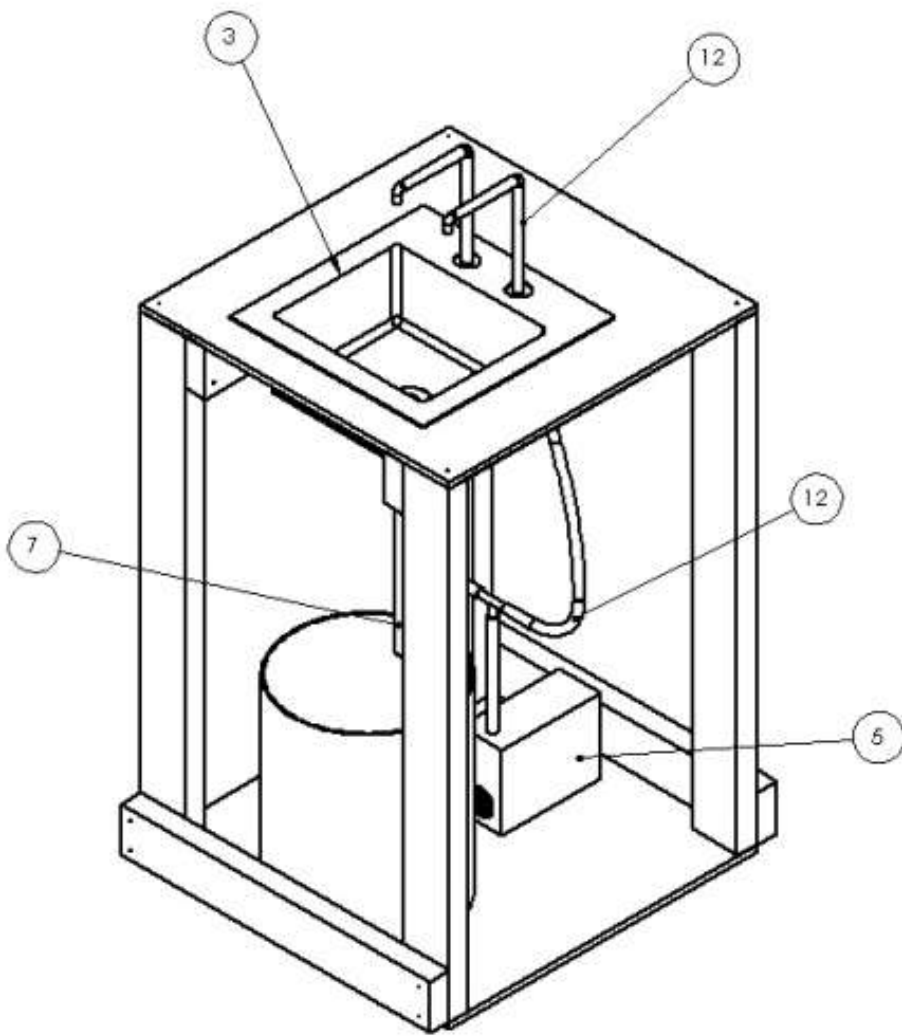
pump. This pump was used to simulate the actual water lines being attached to an electronic valve which like the pump can be controlled electronically and told when to turn on and when to turn off. The third main item that was used for simulation purposes was the air pumps. In the real model these would be replaced by a single much more powerful motor that could potentially produce up to 60 CFM and dispersed out of a razor thin aperture on the air duct, which together helps to scrape the water from the user's hands as they remove them from the system.

In the following pages more drawing views of the model, detailing different components will be presented that each reference Table 5 with the given numbered labels and item.

Figure 41, shows the full prototype with a few walls of the housing set to transparent in order to see the setup of the interior components lay out and displayed as they would be in the prototype model. Again the model has labels that reference Table 5.

In Figure 41 we can see the layout of the interior components as they would be placed in the prototype model that the group built. In this particular layout we get to see a clear separation between the different interior components and the jobs that each of them has. For example, both the soap and water components are relatively close for the sake of not wanting the user to have to really move during the cycle until the end as well as to trap all waste to the area of the sink and drain. Then the air blowers and air duct are completely separated from the rest of the system remaining out of the way and untouched by the user:

Figures 42 through 44 illustrate each of these subsystems on their own inside the prototype in order to get a better idea of the overall layout. Figure 42 shows the layout of the water system from the pump to the split water lines to spouts at the end located right over the center of the bowl of the sink. Figure 43 shows the air components layout from the two air pumps located behind the unit to the air lines running along the top of the housing to the dispersion duct at the top entrance of the unit. Figure 44 shows the soap dispenser layout with both dispensers and soap reservoirs located on the edge of the sink so any excess soap will drip into the sink below and be washed away down the drain.



| | | | | | |
|---|------------|--|------|--------------------------------------|-----|
| PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF -IEEE COMPANY- HAVE BEEN- ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF -IEEE COMPANY- HAVE BEEN- IS PROHIBITED. | | DIMENSIONS ARE IN INCHES TOLERANCES: FINISHES: UNLESS SPECIFIED OTHERWISE: FRACTIONS: ± .005 DECIMALS: ± .001 HOLE POSITION: ± .005 HOLE SIZE: ± .001 | | Part | Rev |
| | | DATE | REV | DATE | REV |
| DESIGNED BY | CHECKED BY | DATE | REV | Prototype water components | |
| DRAWN BY | DATE | REV | DATE | | |
| APPROVED BY | DATE | REV | DATE | IEEE A Full Assembly Prototype | |
| SCALE | UNIT | DATE | REV | | |

Figure 42 Prototype Water Components

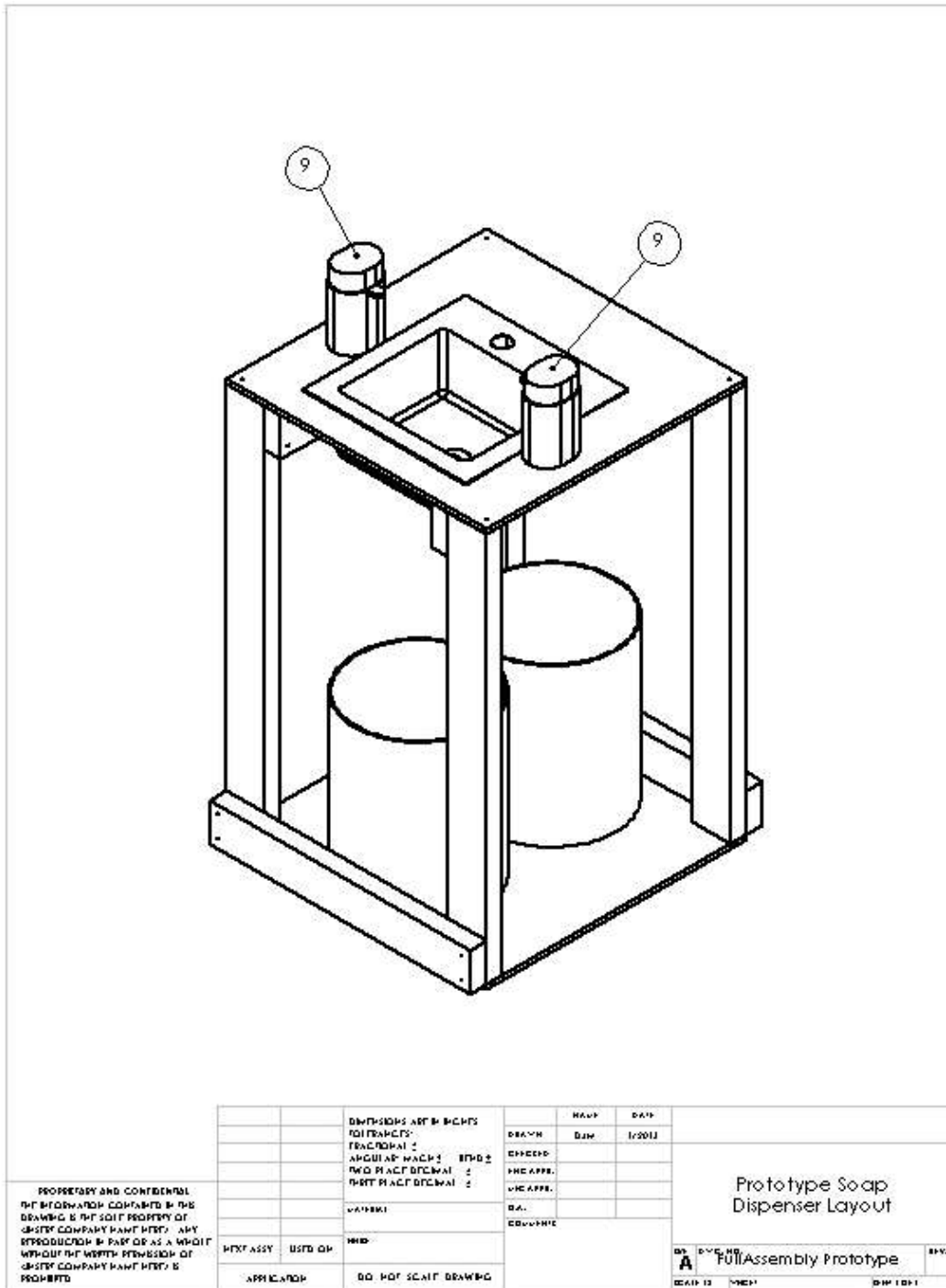


Figure 44 Prototype Soap Dispenser Components

3.1.2 Electrical Prototype Design

Our prototype idea for the electronic control system was to use a microcontroller to receive an input signal from a motion sensor array and to then output signals to a soap dispenser, water sprayer, and air pump which would tell them when to turn on and perform their task. This microcontroller would need to be programmed using the C programming language in an Assembler program which would allow the programmer to download the program directly to the microcontroller.

The system will rely on an input from a photodiode. There will be an IR light and a photodiode, which are within each other's line of sight. Once this LOS connection has been severed, the system will start the hand washing process. The system will be run by an MSP430 microcontroller that uses simple timing to decide which step to complete. These steps will be governed by solid state electronic switching devices such as MOSFETs and BJTs. These devices function as switches that can be controlled by an electrical signal. They are inexpensive and familiar components that will function well in our system.

We implemented these design ideals in the circuit illustrated in Figure 45. This is the only logical candidate for our final model because it is fairly easy to implement without the risk of having a lot of component connections to worry about where the system could fail. Also it could be easy to implement because everything is controlled by one central device which makes it easier to understand. Our only other option would be to create an entirely analog electronic circuit which would be over complicated compared to this system.

Our electrical design was meant to accomplish two tasks:

1. Assist in hand washing by automating the entire process
2. Alert the user when they need to actively do something

With these goals in mind, we design the following circuitry:

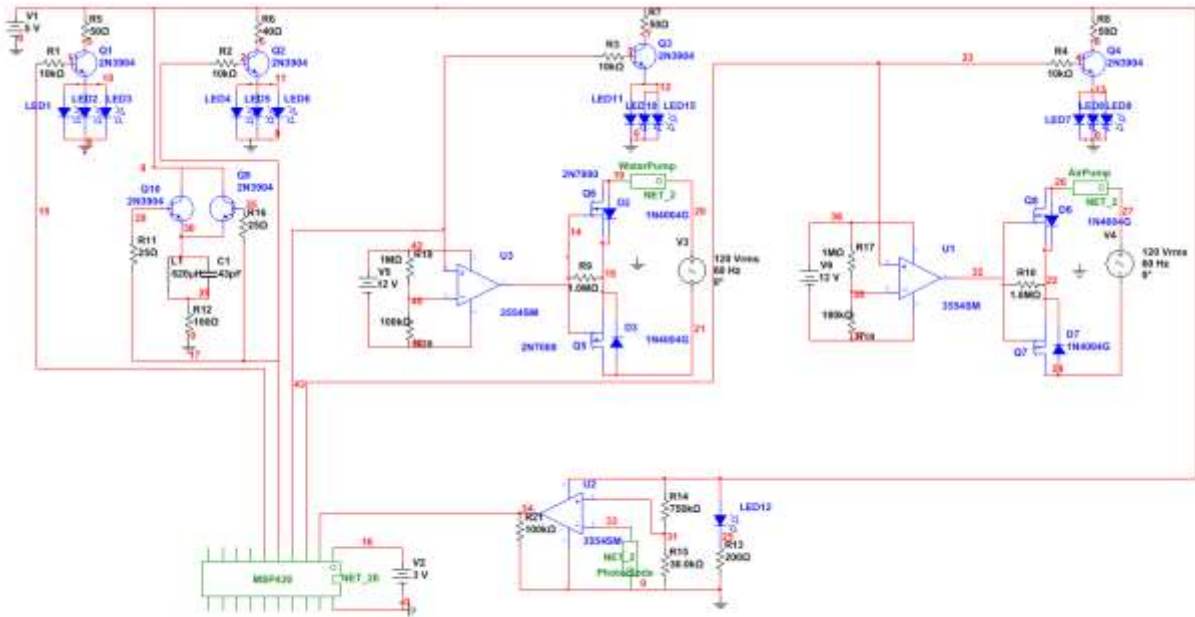


Figure 45 Control Circuit

In Figure 45 we can see the entire control system for the overall project. Noteworthy components include the MSP 430, which drives the whole system by receiving inputs, making decisions, and changing its output in order to cause a cascade of events that result in sanitary and fresh hands on the part of the user. The MOSFETs and BJTs allow for the MSP’s control signals to start and stop different functions.

The control circuitry also illuminates LEDs, which tell the user where they are in the cleaning cycle. These will also illuminate instructions as to that the user should be doing, which includes rubbing hands together while the water is on, and removing hands slowly during the drying cycle.

Our design performs multiple tasks, and as such it is split into multiple blocks. There is an image of the block-by-block breakdown below:

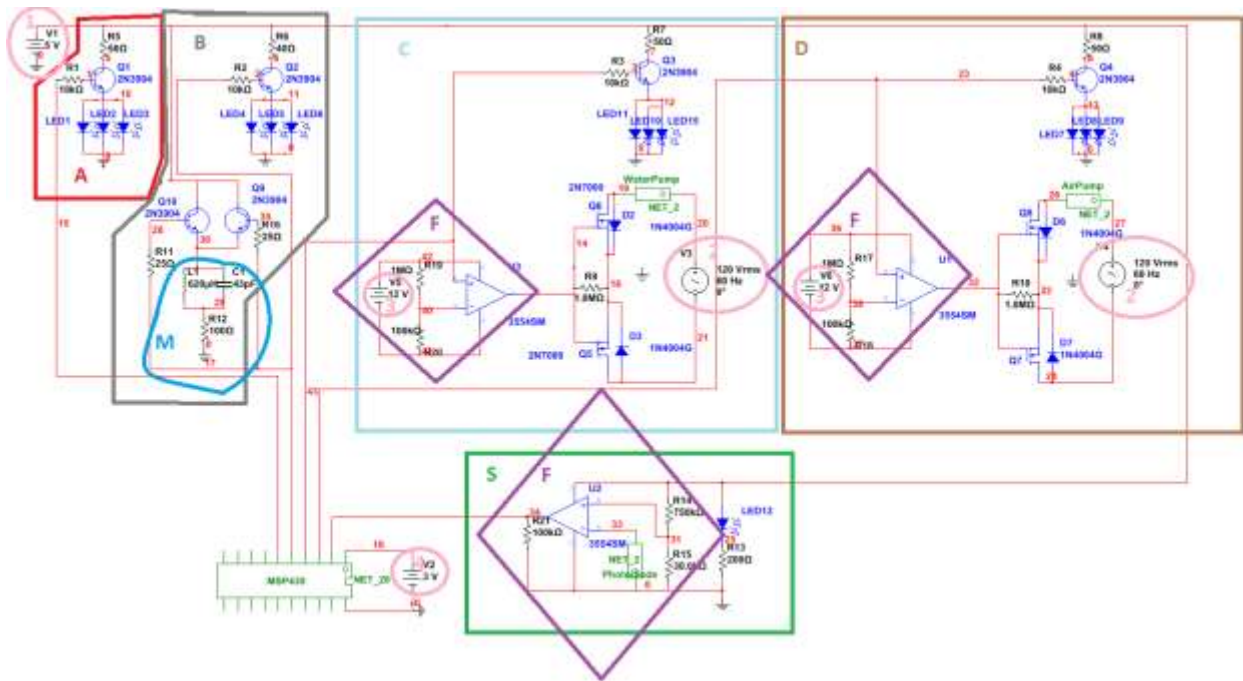


Figure 46 Input and Output and Power block diagrams

As we can in figure 46, there are four rectangular blocks, which represent inputs and outputs. There are also four circles, which represent power. These blocks will be described in detail below.

The first thing that we need to do is clarify some of the circuits and functional blocks in Figure 46. The first functional block that we will investigate is labeled “M” for motor.

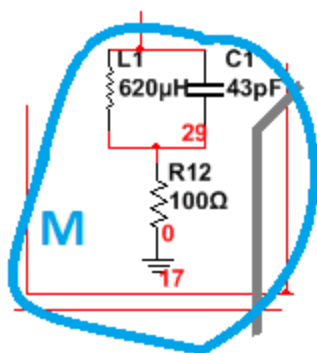


Figure 47 Motor Block

As we have explained the soap dispenser is essentially a hydraulic press that uses a motor to drive a cam and extrude soap. The circuit diagram software, MultiSim, which we utilized to design our circuit, did not have a DC motor block, so we used the circuitry in figure 46 to

roughly define the function of the motor. There was a 43pF capacitor in parallel with the motor, which is essentially an inductor. This was a mediocre representation, but it did allow us to put a simplified block diagram on paper. The block is known as an LC circuit which causes DC voltages to oscillate, in this case between a high voltage of 5.3 and a low voltage of 4.7 Volts.

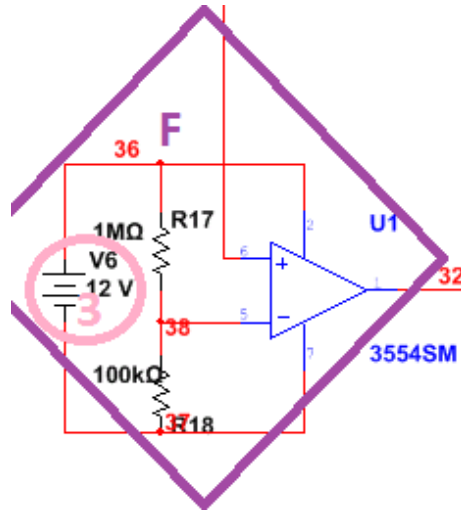


Figure 48 Comparator Block

Figure 48 is a comparator circuit. The way that this works is that an operational amplifier, which is represented by the blue triangle labeled U1, is used to flop a signal.

The device uses two resistors to create a voltage divider. Some voltage drops over the first resistor and some over the second. Each drop is proportional to the resistance value of one of the resistors over the total resistance, which is the sum of both resistances since they are in series. The equation for this phenomenon in Figure 47 is simply $V_{38} = V_{source} * (R_{18} / (R_{18} + R_{17}))$. In this case the bias voltage was $v_{38} = 12V(0.1\text{Mohm}/1.1\text{Mohm})$, which comes out to just over one volt. We used high value resistors to limit current and reduce wasted power.

The output is determined by which voltage is higher, the voltage at the input marked “-” or the input marked “+”. When the voltage at the positive input is higher, we get an output that is equal to the source voltage, because that is what is connected to input ‘2’ (the one coming directly up from the amplifier) and provides the highest possible output voltage. When the negative input is higher, we get 0V, because input 3 (the one coming directly down from the amplifier) is grounded. All of the operation amplifier comparators are organized this way, and they are denoted in Figure 46 and any subsequent figures by being surrounded in a purple diamond with a purple “F.” Two of the comparators are identical to the one featured in Figure 48, and one is different because it is used for the sensor and we wanted a lower voltage output.

Block S is one of the most important parts of our system, and one of the most complex as well. We need to be able to sense a user’s hand in order to begin our control sequence. This is Block S’s function.

The output of block S is either 0V or 5V. If the output is 0V, we call the output a digital '0', and if the output is 5V we call the output a digital '1'. This is how digital signals work, and this allows more simplicity while coding the MSP430.

The digital output of this block is then fed to pin 2 of our MSP, which allows the unit to be running its code once a user has broken the beam of light between the photodiode and LED, which sends a 0 to the MSP430 and gets our system to begin its routine.

Block A is an LED cluster that illustrates that the device is ready to use for the user. The LED cluster has no practical application whatsoever, so it was simple to create. The cluster is controlled by the MSP430 and it is powered with a 5V DC power supply. There is a current limiting resistor and a group of LEDs in parallel. This cluster can be seen in Figure 50.

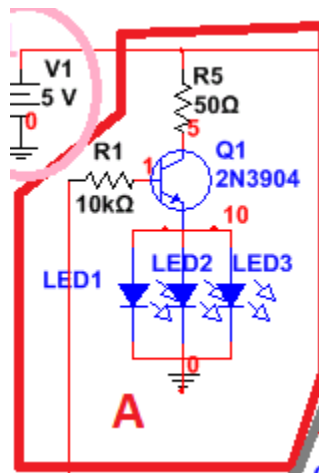


Figure 50: Block A

Block A has one BJT. This BJT only allows current flow between the node 5 and 10 when a positive voltage is applied to the gate, which is node 1.

R1 is a resistor that is present in all BJT arrangements. We cannot feed more than a few microamperes to the base of the BJT, or else the current at the emitter would be very high. By using a large resistor, on the order of 10,000 Ohms, we can control the current much more consistently at the emitter, which will extend the lives of the LEDs.

This block is very simple, but it is extremely helpful in terms of interfacing with the user because it lets them know the system is ready to use. This light cluster glows a bright green when

the system is ready to use. If these lights are off the system is either iterating through its programmed hand washing process or something is broken.

The second function block, Block B, turn on LEDs when the system is pumping soap. This block is similar to Block A in that its only function is to alert the user of the status of the machine. This block would include a soap dispensation sub-block if we were not using a prefabricated soap dispenser and light sensor all built into one unit. Block B can be seen in figure 51

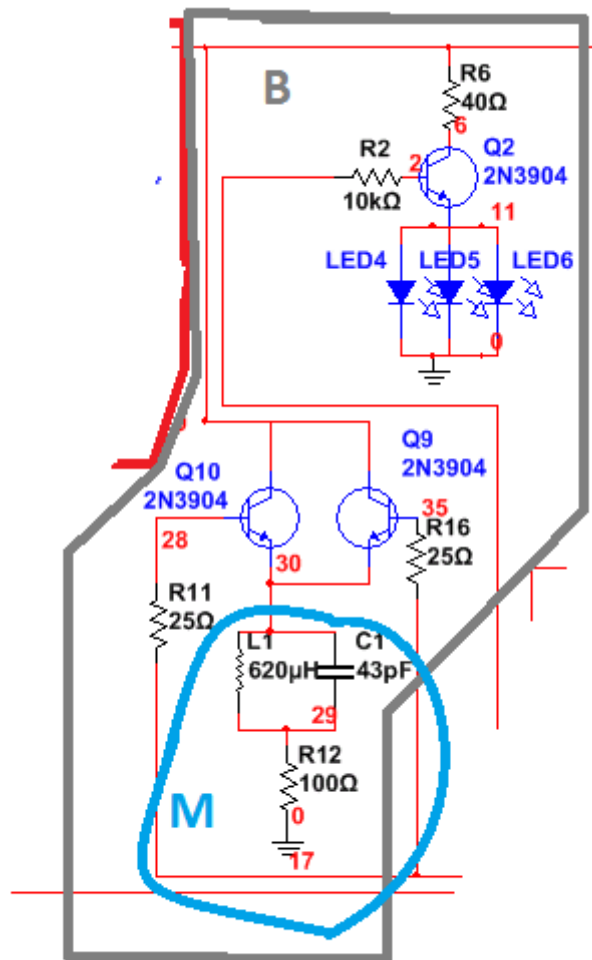


Figure 51: Block B

Block B utilizes a BJT with a current limiting resistance between the voltage source and the collector pin of the BJT. The LEDs in this sector are white, and as such they require 3V and

60mA of current to drive the three of them in parallel. The resistor, R6, helps to mitigate the current that is pulled from the 5V source. The order of magnitude of this current is decided by R2, which is very high to prevent an excessive collector current, which would destroy the LEDs.

These LEDs may be prone to a color change for a final model, but our choices of colors were very limited, and only included blue, red, yellow, green, and clear LEDs.

The second part of block B drives the motor circuitry, which is represented as block M and is described in detail above. We needed two BJTs because the maximum current draw is 0.4 Amperes, and the BJTs can only accommodate 0.2 Amperes. Thus, we needed two in order to disperse the power across more than one BJT.

Block C is the third output block of the circuit, and it controls the water pump, which runs for almost the entire duration of the functional cycle. A close-up of this circuit block is included in Figure 52:

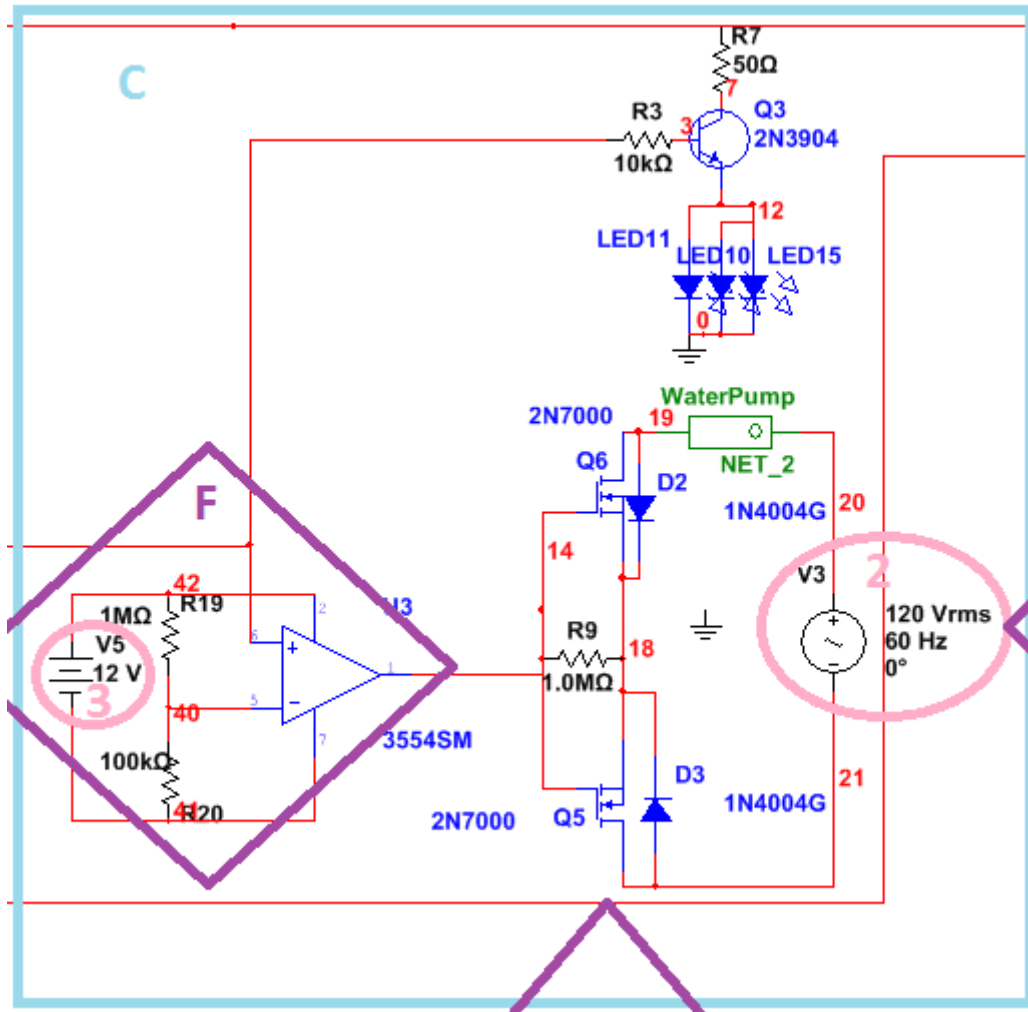


Figure 52: Block C

The top portion of Block C functions very similarly to Block A and Bin that a control signal from the MSP turns on two BJTs that allows a bank of 3 LEDs to turn on.

The second portion of the circuitry, which drives the water pump, is controlled by a set of balanced MOSFETs. These MOSFETs need at least a 5V input, and the MSP can only deliver 3V. The MOSFETs can handle a maximum of 20 Volts across the gate to source terminals, and it becomes more efficient as the voltage is increased from 5V to 20V. We already had a 12V source, so we used that and a comparator circuit in order to feed the MOSFETs the voltage that they needed.

The main difficulty we encountered here was that the water runs off of AC power. Instead of staying constant, AC power fluctuates like a sinusoidal function. This does not inherently change

the function of the MOSFET, but it is an interesting design consideration because the voltage and amperage swings widely across one period of the AC sinusoid. We could not use just one MOSFET, because the relationship between the gate-to-source voltages determines whether or not the MOSFET is on. When we only used one MOSFET, we got a pump that was always on, but usually weak, because we clipped part of the waveform. We had to use two MOSFETs to create a steady ground to compare our gate voltage to in order to actually control the pump with a microcontroller signal, because any other control options either required too much power, were extremely expensive, or a combination of the two. We also had to consider that the reported AC voltage value is not given in maximum voltage, but rather in RMS. In fact, the maximum is not 120 V, but rather, it is close to 170V. If one is not careful, this difference could easily destroy a MOSFET that was only rated for 125 V or 150 V.

Once the MSP gives the signal, a digital 1, Q5 and Q6 receive 12 Volts across the gate to source terminals until the signal changes back to a 0. This cycle allows the user time to wash their hands in order to first create lather and subsequently to wash the emulsified oil, dirt, and soap lather from the hands. Once this sequence is completed, which is determined by a timer, the MOSFETs and BJT are switched back off. This turns off the LEDs and water pump.

Block D controls the final portion of our control circuitry and functional circuitry. This section cues the air blower to turn on and allows the user some time to dry their hands from any residual water. A closer view of Block D is in Figure 53.

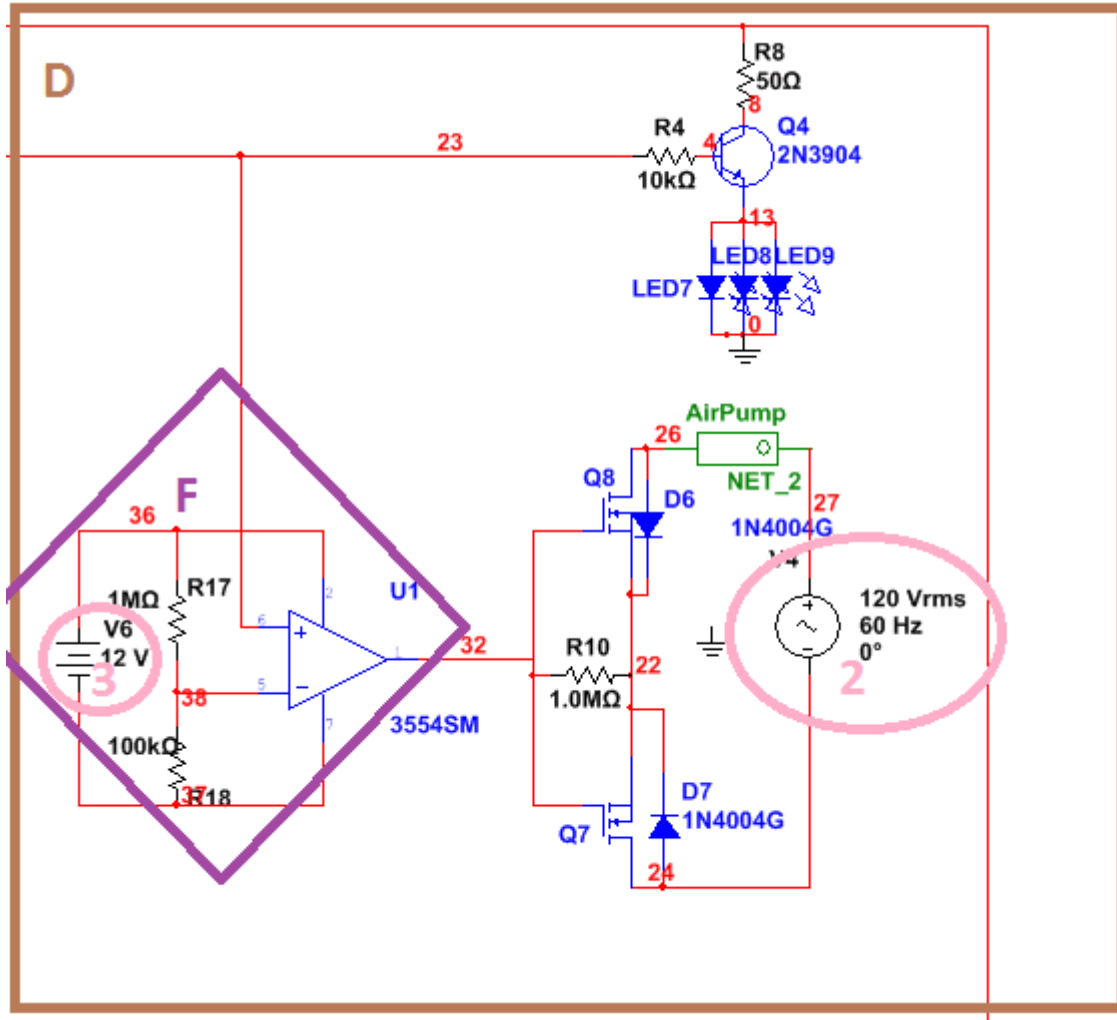


Figure 53 Block D

This system again relies on MOSFET's and BJT's to allow the MSP to control the functionality of the system. Q4 runs LEDs while block 3 is active, just like Q3 did for Block B and Q1 did for Block A. The LED specs are the same, which means all the numerical values regarding voltage and current are also the same. This is true because this step has Red LEDs and the last block had yellow LEDs which require the same voltage and current to turn on.

The sub-block containing the air pump functions identically to that previously discussed. Upon receiving the signal from the microprocessor, the F Block outputs 12 Volts and the MOSFETs and BJTs turn on and behave like a closed switch. This causes the LEDs to light up and the air pump to blow air. for the pump is on for a given time period to let the user dry their

hands, and then everything shuts off again, which signals the end of the system’s functions. The MSP then awaits a new input from the sensor and the entire process can iterate again.

The system is run by different voltage sources and that is due to the different devices requiring widely different forms of power. A diagram of the voltage sources is included below; the voltage sources are circled:

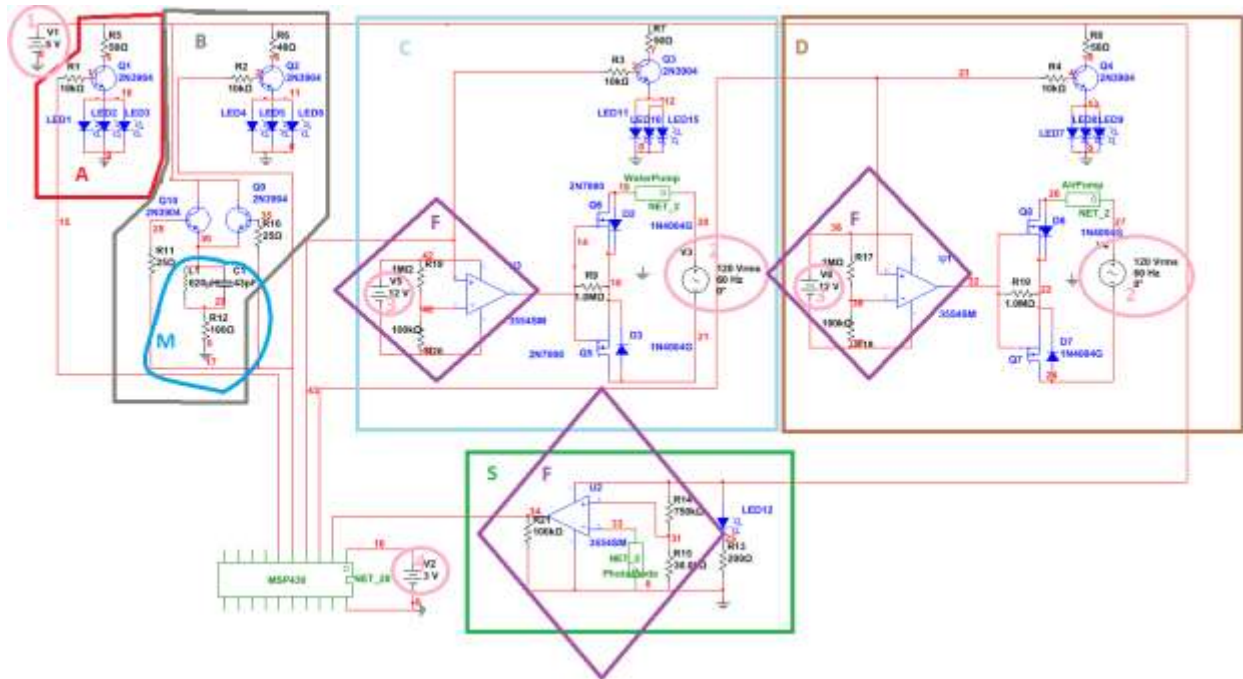


Figure 54 Full Diagram with Power sources are circled

These different power sources seem counter-intuitive to begin with, but they actually were a practical consideration, and the voltages chosen were far from arbitrary. We will break down each of the three voltage choices.

1. 5V Source—The 5V source was chosen because it was an extremely manageable amount of voltage. This source allowed us to run our sensor system, our LED systems, and provided a valid power source for the MSP430, although we did need to drop the voltage to 3 Volts to protect the MSP. This was easily accomplished with three diodes that provided both voltage drop and current limiting characteristics. This source was also very inexpensive to buy, costing only five dollars. They are also extremely common and many cellphone chargers as well as other small power sources are around 5V, which meant that accessibility was simple and straightforward.

2. 3V source—The 3V source was necessary for running the microprocessor. We created this source by attaching 3 diodes to the 5 Volt source. This caused a voltage drop of approximately 2 volts, which can feed the MSP430 without causing any problems.
3. 12V source—The 12V source was chosen to feed the MOSFETs enough gate to source voltage to ensure reliable operation. This source is fed to the MOSFETs through a biased comparator that relies on a signal from the MSP, and outputs 12V when the MSP outputs a ‘1’ and outputs 0v when the MSP outputs a ‘0.’
4. 120V Source—This was simplest source to access, but it was the most complex to integrate into our design because it is simply pure wall power, which is delivered in an alternating current. This is a little bit more dangerous to work with due to the high potential current, and it is much more difficult to control with MOSFETs than a simpler DC current would have been. The entire system is essentially running off of 120V power, but it is typically tamed through the AC to DC converters that gave us both the 5V and 3V sources. In the future, we would like everything to run off of a simpler DC current, but given our time and budget constraints, we had to use AC power as a source.

3.1.3 Materials and Testing

The materials chosen for the prototype model were based on a few criteria; low cost, can mimic control of ideal model items, and more or less be a lower quality model of our ideal system. With that being said a list of the mechanical materials chosen and used for the prototype can be seen in Table 6:

Table 6: Prototype Materials

| Item | Part Name | Description | Quantity |
|------|------------------|---|------------|
| 1 | Frame | 2" x 4" x 24", 2" x 4" x 36" (Studs) | 4 each |
| 2 | Frame | 7/16" x 24" x 24" Sheathing | 2 |
| 3 | Sink | Standard Sink (Bar sink 15" x 15" used in model) | 1 |
| 4 | Housing | Acrylic Cut to Spec | 1 assembly |
| 5 | Water Pump | 300 GPH water fountain pump | 1 |
| 6 | Water Bucket | 5 Gallon Homer Bucket | 1 |
| 7 | Drain | PVC Straight Pipe | 1 |
| 8 | Drain Bucket | 5 Gallon Homer Bucket | 1 |
| 9 | Soap Dispensers | Lysol Touch Free Hand Soap Dispensers | 2 |
| 10 | Air Duct | 0.5" ID PVC Straight Pipe, 90° Elbows, 0.5"ID Flexible Pipe | 1 assembly |
| 11 | Air Pump | Standard air mattress pump | 2 |
| 12 | Water Lines | Flexible PVC, T splitter, 90° Elbows | 1 assembly |
| 13 | Housing Supports | PVC Straight Pipe cut to spec | 4 |

A couple examples of the materials that were used while building the prototype can be seen in Figures 55 through 57. All of the materials listed in Table 6 were easily purchased through Home Depot, with the exception of the soap dispensers; which were purchased at Wal-Mart:



Figure 55 Moen Excalibur Sink

Figure 55 is an image of the Moen Excalibur sink that was used in the prototype. The exterior dimensions of this sink are 15" x 15. This particular sink is made from 22 gauge type 301 nickel-bearing stainless steel and features a 2-hole fixture mounting layout which was utilized in the prototype to run two individual water lines, one above each hand.

Figure 56 is an image of the OPTIX 18" x24" x 0.093" acrylic sheets that were used to make the housing for the prototype. This particular material was chosen due to it being relatively lightweight and strong and water proof. Also, with this being clear we are able to ensure that all subsystems function properly throughout testing:



Figure 56 OPTIX Acrylic Sheet

Figure 57 shows the submersible water pump that we used for the prototype. The pump produces 300GPH at 1ft of lift. This pump was chosen because it can be fully submerged and has flow rates relatively close to those of a normal bathroom faucet:



Figure 57 Total Pond 300 GPH Fountain Pump

The materials for our electrical system were categorized into four subgroups; power, processing, performance, and function. The total cost of our power system was \$23.50. The total cost of our processing system was \$8.30 and for Performance it was \$6.95.

For our power system we used a simple Belkin power strip with a 3 foot cord:



Figure 58 Belkin Power Strip

Figure 58 is an image of this power strip, which was purchased for seven dollars. One of the main advantages of this power delivery system is its simplicity and its price. For 7 dollars, we acquired a functional power distributor that we could control via power MOSFETs. This simple approach was incredibly useful as well because it allowed our unit to plug into a standard wall outlet, instead of needing a special connection that would require an electrician. This was a feature that would appease the home user more than a customer interested in a commercial application, such as a mall or academic building, but there are other examples of the plug-in unit such as everything from drying apparatuses all the way to drinking fountains, so we were confident that this solution would not detract from our design.

It is useful to note that in a final design and not a prototype, the typed of materials used will be different and the power strip may not be a viable power source when we are getting non-consumer components to power.

The second key component was the power MOSFETs that we implemented. These MOSFETs were controlled by our microcontroller, which will be addressed in the processing section:



Figure 59 Power Mosfet

We selected the MOSFETs in Figure 59 because they can handle high current and voltage inputs despite their meager cost of only 75 cents each. The specifications on the datasheet claimed that these small MOSFETs could handle 500V at 8Amps, which is a lot of power, and which leaves us with a significant safety margin in our design, which meant that we would be able to test more vigorously without fear of breaking any of them, we procured 10 of these MOSFETs, which totaled \$7.50.

Our processing system was focused on the MSP 430 microcontroller and the launch board development kit. We purchased a pack of two microprocessors with a development board for only \$4.30. The MSP430 and Launchpad can be seen in Figure 60:

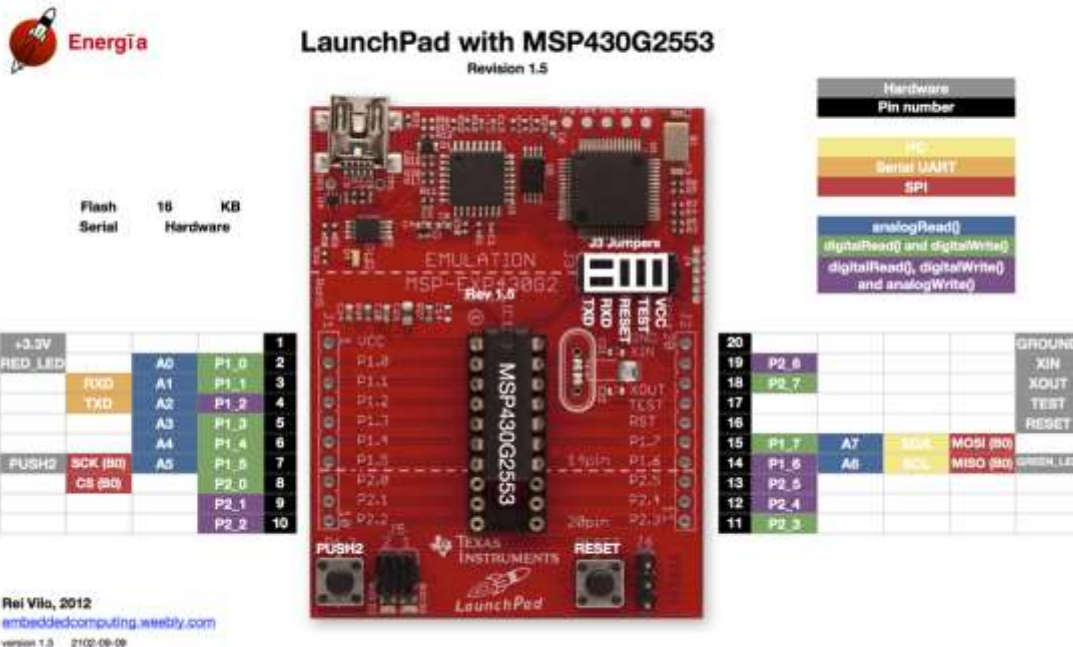


Figure 60 MSP430 on the Launchpad with all pins and connections denoted

The MSP is the rectangular chip in the center of the red board on Figure 60. The chip was selected for its versatility and its extremely inexpensive price tag. We needed to use two in order to control all of the I/O operations that were required in our design.

The other material that we used in our processing circuitry was a pair of motion sensors that we too from preexisting soap dispensers. They were digitized through the use of a comparator biased to 1.0V and simply put out a digital 0 when they sensed motion and a digital 1 when they did not. We used one to sense hands in the unit and one to sense a user’s gesture to toggle the temperature.

The LED-based motion sensor consisted of a photodiode and an infrared LED. When the light from the LED no longer reached the photodiode, the photodiode stopped putting out voltage and cued our system to being working or to change temperature depending on which sensor the user activated. This system was not optimal because it relies on two components, instead of more complex systems that simply have one part that actually senses motion in a field, but due to price limitations, this option was considered adequate for a prototype. The cost on this system was

covered by purchasing a standalone motion sensing soap dispenser, each of which cost around \$8, but we purchased the same simple motion sensing apparatus for around \$4, so that is the price we will list in our totals in the section heading.

We also had materials that we acquired to improve the UI and performance of the system. These included LEDs and other such improvements.

We purchased the LEDs to allow the users to see the progress in their hand washing cycle, as well as to dress the prototype up. The assortment of LEDs the group acquired can be seen in Figure 61:



Figure 61 LED's

For just \$6.00 we got 25 LEDs with 25 resistors to help get them up and running. These were implemented in various places on the prototype, and mostly provided the user some entertainment of seeing what process was occurring at a given time. We also organized the LEDs in such a way that they displayed the stage of cleaning that the user was experiencing.

In order to get our device to function we needed the actual hardware for the processing block to control. The first thing that we needed was a functional way to blow air. We used a PVC tube with a slit on the bottom and one air pump on each side to increase the air pressure in our prototype. We used a Coleman air mattress pump, which can be seen in Figure 62:



Figure 62 Coleman Air Mattress Pump

As we can see in Figure 62, this pump is fairly small, which helped us to easily fit it inside of our prototype. Its output was nothing noteworthy, but this device was meant to create a prototype, and not a fully ideal implementation of our actual design. We wanted something similar to the Dyson Airblade, which can be seen in Figure 63:



Figure 63 Dyson Airblade Hand Dryer

From our experiments, we found this system could dry hands in 5-10 seconds with relative ease. We used the Coleman pump to simply hold the place of a more advanced drying system like the one Dyson has implemented in their hand dryers.

We used a self-contained motion sensing soap dispenser in our prototype in order to provide simplicity and practicality to our design. We took apart the devices and used the soap pump, soap holder, and the motion sensing circuitry in order to quickly develop a prototype. We subsequently attached these to the appropriate parts of our circuitry, which can be seen in Figure 46.



Figure 64 Lysol No-Touch Hand Soap System

The dispenser shown in Figure 64 is the exact soap dispenser that we purchased. The sensor inside was a simple photodiode with an IR LED. When no light got to the photodiode, the machine pumped soap. This is a very simple method for motion sensing, but this is not to be considered a problem.

When we experimented on these devices, we found that the output at the photodiode was not what we had expected. Instead of a simple, stable voltage, the photodiode was destabilized by an LC circuit that caused the voltage to oscillate. We subsequently disassembled the circuit and reconnected it to the signal inputs and outputs.

The reservoir is readily switched out, which we want to eliminate in the final model. The tanks in these pumps hold enough soap for over 160 wash cycles, which is significant given their small size. We would prefer a refillable tank in order to reduce plastic waste from our system.

The soap dispensation is accomplished via a motor that pushes a plunger up and into a store of soap. This soap pool is connected to the reservoir through a one way valve, so none of the soap goes back into the reservoir. The plunger pushes up from the bottom of the soap chamber, which causes the soap to be displaced via the laws of hydraulics and dispenses soap a few inches away at the end of a tube.

The entire system runs off of 4.8V, which allows us to use an AC/DC converter that takes 110-120V AC wall power and turns it into 5V DC power, which is close enough to 4.8V that the system will work. This is excellent because it simplifies our power system.

The best feature of these units is the price. For just \$10 each we got a sensor, soap pump, and soap holder. This simplified our prototype quite significantly, and that was excellent due to time constraints.

In a full-fledged device we would want a better motion sensor that did not rely on a beam of light, but rather other proximity sensing technology. These sensors are more expensive than the entire Lysol device shown in Figure 64, but they are also much more consistent and provide a lot more longevity than the Lysol device. Due to our limited budget, we did not use a more advanced sensor in our prototype.

As discussed in the previous design section, the team had to make adjustments to the prototype in order to remain within budget restrictions as well as enable the group to present the working prototype in a classroom setting. These adjustments begin with the construction of a base for the sink itself. This was constructed out of plywood and two-by-fours in order to create a sturdy enough base for the sink and unit, as well as maintain the correct size requirements in order to fit two buckets under the system. One of these five gallon buckets is used as a water reservoir, in which the water pump sits in and pumps water up through the two jets in the system. The other bucket represents a drainage system from the sink. This bucket is simply connected from the sink drain, through a schedule 40 PVC pipe, to the bucket. This imitates the initial

drainage system of a real sink, but instead of a U-trap and continuing piping, the group's prototype drains into a bucket.

Ideally, this prototype would have the same hook-up that a sink would have. The prototype contains a drain and a tailpiece as depicted in the figure, but this tailpiece leads to a drainage bucket as opposed to the U-trap. As illustrated in Figure 65, it would involve a simple piping attachment to hook the prototype up to an actual sink hookup. Figure 65 portrays different types of piping layouts for altered sink arrangements. All of the drawings below could ultimately be used to attach the real All-In-One Hand-Washing Station design to a sink's plumbing:

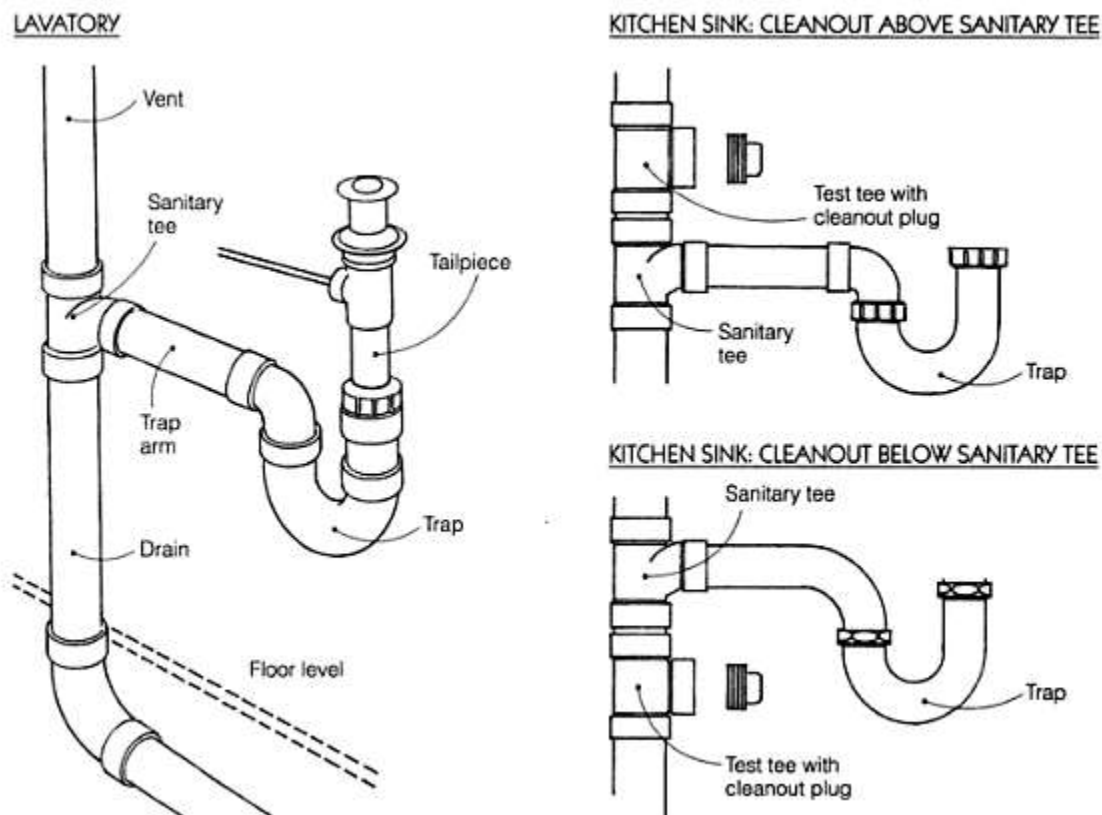


Figure 65 Piping Layout for Kitchen and Bathroom Sinks

Figures 66 and 67 further illustrate specific aspects of a sink design. They allow for a closer look at specific components that Figure 65 does not illustrate. The drainage assembly is

important to prevent the sink from clogging and leaking, so it contains several different components to ensure these problems do not occur. The sink supply is important to the design because this is how the ideal prototype would attach into a bathroom setting.

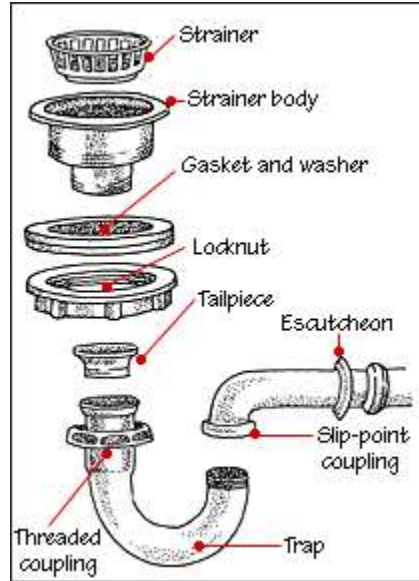


Figure 66 Sink Drain Assembly

Figure 66 shows the drainage assembly of a common sink, which are mirrored in the prototype construction. The strainer and strainer body are in the bottom of the sink to fill the initial hole in the bottom of the sink. Next, the gasket, washer, locknut, and tailpiece are attached to the bottom of the sink in order to allow for further piping to be attached. In the prototype's case, a straight PVC pipe is attached to drain the water into the bucket below. In a normal sink design, a trap is attached to a horizontal pipe, which then leads to a sanitary T that allows for the water to finally drain from the sink.

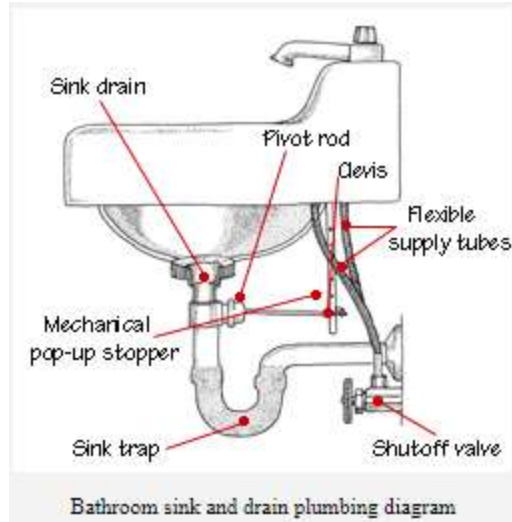


Figure 67 Sink Supply

Figure 67 helps the user understand the inflow of water to the faucet. Like a real sink, the prototype employs flexible tubing to supply the water to the faucets. The ideal model would attach to the piping the exact same way a household sink would.

The next features of the construction of the prototype consist of the counter and sink reproduction. This is done using another sheet of plywood and a layer of thin Plexiglas in order to give the counter water-repelling properties. Next, the sink is placed into a hole cut in the counter and caulked in place to further enhance leak resistance. While cheaper, this model is a reasonably accurate representation of a countertop and sinks assembly. The prototype is water resistant and resembles the same shape a countertop would have in any given bathroom. The sink is inserted into the counter, and recessed so it is flush with the countertop.

The final part of the assembly is the housing placed over the sink. In the prototype, this housing is attached to the counter in order to ensure stability of its components. The sides of the housing are constructed out of a similar style of Plexiglas and the group used eight inch cuts of schedule 40 PVC pipe to reinforce the top of the housing. This was chosen because of its strength properties appropriate for the desired need, along with its inexpensiveness.

Contrary to the prototype, the design of the over-the-sink attachment housing could be created out of different materials in order to fit the customer's needs. The housing material could be altered in order to match the design and décor of the room in which it would be placed. If the housing were going to be mounted on a wall in a commercial area, it could also be altered

in order to fit the design of the building in which it is placed. Materials like ceramics, metals, and other polymers could be adapted in order to fit the specifications of the particular location.

The water is brought through the system from a reservoir bucket under the sink through one half inch tubes. These tubes are threaded through the sink in the spots where the hot and cold water would be run through a normal sink. As illustrated in the schematic of the prototype, ninety degree PVC nozzles are used to redirect the flow until it is over the sink itself.

Table 7 illustrates the volumetric flow rate of the pump used by the group at several different height specifications. The group will be utilizing the pump at a height between two and three feet, so the flow rate of the pump will be around 220 gallons per hour. This is split into two hoses with a radius of a half of an inch, causing the flow rate in each tube to be approximately 110 gallons per hour:

Table 7: Volumetric Flow Rate of Water Pump

| Lift Height (feet) | Flow Rate (GPH) | Flow Rate (m ³ /min) |
|--------------------|-----------------|---------------------------------|
| 0 | 363 | 0.0229 |
| 1 | 308 | 0.0194 |
| 2 | 254 | 0.0160 |
| 3 | 212 | 0.0134 |
| 4 | 167 | 0.0105 |
| 5 | 126 | 0.00795 |
| 6 | 67 | 0.00423 |

Ideally, this unit would be hooked up the same way a sink would, therefore the flow rates of the hot and cold water would mimic that of any household or bathroom sink. This would increase the flow rate of the water, allowing the soap to be washed off faster and potentially reducing the rinsing time of the system. The volumetric flow rate of an average sink is approximately three gallons per minute, which is equivalent to 180 gallons per hour. This implies that the group’s prototype will only have approximately two thirds of the flow rate of a normal sink. Ideally, the faucets in the prototype would be attached to a sink hook-up, so the flow rate going through the water jets would be higher than the pump can produce.

Next, the air-drying mechanism on the prototype is based on the Dyson Airblade represented in Figure 63. For the prototype, the group decided to use one half inch schedule 40 PVC pipe with a 14 inch long and 1/32 inch wide slit cut in it along the length of the pipe. The air is fed into each side of the pipe from two air pumps, originally created for air mattresses. This pipe will be placed on the top of the unit, with the opening facing down in order to strip the air from the user's hands before removal from the unit. Each of these pumps is rated at 12 volts and approximately 10 liters per minute ($0.01 \text{ m}^3/\text{minute}$ or $0.0001667 \text{ m}^3/\text{second}$). Based on this information, the flow rate of the prototype should be approximately $0.000333 \text{ m}^3/\text{second}$. This is because the group is utilizing two air pumps on the air-blowing system.

The group decided to use both air pumps to provide air to the top blower because higher rated air pumps are significantly more expensive. In order to remain within budget, the lower blower has been removed from the prototype. Ideally, the unit's air flow capabilities would match that of the Dyson Airblade. The hand dry time of the Airblade is estimated at ten seconds, with an airspeed of 400mph at operation and an airflow of 74CFM ($0.0349 \text{ m}^3/\text{s}$). This is over one hundred times the combined flow rate of the two pumps being used in the group's prototype. Unfortunately, this Dyson technology was not plausible given the current restrictions.

The Lysol Healthy Touch Soap Dispenser, depicted in Figure 68, is a perfect addition to the prototype. The group was able to utilize the sensors from two of the soap-dispensing units to be used as sensors for the entire system. When signaled, the soap is pushed through a small, four inch tube, and dispensed out the other end. One of these housings and soap dispensers is located on each end of the unit, allowing for soap to be distributed on each of the user's hands. The device works as follows; as the users hands cross the Infrared LEDs path it will disrupt the signal it is emitting and will cause the sensor to send a voltage to the microcontroller we are using. This will then start the entire wash cycle of the device:



Figure 68 Lysol Healthy Touch Soap Dispenser

The electrical construction was a descent portion of the build. When building the prototype the group had to consider the fact that our electronic system needed to remain dry during the entire washing process. If almost any part of our electronic system was to get wet then there would be a chance that the entire system could fail and make it useless. This meant the group needed to take precautions in setting the system up while also configuring it in a way that made it simple to understand.

One of the most important components we needed to keep dry was the MSP430G2553 microcontroller which took in the output from the motion sensor and told the soap, water, and air cycles when to start. This microcontroller is the heart of our device. So as a team we decided we wanted to keep this centralized, because it needed to be connected to nearly every piece of our device. We also decided to put it in a water tight housing which will ensure that no water can come in contact with the microcontroller or any of its electronic connections.

Another important piece of electronics we needed to make sure was set up in a well-protected manner was the motion sensors. This device is used to read that an individual has come to use our device. It will send an input signal to the microcontroller which will then turn on the rest of the unit in the proper steps for the proper lengths of time. In order to make sure this will work properly every time we are using two sensors so if one does not pick up the individual attempting to use the device then the second sensor should. We are also putting them in a position to make sure they cannot get dirty by someone touching them, which would cause them to malfunction and make the device not work properly.

One of the last major concerns we had while setting up the units electronic systems was that they were placed in as easy to access areas as possible. Also that the wiring for each piece of electronics was not going to interfere with any of the processes of the device while running or off. To solve this we made sure all the wires and electronic units were laid out in an organized fashion.

Testing was a huge part of the design process since we had to ensure all components, both electrical and mechanical would work together and effectively. We established which individual components we could ideally control the most and ran tests and made calculations accordingly. These tests and calculations can be seen here:

Calculations for the water flow rates are as follows:

$$Q_w = \text{volumetric flow rate of water through tube} \quad \rightarrow \quad Q_w = 110 \text{gph/tube} \quad (0.0069399 \text{m}^3/\text{s})$$

V_w = velocity of water

A = cross sectional area

$$R_1 = \text{radius at end of water pump} \quad \rightarrow \quad R_1 = 3/16'' \quad (0.0047625 \text{m})$$

$$R_2 = \text{ideal radius out of nozzle} \quad \rightarrow \quad R_2 = 1/16'' \quad (0.0015875 \text{m})$$

$$Q_w = V_w * A = V_w * (\pi * R^2)$$

$$\text{Cross sectional area at exit of water pump} = \pi * R_1^2 = \pi * (0.0047625 \text{m})^2 = 7.12557 \times 10^{-5} \text{ m}^2$$

$$\text{Ideal cross sectional area out of nozzle} = \pi * R_2^2 = \pi * (0.0015875 \text{m})^2 = 7.9173 \times 10^{-6} \text{ m}^2$$

Ratio of two areas: $(7.12557 \times 10^{-5} \text{ m}^2) / (7.9173 \times 10^{-6} \text{ m}^2) = 9.000$

The group was only able to find a nozzle with an inner radius of three-sixteenths of an inch, which matches the exit radius of the pump. Based on the equations above, it can be inferred that the velocity of the water of the unit will not increase through the exit nozzle because there is no difference in radius.

Ideally, the group would have used a nozzle with a much smaller radius in order to increase the velocity of the water exiting the nozzle. This would increase rinse speed, therefore reducing overall usage time of the All-In-One Hand-Washing Station prototype. Using the ideal exit nozzle radius, R_2 , it would be one-third the size of the exit radius of the pump. As illustrated through the calculations above, this would increase the ratio of the two areas by a factor of nine. One can assume a constant flow-rate of the water because the pump will consistently be pumping water at the specified volume per hour. Assuming this constant flow rate, this would imply that the velocity of the water from the exit nozzle would increase by a factor of nine. This would significantly reduce rinse time of the prototype.

Calculations for the air flow rates can be as follows:

Q_p = volumetric flow rate of air inside pipe

Q_a = volumetric flow rate of air through slit cut in pipe

V_a = velocity of air

A = area of slit cut in pipe

R = inner radius of pipe $\rightarrow R = 3/8'' (0.009525\text{m})$

w = width of cut $\rightarrow w = 1/32'' (0.000604762\text{m})$

L = length of cut $\rightarrow L = 14'' (0.3556\text{m})$

$$Q_a = V_a * A = V_a * (\pi * R^2)$$

$$Q_a = V_a * A = V_a * (w * L)$$

$$\text{Cross sectional area inside pipe} = \pi * R^2 = \pi * (0.009525\text{m})^2 = 2.85023 \times 10^{-4}$$

$$\text{Area of slit cut in pipe} = w * L = (0.000604762\text{m}) * (0.3556\text{m}) = 2.15053 \times 10^{-4}$$

$$\text{Ratio of two areas: } (2.85023 \times 10^{-4} \text{ m}^2) / (2.15053 \times 10^{-4} \text{ m}^2) = 1.325$$

Assuming that the flow rate of the air is going to remain the same, as the air pumps will always pump at the specified value, the group is able to increase the velocity of the air coming through the slit in the tube by a factor of 1.325. This is illustrated through the equations and calculations above. If the group had a finer instrument to make extrusions in the pipe, it would have been possible to increase the velocity of the air coming out of the slit even more. This increase in velocity is done simply by reducing the exit area of the air while holding the flow rate of the air constant.

The testing for the electrical components was split into two subheadings: sensor setup, microprocessor coding and implementation.

Since the control system of this device is all controlled electronically, we completed most of the testing for the device's time cycle. We originally set our product to take thirty seconds between the soap and water dispensation. This timeframe was suggested in CDC hand washing materials. We first set up several different timing clusters. These timing settings went from 10 seconds of washing time to 30 seconds of washing time. The time for soap and air were fixed because the soap sub-block simply needs to pump soap once, which only takes two seconds. The air time was fixed because we determined that 5 seconds was adequate to dry hands at the end of the system's iteration. We decided to test the timing structure of our device with three different arbitrary time settings. We completed these tests by asking ten people which of the time settings the preferred. This data can be seen in table 8:

Table 8: Test timing breakdown

| | Test 1 | | | Test 2 | | | Test 3 | | | Test 4 | | | Test 5 | | |
|-------------------------|----------|-----------|------------|----------|-----------|------------|----------|-----------|------------|----------|-----------|------------|----------|-----------|------------|
| Function | So ap | Wa ter | Dryi ng | So ap | Wa ter | Dryi ng | So ap | Wa ter | Dryi ng | So ap | Wa ter | Dryi ng | So ap | Wa ter | Dryi ng |
| Time of Function (s) | 2 | 10 | 5 | 2 | 15 | 5 | 2 | 20 | 5 | 2 | 25 | 5 | 2 | 30 | 5 |
| Total Time (s) | 17 | | | 22 | | | 27 | | | 32 | | | 37 | | |

We then had to ask the participants non-WPI members, what their favorite timing set up was. This data is contained in table 9:

Table 9: Participant reaction to different timing schemes

| Favorite Timing | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
|--------------------|--------|--------|--------|--------|--------|
| # of agreements | 1 | 2 | 6 | 1 | 0 |

As we can see, the most preferred timing scheme was the 20 seconds of washing. Users said that this gave them enough time to completely wash the soap off without rushing them. We did not use warm water in this test, so we believe that the water’s temperature may have motivated users to want to finish the cycle faster.

We also asked the users several questions:

1. Is the cycle too short, too long, or just right?
2. Were your hand’s cold by the end?
3. Could this device replace a sink in an academic, residential, or commercial location that is primarily used for hand washing?
4. Would you use this device over a sink?

The answers to these questions were compiled in table 10:

Table 10: Survey Responses Regarding Hand Washing Station

| Favorite Timing | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
|------------------------|--------|--------|--------|--------|--------|
| Too Short? | 9 | 7 | 1 | 1 | 0 |
| Too Long? | 1 | 1 | 2 | 6 | 10 |
| Right Timing | 2 | 3 | 6 | 2 | 0 |
| Cold hands? | 0 | 1 | 2 | 4 | 4 |
| Replacement for sinks? | 7 | 8 | 7 | 5 | 4 |
| Would you use this? | 8 | 8 | 8 | 6 | 5 |

We asked each of the questions at the end of each test and asked the users to pretend they had just used the machine for the first time. Obviously this method is far from perfect, but it does illustrate some of the responses that different people had for the different testing times.

We can see that the data is fairly easy to predict. Users commented that the shorter cycles felt as though they were not long enough to be effective. Some users acknowledged that a time that was shorter than their favorite time may have been effective, but that the extra time made them feel cleaner, and that influenced their responses.

We did see a few users complain about cold hands, but our prototype was not connected to any hot water, so it was never getting any warm water. We think this illustrates a point that water temperature is important, but we would never use water this cold in a properly installed model.

We did see several individuals say that they believed there were applications in commercial, academic, and/or residential settings for our station. At maximum, eight people believed that there were some practical locations for these devices because they force soap on the user and do not spill water. Many users also commented that they liked how all these separate devices were now combined so well.

Our sensor setup was a simple IR LED and a photodiode that were placed in such a way that a continuous beam of light shined from the LED to the photodiode. When this beam was interrupted, the system began cascading through the events that we had programmed and designed. We used a threshold value to determine an interruption, and we set this value as 0.25

volts, because we were conscientious that there may be background interference that excited the photodiode. When the photodiode put out less than 0.25 Volts, our program began.

This sounds simple in design, but we had a lot of issues establishing a consistent power source that allowed us to get a signal on the first swipe of the hand every time. We also had trouble positioning the sensors. We did not want the Led or the photodiode getting wet, but the maximum distance difference that we could get to work was around six inches. We ended up finding a suitable location in front of the air blower relative to the user. The pipe we used as a blower gave us a stable support to lean the photodiode on, and the led was mounted directly into the bottom of the unit.

In the end, we did get the sensor to function, but it was interesting to note the issues that we had in implementing the simple sensory system. In the future, we advise moving to a self-contained motion detector, because then there is only one component to keep dry, and the output is far more predictable, because we are only relying on one component and not on two. That being said, we were comfortable with our solution because it was much cheaper.

We ran into many issues with the microprocessor implementation, with the microprocessor power being our first problem, and we used diodes to take a 5V source down to 3.0 volts with diodes. This was a simple fix, but it was yet another point where we had to take less-than-ideal circumstances and work around them.

We also ran into a timer issue when we got to getting water out of the pump. The pump took around 2 seconds after being turned on to send water all the way to the nozzles. For this reason we simply started the pump right after the user triggered the sensors.

In summary, the testing section for the electronics is rather short because it simply works or it does not, that is to say, we either controlled our circuitry in the manner that we had ascertained while designing, or we didn't. We had some setbacks along the way, but eventually we managed to match our actual process flow with the one that we had. We would like to note that we will need to change the code and the circuitry in order to create a finalized version of the design instead of our prototype which is meant to be an allegory to our actual implementable design.

3.2 Ideal Model

Ultimately, the group used the created prototype to test efficiency and timing. Based on the construction and testing of the prototype, the All-In-One Hand-Washing Station team was able to determine improvements and alterations that could be made to make the product more commercially plausible. The knowledge that the group obtained from these tests allowed for the design of a final model. This entire process is discussed throughout this section.

3.2.1 The Mechanical Model

The ideal model was designed to function as previously described in the chapter and in the same general manner as the prototype with the exception of improved parts and improved performance. This particular model was designed to replace the current sink and so would sit on the same countertop as the current sink and in some cases even mount around the previous sink. The goal of the actual model is to be able to simply remove the old sink and put this device in its place with the same drainage connection and hot and cold water hookups and plug into a standard AC house wall outlet, in a sense a plug and play operational unit. With this design we also made it extremely easy to maintain with minor maintenance required at routine intervals, such as changing the air filter at the rear of the unit and adding soap to the soap reservoir when it gets low. Outside of those scheduled services the only additional maintenance would be ensuring that the drain does not become clogged in any manner which is already a precautionary measure with current sinks. The ideal model that is being described here can be seen in Figure 69:

Figure 69, Ideal Model Full Assembly, shows the complete unit installed over the current sink on top of the current counter. The list of items used for this model can be found in Table 11 and are labeled accordingly in Figures 69 through 73. A more thorough description of the items will be discussed later in the chapter.

Table 11: Ideal Model Items Used

| | |
|----|-------------------------------|
| A | Counter Top |
| B | Housing/interior splash walls |
| C | Air Blower |
| D | Sink |
| E | Drain |
| F | Water Lines |
| G | Electronic Valve |
| H | Soap Reservoir Access Cap |
| I1 | Soap Reservoir |
| I2 | Soap Pump/Base |
| J1 | Actuator |
| J2 | Custom Bracket |
| K1 | Sprayer Assembly |
| K2 | Custom Bracket 2 |
| L1 | Flexible Water Hose |
| L2 | Combined Hot/Cold Water In |
| M | Flexible Soap Line |
| N | Air Line |

Figure 70 illustrates the setup of all the interior components of the ideal system in their respective first positions. This illustration is the complete model with certain walls of the housing set to transparent in order to see the full interior. In this model we are able to see how everything is separated but yet connected in all activities. In order to not only increase safety but also decrease the affected area of the water and soap spraying interior walls were placed on both the right and left sides of the sink and water/ soap sprayer. The walls not only make the working zone neater and easier to clean but they also do not allow any water to access the soap reservoir and pump on the left hand side nor the actuator on the right hand side. They do however have cuts running down the middle to allow for the actuator bracket to slide the sprayer from front of sink to the back of the sink on the right hand side and to allow the soap sprayer hose to follow along this same path. Although there are cuts in these walls they are sealed in by rubber stripping that runs the length of them which doesn't permit the access of water to those side

sections. A closer look into the subsystems of the ideal model and how they are laid out by themselves can be seen in Figures 71 through 73:

In Figures, 71 through 73, we are able to get a very general yet visually descriptive idea of the exact locations of the three main subsystems. In Figure 71 we are able to see the starting position of the water system as well as how the water system is plumbed in and reliant upon the actuator for its motion and stability. This connection between the water system and actuator allows for the movement of the sprayer system and also maintains the sprayer's structural rigidity and levelness without being directly connected to any part of the housing. The actuator that was specified for this job has a carrying capacity of approximately 35 pounds which is more than enough to support the sprayer assembly and custom brackets, while still moving the sprayer system at a rate of 2 inches per second. The sprayer frame is made from rigid schedule 40 PVC and the water lines into the sprayer frame are made out of flexible PVC which allows for it to conform during the motion of the sprayers. The water sprayer is supplied by the standard hot and cold lines found on your sink however with this they are attached to an electronic valve which is able to automatically start and stop the flow of water when signaled by the system to do so. This unit will be shown in greater detail later in this section.

In Figure 72, we see the soap assembly setup off to the left hand side of the unit in the starting position. Here, the end of the soap line at the sprayer nozzle will be connected to the water sprayer and will travel with it, which is why the sprayer line is made of a flexible tubing. The main dispenser is a custom made soap reservoir that rest upon a stand that holds the reservoir up while protecting the pump that physically transports the soap. This unit can be seen in more detail later in this section. In Figure 73 we are able to see the Ideal Model Air Blower Assembly. In this illustration we are only able to see a simple model of the system due to the fact that the majority of this process takes place inside the blower housing where the motor and air filter are located. However, we can still see how the air ducts are set up (top and bottom of entry/exit) and lines run from the blower to the ducts.

Figures 74 and 75 illustrate a more detailed view of the sprayer assembly and soap dispenser assembly respectively. In the first we see the dimensions as well as descriptions of some of the components in a closer up view as well as from different points of view. Figure 75 shows the same views for the soap dispenser:

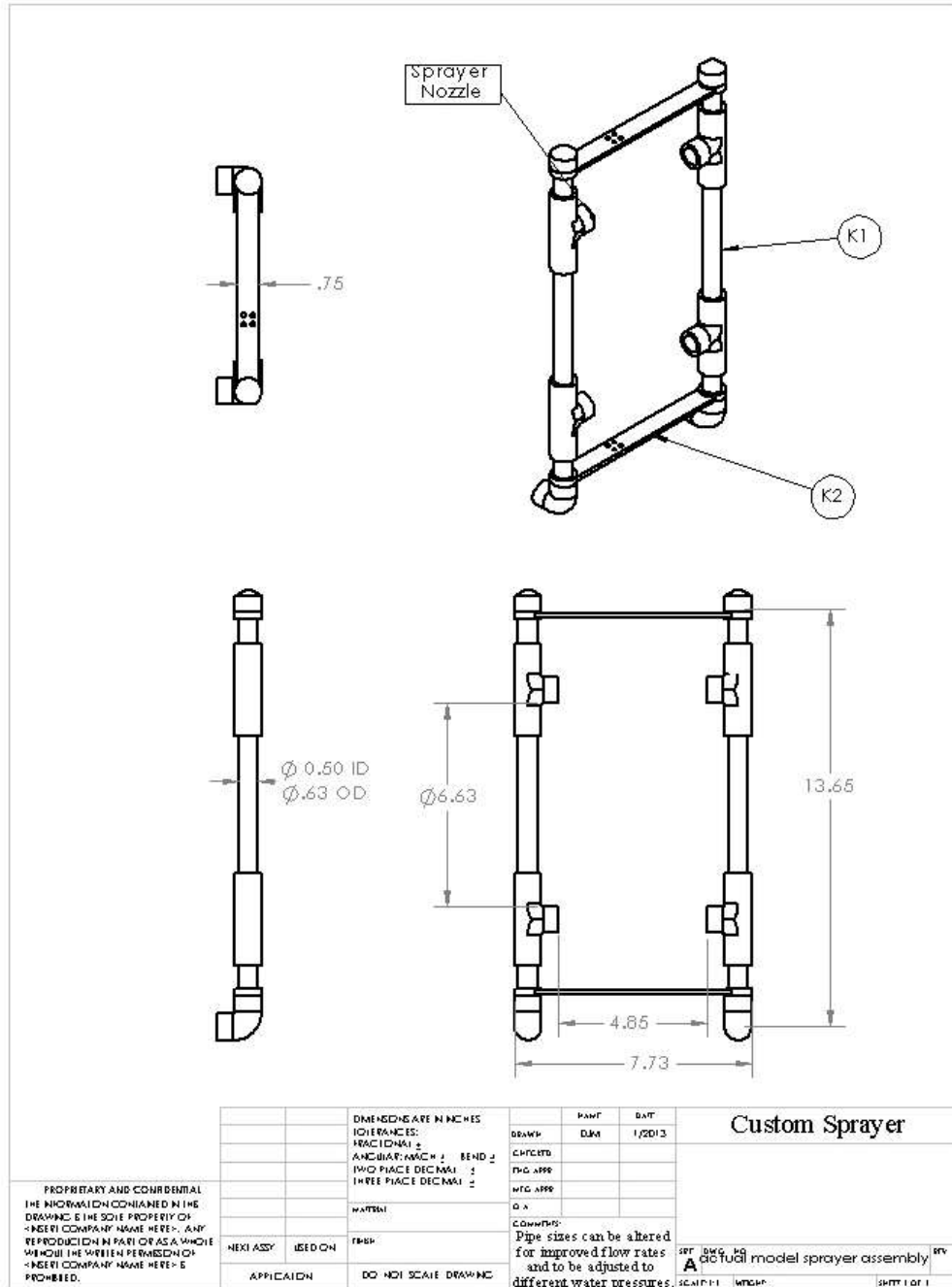


Figure 74 Custom Sprayer

The two figures above simply put represent two custom components of the ideal model that relatively easy to conceptualize. Figure 74 depicts the sprayer bar for the water. This component is made of SCH40 PVC and custom fabricated brackets that separate the top and bottom levels while not only supporting the water system but also giving an anchoring point for the actuator to attach. The pipe sizing on this can vary depending on the water flow and pressure requirements, as well as personal preferences. The second, Figure 75, illustrates the custom formed soap dispenser. This dispenser has no specific brand fit or recognition which allows it the unique ability to accept any and all types of liquid soap and can be refilled simply by twisting off the top cap and pouring new soap in. This dispenser works in the same manner as the Lysol soap dispensers do, being gravity feed, once triggered a motor will more or less pull the soap through and push it out along the soap lines that run out and attach to the water sprayer.

3.2.2 The Electrical Design

Since we created a functional prototype circuit, we will not need to change anything for our final electrical design. The only major change we would make would be manufacturing optimization. This includes the manufacture of purpose-built printed circuit boards, or PCBs for short. These boards will contain all of the wiring. Circuit components are then placed in the correct locations and the whole device is soldered. There are multiple methods for this including solder baths and robotic soldering.

Through prototype experimentation, we were able to simplify our design circuitry down to a much simpler final circuit. This simplicity also means we would be able to use a very small electrical board to hold all of our circuitry. This reduces cost by reducing the amount of actual board needed per device as well as reducing the number of solders per device.

Our electrical circuit's function is exactly the same as above. The device scans for an input, and once it receives a high voltage signal from the comparator, it begins iterating through a process. The device also scans to see if it goes for one second without any input and that causes the system to stop all functions and await a new input. This reduces water waste as well as allowing a user to get more soap if they are so inclined. A flowchart of the electrical designs motion sensors can be seen in the schematic shown in Figure 76:

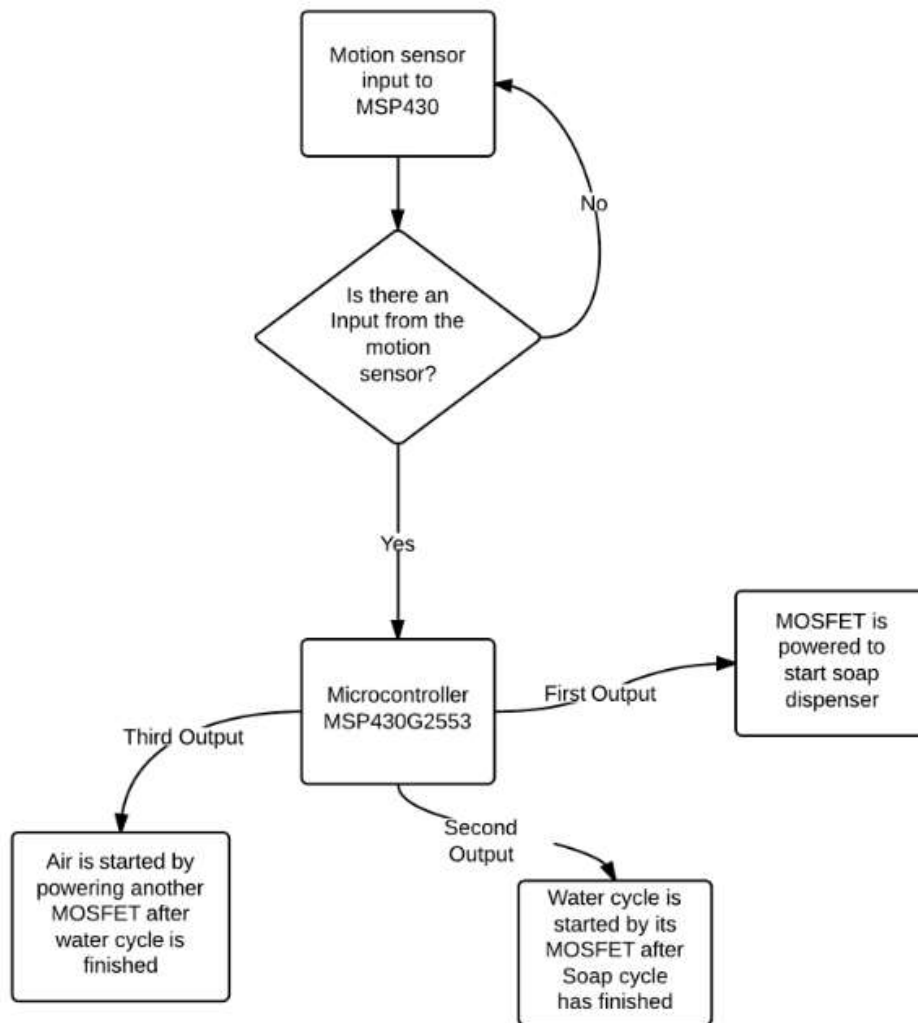


Figure 76 Basic Electrical System

As you can see in Figure 76, the system consists of a motion sensor array, a microcontroller, a soap system, a water system, and an air system. This system will be powered by the consumer's electrical system such as a wall outlet or could even be hard wired into the consumer's electrical system.

From Figure 76 it can be seen that the microcontroller will be waiting for an input signal from the motion sensor array before it will start any of the cycles. This input will tell the controller to start the soap cycle after it waits for half a second in order to let the user get their hands into position. It will then tell an actuator to start spraying the soap solution onto the user's

hands. After the soap has been applied by the sprayer it will return the actuator to its “home” or starting position while the user can begin to scrub their hands. The controller will then tell the water system to start which starts by telling the actuator to begin to rotate again while this time spraying water onto the users hands to rinse them. After the water cycle has finished, the actuator will begin to return to its starting position as it also starts the air cycle for roughly 10 seconds so the user can dry their hands as they remove them from the device.

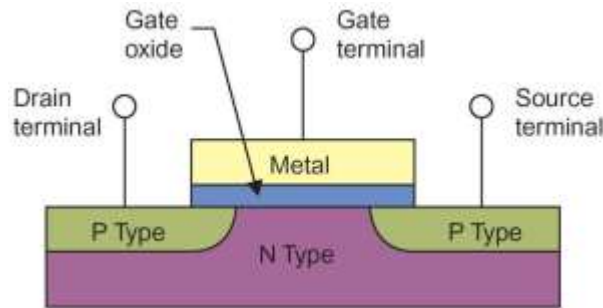


Figure 77 Basic MOSFET Schematic

The MOSFETs are the connection between the microcontroller outputs and the air, water, soap, and actuator systems. The MOSFETs we are using are rated for 500V and 8Amps which allows us to apply as much power as needed to the circuit. As the MOSFET receives a voltage from the microcontroller into its Gate terminal it will allow power to flow freely between its source terminal and its drain terminal which is illustrated in Figure 77. MOSFETs are being used to control the power connections between the soap dispenser, water sprayer, air blower, and actuator motors.

Figure 78 is an illustration of components involved in the motion sensor, a photodiode and an infrared LED:

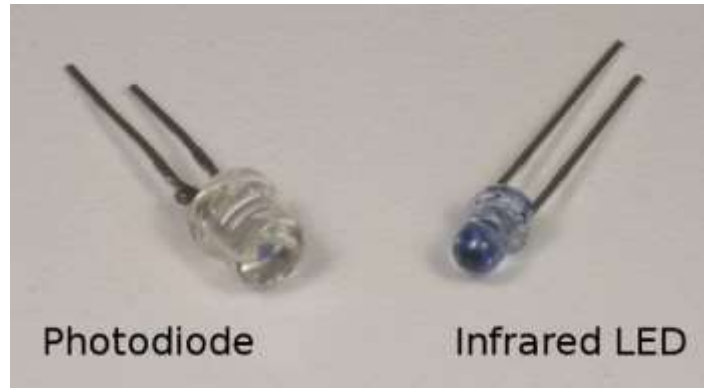


Figure 78 Photodiode and IR LED

For our motion sensors we are using two IR or Infrared LEDs with two photodiodes. The IR LEDs do not emit a visible light but instead emit a light that can be picked up by the photodiodes. The sensors react when their stream of light connecting the IR LEDs and the photodiodes is broken which cause the sensor to emit a voltage of about 3V to the microcontroller and start the devices run cycle.

For our final electrical system we chose to use an MSP430G2553 microcontroller which will collect the input from the motion sensor array and send outputs to the MOSFETs that will supply power to the air, water, and soap systems. This controller will be programmed using the C programming language. It will be coded so that as it receives an input voltage of higher than 2.5V, which is the internal reference voltage, from the motion sensor array it will cause the system to begin iterating through the functions and causing the system to run.

Once the microcontroller has the binary value from the input it will start a function within the coding for the microcontroller. It will send a constant voltage of about 3.6V to the MOSFET connected to the soap systems power and will cause the soap to dispense for roughly 2 seconds onto the users hands using a rotating actuator. The soap function will also output to an array of LEDs which will tell the user that the soap function is running. The system will then begin to return the actuator to its starting position. Next the system will send a 3.6V voltage to the MOSFET connected to the power for the water cycle. It will start spraying water onto the user's hands which should remove all the soap and grime. Another LED cluster will be turned on using the same output signal powering the water cycle. This will notify the user that the water cycle has begun. Also at any point during the water cycle if the user removes their hands for more than

four seconds the system will reset and wait for a new user. This is to prevent the users from wasting water and power if they leave at the middle of the water cycle. After the water has sprayed the actuator will begin to return to its starting position. Once this happens the controller will send a 3.6V voltage to the MOSFET connected to the power for the air system and it will begin to blow air which will allow the user to dry their hands and be done with the washing cycle. During this air cycle a third LED cluster will light up and tell the user that the wash cycle is over and they can now dry their hands.

An example of the C code being used to program the microcontroller can be seen within the Appendix. It shows the steps that the system must go through in order to complete one entire device cycle. It starts by setting up an internal timer called `Timer()` which selects the clock type and sets it to count up from zero. We then set the clock so that every 1 tic of the system occurs every 0.25 seconds. From here the code enters its `main()` function.

First the `main()` function sets up the pins that are going to be used on the MSP, if they will be inputs or outputs, and also sets all output pins to logic low or 0V. Next the `main()` calls for a function called `StartCycle()` which looks for an input of higher than 2.5V, which is a reference within the microcontroller, from the motion sensor. If this input is obtained it is saved as a variable called `inbit`. The code then jumps back to the main and goes into a while loop which means that while the value stored in `inbit` from the sensor is greater than zero the loop will run. The while loop starts by sending a 3.0V-3.6V voltage to the MOSFET connected to the power supply of the soap system by running the function `Soap()`. Within this function it sets what pin on the controller will be outputting the voltage, for this function it outputs to pin 3 and pin 4 on the microcontroller. Next the `StartCycle()` function starts a `wait()` loop which cause the controller to wait a certain number of n-periods of the clock cycle. So if we set this to 2 periods it would wait 2 cycles of the clock before moving onto the next step of the while loop located in `StartCycle()`. Next it starts the `Water()` function which will power the water pump and actuator using pin 5 and pin 6 of the microcontroller. It will send a voltage of 3.0V-3.6V to the MOSFET and turn this system on. Then another delay cycle will be started of about twenty seconds to give the system enough time to spray the hands and return the actuator to starting position. After that it will start a cycle called `Air()` which starts the air blower to dry the users hands. This output has been set to pin 14 and 15 and will also be outputting 3.0V-3.6V. The system will then delay for another 20-

periods or about ten seconds when the Air() function will stop and the while loop will then call the main() function which starts the whole process over again.

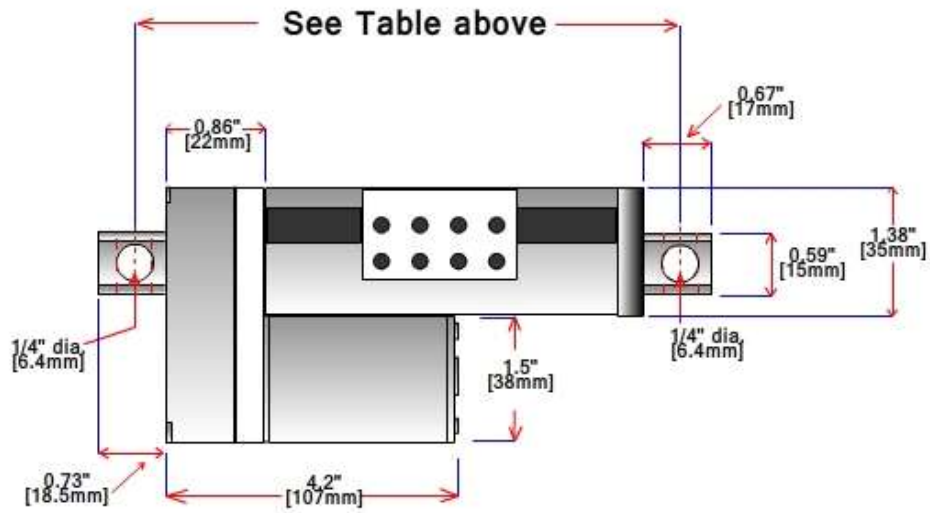
3.2.3 Materials used in Ideal Model Design

The materials that are described in the mechanical design for the ideal system were essentially chosen to simply improve the quality, performance, aesthetics, and durability, ease of use and hookup, and ease of maintenance. With that being said, the materials chosen can be seen in Table 12 with some shown in Figures 79 and 80. Some of the materials on this list will be readily available when replacing the system, such as the counter top, drain, sink, in some cases, and water lines, thus allowing for a plug and play system that is easy to install:

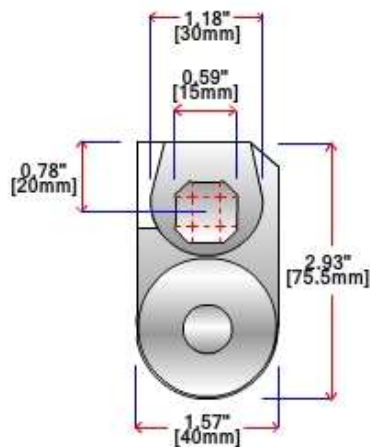
Table 12: Ideal Model Materials

| Item | Part Name | Description | Quantity |
|------|-------------------------------|--|------------|
| A | Counter Top | Standard Commercial Restroom Counter | 1 |
| B | Housing/interior splash walls | Plexiglass walls cut to spec | 1 assembly |
| C | Air Blower | Blower motor, housing, filter | 1 assembly |
| D | Sink | Standard Sink (Item modeled is a Bar sink) | 1 |
| E | Drain | Standard Drain Assembly (PVC Pipe(Straight Pipe, Ptrap, 90° Elbow)) | 1 assembly |
| F | Water Lines | Standard water lines (Hot and Cold Lines In) | 1 each |
| G | Electronic Valve | Control Valve for water flow in | 1 |
| H | Soap Reservoir Access Cap | Refill point for soap replenishing | 1 |
| I1 | Soap Reservoir | Custom Made Reservoir (plastic) | 1 |
| I2 | Soap Pump/Base | Custom Base, pump | 1 assembly |
| J1 | Actuator | Firgelli Automations Model FA-35-TR-10 | 1 |
| J2 | Custom Bracket | Custom made bracket to fit actuator and sprayer bracket | 1 |
| K1 | Sprayer Assembly | Custom Made Sprayer (PVC) to spec | 1 assembly |
| K2 | Custom Bracket 2 | Custom made to fit sprayer assembly and actuator bracket | 2 |
| L1 | Flexible Water Hose | 0.5" ID, Length cut to spec | varies |
| L2 | Combined Hot/Cold Water In | 0.5" ID, Length cut to spec | varies |
| M | Flexible Soap Line | 0.25" OD, Length cut to spec | varies |
| N | Air Line | 0.25" OD, Length cut to spec | varies |

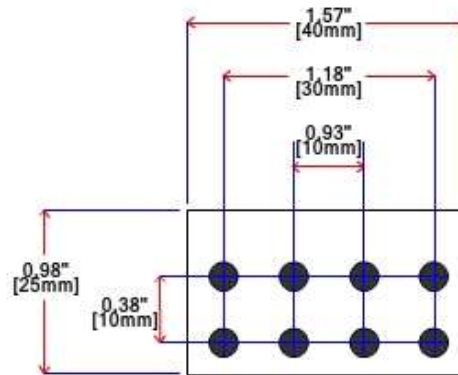
| Models | Load capacity | Stroke Length | Hole to Hole Dimensions |
|--------------|---------------|---------------|-------------------------|
| FA-35-TR-5" | 35 pounds | 5 inches | 10 inches |
| FA-35-TR-10" | | 10 inches | 15 inches |
| FA-35-TR-15" | | 15 inches | 20 inches |
| FA-35-TR-20" | | 20 inches | 25 inches |
| FA-35-TR-25" | | 25 inches | 30 inches |



1 Side View



2 Top View



3 Carriage View

Figure 79 Fingelli Automations Model FA-35-TR Mini Track Actuator

Figure 79 illustrates the Firgelli automations mini track actuator model's FA-35-TR. This particular actuator was chosen due to the compact size and the power and speed of the unit fit well into the constraints we set. This model is able to withstand 35lbs and still move at a rate of 2" per second which was pretty much exactly where we needed it to be for the sake of moving the sprayer assembly down the length of the user's hands and back. This was also chosen because it is easy to use on requiring a change in the polarity to reverse its direction, and can be connected very easily to the control system.

Figure 80 is an image of the Dyson Digital Motor that is used in the Dyson AirBlade. The ideal model would hopefully utilize a motor of similar specifications and characteristics to produce the air flow required to scrape the water off the user's hands:



Figure 80 Dyson Digital Motor v4

Additional items specified for the ideal model would either be very similar to those currently used in restrooms or they would be custom made to specs previously described, such as the sprayer and soap assemblies previously discussed.

3.3 Overview of Ideal System

The final design that the group developed is extremely user friendly, not just for the user but also for the maintenance and installation personnel. This device is designed in such a manner that it can replace an old sink and faucet, with minimal change, while maintaining the existing counter top and plumbing configurations. The existing hot and cold water lines connect directly into an electronic valve located at the base of the device, and the drainage simply screws into the base of the sink in the same manner as current installation procedures suggest. This device operates off of a standard wall outlet and is completely touch-free for the user. All processes are pre-determined and operate off of a control circuit. As soon as the user places their hands inside the housing IR sensors detect them and start the process.

The process starts off by spraying soap from the user's wrists down to their fingertips in approximately 3 seconds. A delay is introduced as the actuator pulls the sprayer assembly back to the starting position; this allows the user an opportunity to scrub their hands together to get rid of any set in grime. Once the sprayer reaches the starting point the water begins to spray and runs again from the user's wrists to their fingertips again in approximately 3 seconds. The water sprayers are located above and below both hands for a total of 4 spraying nozzles. Once the water cycle is completed the system then initiates the hand dryers, located at the entrance to the housing. The hand dryers then produce powerful streams of air that scrape the water from the user's hands as they slowly remove them from the system. This process will last for approximately 10 seconds, during which the actuator returns the sprayer assembly to the starting position in preparation for the next user.

At any point during the process if the user removes their hands from the system for over a second the sensors will terminate the session and everything will return to the starting point in preparation for another user. This design is extremely easy to clean, with all operations contained inside the housing, and upkeep with direct access to the soap reservoir on the top of the unit for refill purposes. This proposed device will also be extremely helpful in the upkeep of public restrooms since it keeps all activity confined to one area inside the housing, this means no water pools on the floor or counter should occur in relation to this process. A flow diagram of the operations can be seen in Figure 81:

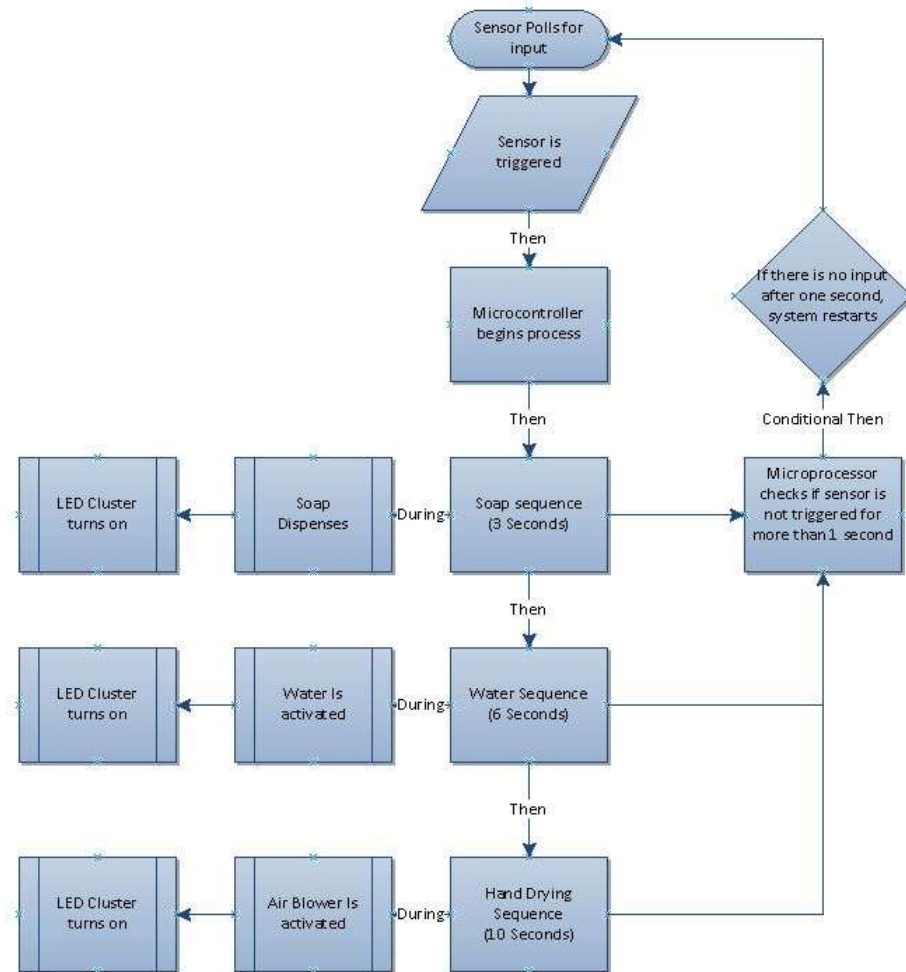


Figure 81 Operational Flow Diagram

This diagram basically represents in a simplified manner what exactly the control system is doing before the process even begins as well as throughout the entire course of the hand wash cycle. In this diagram we can see the phases that the system runs through and what it is looking for during the process to ensure proper function. We are also able to see the interactions that the control system has with the user, notifying them about each phase of the system by means of an LED light that turns on during each individual process.

3.3.1 Financial Breakdown

When designing the device the group faced the task of making sure the total cost for the consumer would be comparable to the current methods and materials used. This cost would include the price of the individual components as well as the manufacturing costs and a profit margin placed on the device. After conducting a cost analysis for the design that the group developed versus comparable equipment in use in restrooms currently we found that there was approximately a \$600 difference in favor of our design. This breakdown can be seen in Tables 13 and 14:

Table 13: Cost Analysis for New Device

| Use | Material | Dimensions | Cost (\$) | |
|-----------------------|-------------------------------------|--------------------------|-----------|--|
| Housing | Plexiglas | .08"x48"x48" (sheet) | 48.65 | |
| Soap Reservoir | Plexiglas | 1/16"x24"x48" (sheet) | 20.46 | |
| Actuator | Linear Actuator | 8" Stroke Length | 159.99 | |
| Water Distribution | Electronic Valve | 125psi | 225 | |
| Soap Distribution | Diaphragm Pump | 60 psi max | 69.99 | |
| Air Distribution | Air Pump assembly | | 90 | |
| Connections and hoses | Flex pipe, pipe, screws/bolts, etc. | Miscellaneous | 150 | |
| Electronics | Control Circuit | | 25 | |
| Sink | Stainless Steel | Varies | 50 | |
| | | | 839.09 | Parts Total |
| | | | 100 | Manufacturing Cost (approx.) |
| | | | 234.77 | Profit (Total + Manufacturing cost x 0.25) |
| | | | 1073.86 | Adjusted Total |

As can be interpreted from Table 13, the adjusted total at the bottom of the table includes manufacturing cost, parts, and a 25% profit margin based on the parts and manufacturing totals. This would be the approximate sale price for a single unit. These values in the table represent the cost per single unit which would dramatically decrease if purchased in bulk. In addition, there may also be a greater profit increase depending on future findings with additional overhead costs, and/or additional fees associated with the sale of the device.

Table 14: Cost Analysis of Current Items Used

| Use | Material | Description | Cost (\$) | |
|----------------|--------------------------|--------------------|------------------|---------------|
| Sink | Porcelain | Drop in Sink | 69 | |
| Soap Dispenser | Plastic | Gojo touch-free | 30 | |
| Faucet | Chrome | Touch-free faucet | 367 | |
| Hand Dryer | Plastic/mechanical parts | Dyson Airblade | 1199 | |
| | | | 1665 | Overall total |

As seen in Table 14, the overall total includes the four individual components that are needed for the full hand washing cycle. These components were chosen based upon their individual performance based comparably to the subcomponents of the all-in-one device designed by the group. The cost found in the table is the retail price for these components which already has the company profit and manufacturing costs included. The overall difference in price is close to \$600 in favor of the design developed by the group.

3.3.2 Locations for the Device

The all-in-one unit that was designed by the group has many key features that make it desirable for many types of locations and users. The primary locations that this design is perfect for are public restrooms in higher traffic areas such as malls, schools, sporting arenas, and many more. The great features of this design improve the overall quality of the restroom for all users. With all of the aspects of hand washing taking place in a single unit there is no water that spills out on the floor or countertops, no soap lying on the countertop, and no paper towels strewn across the floors and counters and everywhere except the trash. Another nice feature that this design includes is the reduction in the hand washing and drying cycle time down to one-third of the current time allowing a greater turnover rate of users. Other features which make this great for public restrooms are; the completely touch-free nature of the device, the ability to simply replace the existing sink with this unit and not have to adjust any plumbing or walls to accommodate it, the resource conscious nature of the device, and the ease of use and maintenance.

Additional key features that help expand the uses and locations that this device can be used in are the fully programmable control circuit, which can be adjusted to allow for a longer or shorter process of any or all of the three main functions of the device, and the ability of the device to accept any liquid hand soap. These two features give the device the potential to be utilized in the health industry and the food industry, where more stringent requirements are in place for hand washing. In general this design would be great for pretty much any location that requires users to wash their hands, or at least inspires users to sanitize and prevent the spread of germs.

3.3.3 Motives to Switch to New Device

Several motives to switch to this new device designed by the MQP group include but are not limited to: resource conscious operations, fully touch-free setup, and restroom cleanliness, ease of use and maintenance, programmable cycles, space saving design, cost, and speed of a hand wash cycle. This multitude of features makes this design desirable for numerous locations, and if saving money is not motive enough to switch the resource management and space saving design should be more than enough motivation to switch. Whether you're looking to update or restore a restroom in a public venue, or you're looking to build a new restroom this design will fit into your budget and layout with ease. The device is easy to install, with no more installation time or work than a traditional sink, and is 100% operational once fully plumbed and plugged into the wall outlet for power. So, this even saves time and hassle for the maintenance crew to install, and upkeep with easy access to refilling soap reservoir, and little to no need to clean up pools of water left between stations of the traditional hand washing technology.

CHAPTER 4 – CONCLUDING REMARKS

Besides obvious improvements technologically, which would significantly increase the budget of the project, there are several simple design changes that could be implemented on the All-In-One Hand-Washing station in order to improve production. One last minute improvement the group was able to make in order to improve the flow rate of the water was to raise the height of the reservoir below. This allowed for over six inches of tubing to be removed, therefore increasing the flow rate of the water by approximately 25 gallons per hour. This improved the quality of the prototype, making it more similar to the flow rate if the housing was attached to the plumbing of a sink as opposed to a water pump. This allowed the group to run improved tests of the prototype.

Air flow rate is another factor that could be improved upon in a future design. Ideally, the group would have liked to match the flow rates of the Dyson AirBlade illustrated in Figure 15 but this was not within budget. Instead the group used a similar method as the water pump in order to produce a blow-drying effect. In order to remain within budget, the group only purchased one air pump. Ideally, two would have been used to mimic the AirBlade's design to strip the water off both sides of the user's hands. The slit in the pipe only increased the air flow rate by a factor of 1.325 because the group used a knife to cut the slit in the tube. Had the slit in the tube been made smaller, the flow rate of the air could have been increased to over two times that of the pump itself. These several factors could be used to improve a future model of the All-In-One Hand-Washing station.

Further improvements can and should be made before actually building a real model of the device for sale. These improvements include building an updated model with all of the components specified from the ideal model design and actually physically attaching it to a real water line and drain setup and running actual tests in an actual restroom. This would help greatly prove the effectiveness of the device on the user-friendly aspect, as well as cleanliness and speediness of the process.

Additional future improvements that are suggested to be made fall well after extensive further testing. Some of these ideas include; creating a self-cleaning function where after a certain length of time or number of users the system will run a cleaning mode. This will close off

the unit for one cycle and instead of running normal operation will run a cleaning spray that will wash down and sanitize the interior of the unit. Another idea would be to possibly run the system partially off of solar power. This would mean affixing solar panels to the exterior of the housing that would be able to operate off of power harnessed from the florescent bulbs in the restrooms.

The project can be broken down into two main sub groups that have equal pull on the success of the project. These two sub groups are mechanical design and electrical design, without both the project would have failed.

The mechanical design of the project helped to bring the visual aspect of the system into grasp with three dimensional models developed through CAD software and later on through actual prototype models being produced. This all goes together with proper calculations for sizing and materials to be used for the models, as well as extensive research for methods and processes to utilize in our designs. The mechanical design was fueled by many factors which can more or less be summed up with one word, improvement. This one word sparked many ideas and to this day continues to spark ideas on ways to improve upon the design.

The electronics also play a major part in this project. They control all of the functional blocks, sense user inputs, and deliver power where it is needed at any given time. The electronics were developed with two foci in mind: simplicity and effectiveness. We went through many iterations of our design circuit, but finally created a functional and responsive device.

The electronics in this system are broken down into five blocks:

1. Sensor block—this block is comprised of an LED, a photodiode, and a comparator. These components come together to allow the device to sense a user's hand, or any other non-transparent object, and begin the cascade of events that cause the system to perform its tasks. This block is the input to a microcontroller.
2. Block A—This block simply tells the user, by illuminating LEDs, that the device is not stuck on some functional task and that it is ready to begin washing hands. It is controlled by a microcontroller.
3. Block B—This block activates once a user's hand begins the hand washing process. The block lights up LEDs to alert the user that it is dispensing soap,

which the device accomplished by driving a DC motor with 5 Volts. This block is also controlled by a microcontroller.

4. Block C—This block activates a water pump in our prototype, which we would replace with an electronic valve once the device is plumbed into a permanent water source. Again, LEDs alert the user that the device is performing the task of delivering water to the hands. The power management system was difficult because we had never learned to control an AC voltage source before. This block is controlled by a signal from our microcontroller
5. Block D—This is the final block in the system and alerts the user that it is active with LEDs. This block also delivers power to an air blower, which delivers pneumatic pressure to a pipe with a slit that blows water off of the hands. This block also caused difficulties because of the AC power management that it required. This block is controlled by our microprocessor.

The electrical system is complex as a whole, but taken in parts it is easy to understand. Each block has a specific function. Each block successfully manages that function. In total, this device completes the hand washing process due to the success of the electronic components.

In the end the project proved to be a success. The group was able to build a functioning prototype that successfully portrayed our ideal model and also set the path for future work to be done developing the full scale model that will hopefully make its way into restrooms in the near future.

Works Cited

- [1] [US], LEWIS RICHARD P, TRAMONTINA PAUL F [US], KAUFMAN KENNETH [US], and YORK CHERYL L [US]. A Device For Encouraging Hand Washing Compliance. Europe Patent 1794727. 6 13, 2007.
- [2] *ReStockIt.com*. 2009. [http://www.restockit.com/kess-industrial-products-pearldrop-liquid-hand-soap-1-gallon-\(pearldrop\).html](http://www.restockit.com/kess-industrial-products-pearldrop-liquid-hand-soap-1-gallon-(pearldrop).html) (accessed 12 2011).
- [3] Advameg, Inc. *Science Clarified*. 2011. (accessed 2011).
- [4] Albert, Stephen B., and W. Benjamin Thomas. Surgical Soap Dispenser. United States Patent 4946070. February 16, 1989.
- [5] "AODD Pumps & AODD Pump Suppliers." *PumpScout*. 2011. <http://www.pumpscout.com/all-pump-types/air-operated-double-diaphragm-pumps-aodd-ptid77.html> (accessed December 2011).
- [6] Bargaquast, Scott. Portable Hand Cleaner. United States Patent 6161227. 8 17, 1999.
- [7] Barnhill, Paul R., James Glenn, and Timothy Prodanovich. Appendage Cleaner with Brush. United States Patent 7698770. 4 20, 2010.
- [8] Barnhill, Paul R., James Glenn, and Timothy Prodanovich. Automated Washing System. United States Patent 8110047. 12 4, 2008.
- [9] Brassard, Jeremy, David Markham, and Amber Truhanovitch. *Replacement Hand Washing System*. Worcester: Worcester Polytechnic Institute, 2011.
- [10] Chardack, William M. United States Patent 5,727,579. 1996.
- [11] Colorado Department of Public Health and Environment. *Infectious Disease In School Settings*. Denver, December 2004.
- [12] "Comparing 4 Types of PD Pumps." *Pump School*. 2007. <http://www.pumpschool.com/intro/selection.htm> (accessed December 2011).
- [13] Davies, Joseph R. United States Patent 4,606,085. 1985.
- [14] Depot, Office. *Office Depot*. n.d. <http://www.officedepot.com/a/products/625999/Purell-NXT-Hand-Sanitizer-Dispenser/> (accessed October 5, 2011).
- [15] Dispensers, Dolphin. *Dolphin Dispensers Hot Air Dryers*. n.d. <http://www.dolphindispensers.co.uk/products/bc2200sa-r-dolphin-recessed-hot-air-dryer/154.htm> (accessed September 19, 2011).

- [16]Dunkin, Mary Anne. "Surprisingly dirty places in your home." 2009.
<http://women.webmd.com/home-health-and-safety-9/places-germs-hide> (accessed September 2011).
- [17]Dyson. *Dyson Airblade*. n.d. <http://www.dysonairblade.com/homepage.asp> (accessed September 19, 2011).
- [18]Ennis, G. Thomas, and Robert G. Chelton. United States Patent 4,652,368. 1986.
- [19]"Flat Bottom Utility Tanks." *The Tank Depot*. 2011. <http://www.tank-depot.com/product.aspx?id=125&c=5> (accessed December 2011).
- [20]Foster, Frank. United States Patent 6,125,482. 1997.
- [21]Foster, Frank. Hand Washing Apparatus. Europe Patent EP0848114 A2. 1 17, 1998.
- [22]Fraser, Susan L. "Medscape: Drugs, Diseases & Procedures." *Enterococcal Infections*. September 19, 2011. <http://emedicine.medscape.com/article/216993-overview> (accessed 2011).
- [23]*Georgia Pacific*. n.d. <http://productcatalog.gp.com/Product.aspx?Pid=9734&View=2> (accessed 11 13, 2012).
- [24]*Google Books*. n.d.
[http://books.google.co.in/books?id=MpvvManMyl0C&pg=PA105&lpg=PA105&dq=piping+schematic+household+sink&source=bl&ots=n4PvjAMZs1&sig=eylhnn6WXeCsFUKKIJeIYjsox8o&hl=en&sa=X&ei=JpwJUzqpFMbX0QGrvoGYAQ&ved=0CEgQ6AEwBw#v=onepage&q=piping%20schematic%20household%](http://books.google.co.in/books?id=MpvvManMyl0C&pg=PA105&lpg=PA105&dq=piping+schematic+household+sink&source=bl&ots=n4PvjAMZs1&sig=eylhnn6WXeCsFUKKIJeIYjsox8o&hl=en&sa=X&ei=JpwJUzqpFMbX0QGrvoGYAQ&ved=0CEgQ6AEwBw#v=onepage&q=piping%20schematic%20household%20) (accessed 1 26, 2013).
- [25]*Google Images*. n.d.
<http://www.google.com/imgres?q=motion+sensor+sink&hl=en&sa=X&tbo=d&biw=944&bih=926&tbnm=isch&tbnid=6moW6Wptbbv6VM:&imgrefurl=http://netninja.com/2012/08/21/washing-my-hands-with-help-from-a-makerbot/&docid=iFIMa0lCj7sliM&imgurl=http://netninja.com/wp-content> (accessed 11 6, 2012).
- [26]"HD-950 1" Whole House Filter System." *waterfilters.net*. 2001-2011.
<http://www.waterfilters.net/HD-950-1-Wholehouse-Filter-System.html> (accessed December 2011).
- [27]*Home Tips*. n.d. <http://www.hometips.com/how-it-works/kitchen-sink-drain-plumbing.html#how-a-bathroom-sink-drain-works> (accessed 1 25, 2013).
- [28]Kamal, Ibrahim. *Infra-Red Proximity Sensor (I)*. 01 24, 2011.
http://ikalogic.com/ir_prox_sensors.php (accessed 11 02, 2011).
- [29]Lyon, Donald E. United States Patent 7888657. 2008.

- [30] Maddison, David, and Christopher Dawson. Liquid Soap Dispenser. United States Patent 4573612. November 28, 1983.
- [31] *Mar Cor Purification*. n.d. <http://mcpur.com/main/hfcap.htm> (accessed 11 7, 2012).
- [32] "NDP Derm+." *Vesimin Soluciones de desinfeccion*. 2011. http://www.vesimin.com/producte.php?id_producto=26 (accessed December 2011).
- [33] Ophardt, Heiner. Psychic Dispenser. United States Patent 8245877. 8 21, 2012.
- [34] "Pentek U440 FreshPoint Ultrafiltration Whole House Water System." *waterfilters.net*. 2011. <http://www.waterfilters.net/Pentek-U440-Ultrafiltration-System-160380.html> (accessed December 2011).
- [35] *Permatex*. n.d. <http://www.permatex.ru/brand/img/FastOrangeGroup.jpg> (accessed 11 5, 2012).
- [36] Puente Redondo, Victor A., and et al. *Vesimin Disinfecting Solutions*. n.d. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDgQFjAA&url=http%3A%2F%2Fwww.avicenne-medical.net%2Fapp%2Fdownload%2F3661110352%2FDossier%2Binternational%2BNDP.pdf%3Ft%3D1313487075&ei=GURcUZ_DMbio4AOm8YDwCg&usg=AFQjCNGKYeuUZgsSMBwgttR (accessed 10 25, 2011).
- [37] "Pump Types Guide." *PumpScout*. 2011. <http://www.pumpscout.com/articles-scout-guide/pump-types-guide-aid100.html> (accessed December 2011).
- [38] Rybicki, Ed. *ViroBlogy*. September 28, 2011. <http://rybicki.wordpress.com/2008/03/19/from-what-did-viruses-evolve-or-how-did-they-initially-arise/> (accessed October 2011).
- [39] Stanley E. Flowers, Sr. United States Patent 5,924,148. 1998.
- [40] Staples. *Staples*. n.d. http://www.staples.com/Purell-TFX-Touch-Free-Hand-Sanitizer-Dispenser/product_675291 (accessed October 5, 2011).
- [41] Thellmann, Rick. United States Patent 6,013,181. 1998.
- [42] Todar, Kenneth. "Online Textbook of Bacteriology." *Staphylococcus aureus and Staphylococcal Disease*. 2011. <http://www.textbookofbacteriology.net/staph.html> (accessed 2011).
- [43] "Trojan UVMAX A UltraViolet System." *waterfilters.net*. 2011. http://www.waterfilters.net/Trojan-UVMAX-A-UltraViolet-System_p_29954.html (accessed December 2011).
- [44] *United Broadcast*. n.d. <http://www.unitedbroadcast.com/Home/7760-ndp-med-concentrated.html> (accessed 11 12, 2012).

[45]Zentralbl, Veterinarmed B. *Pub Med*. n.d. <http://www.ncbi.nlm.nih.gov/pubmed/9820116>
(accessed 11 12, 2011).

Appendix

A.1. Control Code

```
/****** Headers *****/
#include <msp430.h>
#include <msp430g2553.h>
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <in430.h>
#include <stdbool.h>

/****** FUNCTIONS *****/
void StartCycle(void);
void Water(void);
void Soap(void);
void Air(void);
void Timer(void);
void Reset(void);
void Delay(unsigned int max_cnt);
/****** Variables *****/
unsigned int inbit;

/****** Timer() *****/
void Timer(void){
    TACTL = TASSEL_1 + MC_1 + ID_0; //
    TACCR0= 3000; // = 0.25 secs
}

/****** main() *****/
void main(void){
    WDTCTL = WDTPW + WDTHOLD; // Stop watchdog timer.
    Timer(); // starts Timer A.
    P1SEL &= ~(BIT7|BIT6|BIT5|BIT4|BIT3|BIT2|BIT1|BIT0); // sets all P1 pins to digital I/O.
    P1DIR |= (BIT7|BIT6|BIT5|BIT4|BIT3|BIT2|BIT1) & ~(BIT0); // sets P1.7-.2 to
    outputs and P1.0 to an input.
    P1OUT = 0x00;
    StartCycle(); // starts main system cycle.
}

/****** StartCycle() *****/

void StartCycle(void)
{
    while(1){
        inbit = P1IN; // sets a variable inbits to the input from P1IN.
        if(inbit >= 1){ // if input logic high (2.5V-3.6V) main cycle starts.

            Soap(); // soap cycle begins.
            Delay(8); // soap pumps for 1.5 secs due to delay.
        }
    }
}
```

```

    P1OUT = 0x00;
    Water();           // water cycle begins.
    Delay(4);         // water runs for 20 seconds due to delay.
    P1OUT = 0x00;
    Air();            // air cycle begins.
    Delay(40);        // air blows for 10 seconds due to delay.
    P1OUT= 0x00;
    main();           // main function restarts and waits for next user.
}
else
    if(inbit < 1){    // if no input startcycle() runs again waiting.
    StartCycle();
    }
}
}

/***** Water() *****/
void Water(void)
{
    P1SEL = P1SEL;    // restates what pins are doing.
    P1DIR = P1DIR;    // restates what Pins are inputs and outputs.
    P1OUT |= (BIT4|BIT5); // sets P1.5 and P1.4 to output 3.6V and power water pump

    unsigned int cnt3 = 0;

    while(cnt3 < 20){
    Delay(4);
    Reset();
    cnt3++;
    }

} // and LED2 array.

/***** Soap() *****/
void Soap(void)
{
    P1SEL = P1SEL;    // restates what pins are doing.
    P1DIR = P1DIR;    // restates what Pins are inputs and outputs.
    P1OUT |= (BIT2|BIT3); // sets P1.2 and P1.3 to output 3.6V and power motor and
} // LED1 array.

/***** Air() *****/
void Air(void)
{
    P1SEL = P1SEL;    // restates what pins are doing.
    P1DIR = P1DIR;    // restates what Pins are inputs and outputs.
    P1OUT |= (BIT6|BIT7); // sets P1.6 and P1.7 to output 3.6V and power air
} // blower and LED3 array.

/***** Delay() *****/
void Delay(unsigned int max_cnt) // creates a time delay for the system.
{
    unsigned int cnt1=0, cnt2; // so it can power specified systems for the
    // time needed.

    while (cnt1 < max_cnt)

```

```

    {
        cnt2 = 0;
        while (cnt2 < 65535)
            cnt2++;
        cnt1++;
    }
}

/***** Reset() *****/
void Reset(void){
    inbit = 0;
    inbit = P1IN;

    while(inbit < 1){
        Delay(6);
        inbit = P1IN;
        if(inbit < 1){
            StartCycle();}
        else
            break;
    }
}

```