$H_2\Omega$

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A smart water bottle system that keeps record of a user’s water intake and self sanitizes.

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1.0 Executive Summary

There are very few, if any, 'smart' water bottles available for consumer purchase. Many people either do not realize that they are not drinking enough for their own body type to stay healthy or they simply forget to drink enough water at all. Our team plans to create a water bottle that can free itself of bacteria and tell you exactly how much water you have consumed during that specific day. One half of this project will be the water bottle, which takes measurements and sanitizes the water. The other half will be a mobile phone application where the user can view their current drinking progress as well as history.

Health should always be a priority and the H-2-Ohm ties that into every user's daily life. It combats issues like when the elderly become dehydrated and sickly, whether it's because they can't remember to drink or they don't realize that they should, or even if someone wants to limit their water intake for a medical condition. The H-2-Ohm will notify its users when they have not consumed water in a reasonable time and keep them aware of their water goal for the day. To make sure the experience is tailored for each user, there will be a portion of the mobile app that pairs with the water bottle. The app will allow for entry of the user's personal information and body type if they choose to have the app estimate a water consumption goal for them. If the user wants to manually enter their own goal, this will be possible as well.

The H-2-Ohm's phone application will be user friendly and will work by wirelessly pairing the user's phone to the bottle and displaying the information gathered from the sensors to keep them aware of their water consumption. Keep in mind that the bottle itself will act just like a regular water bottle so there is no need for the users to have to do anything other than relax and take a drink just like they would from any other bottle on any other day. They can also rest safe knowing that the bottle and the water contained inside will be sanitized to make sure that everything stays clean, safe, and odor free.

2.0 Project Summary

In today's day and age, it seems as though everyone is constantly on the move trying to stay afloat between school, work, exercise, and family time. Getting caught up in the day and forgetting to eat is not unheard of, but in general people don't ignore the feeling of hunger. However, the same cannot be said for remembering to hydrate. Drinking enough water daily is critical to the human body's overall function and health. It is natural for people to be preoccupied and forget to drink, or for some reason, they do not drink enough so they will not need to use the restroom.

The motivation behind creating a water bottle that tracks how much water its user consumes as well as self-sanitizing is to keep people healthy. It should be noted that this does not just stop at helping people who are not drinking enough water, but to those who are on liquid restricted diets due to medical conditions as well. Writing a note every time you refill your water bottle or measuring how much you have already consumed is not only inaccurate but it's also very unlikely a person will stick with it. Older people tend to forget to drink enough water or they can't sense that they are thirsty which can cause a severe decline in their health and renal function. This water bottle would try and preemptively tackle a bad habit before serious health issues arise and cause any permanent harm.

2.1 Project Goals

There are a few water bottles on the market that either track how much water you drink or self-sanitize, but the H-2-Ohm would be combining these critical objectives into one bottle. The main goals are to be accurate, low cost, waterproof, and energy efficient. Accuracy of determining the water level in the bottle is critical to keeping track of the user's intake. To do this, a sensor will need to be set up to take measurements after every time the user removes and then places the cap back on the bottle, indicating they took a sip of water. All of this information will be sent to a microcontroller to analyze. When the cap is placed back on the bottle, a signal will be sent to the controller to indicate that the water level sensor should be activated if the water bottle is upright, which in turn will send its data back to the controller.

Most products strive to be low cost, but it is especially important to this design since water should not be a luxury. Expensive water bottles turn people towards buying plastic non-reusable ones that are polluting the Earth. It also only makes sense that the H-2-Ohm be waterproof. This is critical for the functionality and lifetime of the product. The entire system will always be in close proximity to water, and it is imperative to keep the water from ruining the electronic components.

When it comes to power efficiency, the bottle would run on a rechargeable battery that would only need to be charged a maximum of once a week. The battery will need to power the microcontroller, sensor, detector, communication, and sanitation. The sanitation will keep the bottle and the water clean on the inside. The sanitation cycle will be run on timed intervals throughout the day in order to keep the bottle and its components in the best possible conditions.

H-2-Ohm will tie all of this together into an application for a mobile device that will pair with the bottle to keep the user alerted and engaged with their water consumption. The application will tell the user how much water they have consumed, let them set water consumption ranges/limits, and notify users if they have been drinking too little or too much water. Also, for general safety of the user, the bottle's sanitation cycle will immediately turn off and not activate when the cap of the bottle is off. Overall, this product will improve the health of many people, and since everyone needs to consume some amount of water, it can be used by anyone on Earth.

2.2 Project Milestones

Starting the first day of Senior Design 1, the importance of staying on schedule was hounded into the individual groups because to complete everything and stay on track a lot has to be done and researched. All of this takes time, patience, and teamwork. The schedule seen in Table 1 below are the milestones and dates this team plans to hold ourselves accountable for. These were originally thought up as an assignment after boot camp and meeting regularly as recommended. There is a separate master schedule that is edited every week so this overarching one can be met and our 45-page, 75-page, and 90-page submissions will be complete and on time. It is important that the components are ordered and tested in these weeks so there are no surprises come Senior Design 2.

As for Senior Design 2, the milestones shown are the basic ones that we can follow at the beginning. It will be important to be on a good schedule and get the PCB done fast so there can be multiple revisions if needed, and if not needed, then we can continue testing and refining the project to the best it can be. There are also presentations and a website that will need to be prepared for this class as well as demonstrations, so there is not a lot of wiggle room for slipping behind. Staying with this schedule has some room for changes. But all in all, it is important that it is followed, especially all deadlines being met on time and with the proper materials completed and reviewed by the team.

Table 1: Project Milestones Senior Design 1 & 2

Senior Design I		
Task	**Due Date**	**People**
Form Group	01/10/2019	Group B
Project Idea	01/22/2019	Group B
Initial Report	02/01/2019	Group B
Idea Review with Professor	02/06/2019	Group B
Milestone 1 – Idea Finalized		
Update Initial Report	02/15/2019	Group B
Product Requirements Explored	03/01/2019	Group B
Milestone 2 – Full Requirements & Specifications Defined		
Order Test Components	03/01/2019	Group B
45 Page Document	03/29/2019	Group B
Test Components	03/30/2019	Group B
75 Page Document	04/12/2019	Group B
Final Document Due	04/22/2019	Group B
Milestone 3 – Research & Final Document Completed		
Senior Design II		
Order PCB	TBD	Group B
Parts Check/Order Parts	TBD	Group B
Hardware and Software check	TBD	Group B
Assemble Prototype	TBD	Group B
Test Final Product	TBD	Group B
Milestone 4 – Final Product Works		
Final Presentation	TBD	Group B
Milestone 5 – Senior Design is Completed		

2.3 Functionality

This project is divided between hardware and software, with the functions of each category listed below in Table 2.

Table 2: Hardware and Software Functionalities

Hardware Function:
Components will be powered by a battery housed on the bottle.
The sanitization UVC LED will activate every 3 hours, but only if the cap is on at that time; otherwise it will cycle another 3 hours and check again.
Accelerometer will send readings to the microcontroller to determine if the water bottle is upright.
Sensor will read in the pressure measurements and send them to the microcontroller.
Cap detection will be read by the microcontroller to determine circuit connection.
Software Function:
Display the current water level of the bottle.
Display the user's current amount of water consumed for that day (in oz).
Have user editable fields to enter their personal health metrics to determine water consumption.
Show that a successful Bluetooth connection has been made with the water bottle.
Gather measurements from the pressure sensor and average them.
Use the pressure sensor measurements to calculate water consumption.

2.4 Existing Products

There are several 'smart' water bottles currently on the market. Our design for H-2-Ohm will bring together the best parts offered in some of these unique water bottles in order to create the ultimate portable water bottle. Joining electronics and water bottle functions can be a challenging task. Table 3 shows some of the most successful products available today, comparing the bottles and write-ups of each bottle's specifics.

Table 3: Smart Water Bottle Comparison

Bottle	**H2Ω**	**LARQ**	**H2OPal**	**Hidrate Spark 2.0**	**HydraCoach**
Water Level Sensor	Yes	No	Yes	Yes	Yes
Sanitization	Yes	Yes	No	No	No
Mobile Application	Yes	No	Yes	Yes	No
Cost	TBD	$99	$99	$45	$39.99

2.4.1 The Larq Bottle

The Larq bottle is one of the only UV-C sanitization water bottles available for consumer purchase, currently priced at $99. It is a 500mL insulated stainless steel bottle which houses a waterproof USB for charging, with an IPX7 rating. The bottle's electronics are powered by a Li-Polymer battery, which they claim can run on a single charge for 1-2 months. This bottle uses a 280nm UV-C light to neutralize up to 99.9999% of bacterial organisms. The UV-C light self-activates every 2 hours for a 60 second period, or can be manually activated by pressing the cap. In their experimental testing phases, they used e-coli as the bacterial organism and exposed it to their UV-C LED cap for 1 minute, 2 minutes, and 3 minutes [1]. The only safety measure that was put into this product is a light sensor to ensure the UV-C LED would not turn on while the cap was off. The designers say that due to the UV-C LED 'purifying' the water, the bottle only needs to be hand washed if a drink other than water is put into it; otherwise it doesn't need to be cleaned. The team that built the Larq bottle did an excellent gathering of research and test. Their ability to successfully market their product led to its wonderful success.

2.4.2 H2OPal

The H2OPal is a water bottle that tracks your hydration throughout the day as well as updates this information in an Android (beta), iOS and/or Apple Watch application. The water-tracking technology for this bottle is located at the base of the bottle, and this part can be detached and placed on the bottom of any water bottle with the same bottom diameter. This product is also $99, but it tracks your water intake and has no sanitization component [2]. The accelerometer is in place so the weight measurements can only be taken while the bottle is standing upright on a flat surface. A unique ability that this bottle has is transferring the bottles water tracker to other bottles and then calibrating for the new bottles empty weight using the mobile application. The weight sensor and other electronic components on the bottom of the bottle never come into contact with water inside the bottle. The main draw of this 'smart' water bottle is its fantastic application where you are able to set hydration goals based on how active you are, height, weight, etc. This bottle is a glass bottle, and one downside is that it does not fit inside normal cup holders.

2.4.3 Hidrate Spark 2.0

The Hidrate Spark 2.0 is a water bottle that tracks your intake by means of a sensor stick that is deactivated when the cap is off. It has a light on the side of it that illuminates to remind you to drink water. This bottle is made of BPA-Free Tritan plastic, and it holds 710mL (24 fl. oz). It can be connected via Bluetooth to several fitness trackers: Fitbit, Apple Watch & Health, Under Armour Record, Nokia Health Mate, and Google Fit. The free mobile application sends you drinking reminders and lets you see your friends' hydrating progress (must also use the Hidrate Spark bottle). The sensor stick uses ECR2032 coin cell batteries. You are also able to enter settings into the application to tailor your goals based on your physical size and activity levels. This bottle is dishwasher safe and uses replaceable batteries. A study was done for this water bottle to test the accuracy of the water level sensor. Subjects in the study assessed their fluid intake over 24 hours using two methods: calculating measurements by hand and measurements taken by the capacitive touch sensor in the Hidrate Spark [3]. The Hidrate Spark measurements were found to be accurate within 3% of the handwritten calculations.

2.4.4 HydraCoach

The HydraCoach is a water level tracking smart water bottle that uses an impeller assembly and straw tubing for tracking purposes. There is no mobile application that goes along with this bottle. Instead, it has an LCD screen on the front where all of the settings can be adjusted. The HydraCoach computer, located on the bottle, uses a CR2032 3V Lithium Battery. The Bottle itself holds 650 mL (22 fl oz.). The HydraCoach computer lets you set the units of measure for your water, your weight, and the current time/date. The computer takes this data and calculates your recommended personal hydration goal. The LCD screen will display your total amount of water consumed, personal hydration goal, time/date, your average consumption, total elapsed time for that period (day), and your percentage of daily goal met [4]. Only the bottle part of the HydraCoach is dishwasher safe, and the use of any liquid other than water may damage the components and/or impeller seals.

2.5 Requirements

Engineering requirements are arguably some of the most important metrics and guides to obtaining a fully functioning desired end product. The requirements in Table 4 are all of the necessary technical needs to attain the proper design with the specifications and features that encompass the H-2-Ohm. It was important that all the requirements be thoroughly thought through and realistic since they will have to be verified come demonstration in Senior Design 2.

Each overarching section has its own requirements, so it is easy to checkoff and trace that each area of the design is meeting the needs of the system come prototype testing. The main seven sections are battery, wireless communications, water sip detection, water level sensing, water purification method, system housing, and software application.

Table 4: Project Requirements

Description	Value	Units
Battery:		
Minimum charge lifespan	1	Week
Power allocation	All	Components
Ability to be replaced by bottle owner	-	-
Power supply control	On/Off	Switch
Wireless Communications:		
Bottle shall connect to a mobile device wirelessly	-	-
Minimum connectivity distance	4	Feet
Minimum time for bottle to pair with mobile device	20	Seconds
Water Sip Detection:		
A magnet switch will indicate if the cap has been removed or placed back on the bottle	-	-
Accelerometer will check the bottle's orientation and initiates water level measurements	-	-
Sanitization mechanism is disabled when cap is off	-	-
Water Level Sensing:		
Bottle shall have a sensor that detects the water level	-	-
Sensing accuracy	Nearest	Ounce
Minimum frequency the accelerometer will check if bottle is upright	2	Minutes
Amount of water level readings the sensor will take	3	Measurements
Water Purification Method:		
Percentage of bacteria to be removed from bottle	98 – 99.999	%
Use an electronically powered purification technique	-	-
Purification/sanitization frequency	3	Hours
Purification/sanitization duration	120	Seconds
System Housing:		
The electrical system will be housed in a waterproof environment	-	-
Minimum bottle size	12	Fluid Ounces
Software Application:		
Records users daily water intake	-	-
Allows users to set their water intake levels	-	-
Customizes water consumption goals based on height weight and gender (BMI)	-	-
Utilize local data storage	-	-
Ability to enable/disable notifications if not enough water has been drunk	-	-
Ability to enable/disable notifications to remind the user to drink water	-	-
Graphic image to show consumption progress	-	-

2.6 Project Operation

This section serves as a sort of user's guide for the H-2-Ohm. Starting with the very basics on pairing the bottle with a mobile phone, using the app, filling the bottle, ensuring proper measurements are taking place, and maintaining the bottle will all be explained in detail. It is important that all of these steps and procedures are followed for best results while using the H-2-Ohm.

Pairing with a Mobile Phone: To start out the day using the H-2-Ohm, it is important to first power on the device using the switch located at the base of the bottle. Then on the user's mobile device they should go to their settings and enable (turn on) Bluetooth. The nearest Bluetooth connections will appear on their screen, and the H-2-Ohm Bluetooth should be selected to connect with. After the phone has successfully paired with the H-2-Ohm the mobile device should show a status of "connected". Depending on the phone and environment, it may take a few seconds for the mobile phone to find the H-2-Ohm Bluetooth but the wait should be no longer than 20 seconds.

Using the App: Once the app is open, the user will have the option to manipulate their settings or view their daily water statistics. For first time users, their biographical information such as height, weight, and gender should be inputted, or they can just directly enter their daily water intake goal in the settings page. Notifications can be enabled or disabled in this page as well depending if the user would like to be reminded to drink more water or when they have reached their goal. After all the user information is set up, the daily water statics page can be selected, and this is where the user will spend most of their time viewing their daily progress and goal.

Filling the Bottle and Drinking: For daily first-time use, it is important that the device has been turned on and paired before you fill the bottle. That way, as soon as the user places the cap on and sets the bottle down (preferably on a hard surface), the starting measurements will take place. Other than that, the user can use the bottle just like any other throughout the rest of the day. It is important that the cap be placed back on the bottle if the user would like to see the measurements of the sips they just took right then and there. Measurements only take place after the cap has been placed back on the bottle, so if the user finishes the contents and does not replace the cap before refilling, whatever they drank after the last measurement will not be accounted for. A simple way to keep this from happening is to replace the cap and allow time for a measurement to take place before filling the bottle again.

Maintaining the Bottle: After the user is done using the bottle for the day, the power should be turned off to save the battery and the remaining water should be poured out. Store the bottle on a drying rack or in a cabinet without the lid on. The lid can be washed by hand with soap and warm water. It is very important that the bottle itself is NOT washed since it self sanitizes and has electronic components. If the user feels their bottle is particularly dirty a wet wipe should be used to wipe the bottle clean. Please make sure the bottle has no liquid in it and can dry overnight. This will help the overall user experience and the lifespan of the H-2-Ohm.

2.7 Bill of Materials & Project Budget

Keeping the H-2-Ohm within a reasonable price range was always a priority. No water bottle should put someone in a financially awkward position or cost an arm and a leg. Also, the more expensive, the less marketable, and as mentioned before expensive water bottles turn people towards buying plastic non-reusable ones that are polluting the Earth.

The budget for this project was $150 since this project is self-funded but also because the bottles currently on the marked that only have a sanitization component or a water tracking component cost $100 and under. This project plans to double the functionality without doubling the cost. Table 5 shows the bill of materials for all of the components researched and selected for the H-2-Ohm. It can be noted that the total cost is under our budget of $150, which not only helps our pockets as students but also the feasibility of the project working in the real world. The PCB and Miscellaneous parts are an estimate as of Senior Design 1 because neither of these have actually been ordered at the time of this paper.

Table 5: Bill of Materials

Part	**Quantity**	**Cost (each)**	**Total Cost**
Bluetooth Module	1	$7.24	$7.24
Power Supply	2	$9.95	$19.90
Pressure Sensor	1	$16.67	$16.67
Bottle Cap Sensor	1	$1.88	$1.88
UV-C LED	1	$16.45	$16.45
Microcontroller	1	$2.04	$2.04
PCB	1 (5 pack)	$22	$22
Water Bottle	1	$35.98	$35.98
Accelerometer	1	$4.95	$4.95
System Housing	1	$10	$10
Miscellaneous Parts	-	-	$10
TOTAL			**$147.11**

2.8 Safety Warnings and Hazards

H-2-Ohm intends to be absolutely safe for all users. Obviously, safety is a main priority of any project, especially one that concerns fluid intake and anything that will be consumed by a human being. All of the materials will be safe and not degrade the quality of the water, which is critical to the design. The main safety concern is the UV LED. Human exposure to this light can be harmful and this project will avoid having it on if the user may be able to see it. There is a special sensor for the cap housing that will detect if the cap is on. If the cap is on, then and only then will the UV LED shine to complete its sanitization process.

This process will be disabled if the cap is off since the UV LED shinning in someone's eyes could be harmful. Another precaution is to make sure that the bottle is not see through. That way there won't be any indirect contact from the light to its human user.

The main warning for this project is that the H-2-Ohm should NEVER be placed in the dishwasher and should only be used for water. This will destroy the device and prevent the user from enjoying the product. The reasoning behind this is because sanitation already occurred, so there is no need to further wash the bottle. The cap is safe to hand wash as there will be no electrical components that can be affected.

Water consumption should also always be checked by a medical professional. The app is merely a suggestion and should always be confirmed by a doctor. If the user is ever uncomfortable with the suggested water consumption for their body type, they are under no obligation to keep it and can and should manually change it. This product should be used as an aid and never in the place of actual medical advice.

Lastly, an important disclaimer is that everything will be waterproofed to the best of the team's ability but that does not guaranty if the bottle is unintentionally mishandled it will not have some water damage. It is important to follow the user guide and make sure that the H-2-Ohm is not surrounded by water or other things that could potentially harm it.

2.9 House of Quality

This section outlines the House of Quality diagram which is used to map out how the product's engineering and marketing requirements drive the entire design process. It should be stated that the house of quality targets mentioned below are more of an approximation, not the actual final products results.

2.9.1 Overview

The purpose of a House of Quality diagram is to compare and contrast the relationship between what the customer desires and the capabilities of the product itself. This process of mapping out the needs of the customer in comparison with the limitations of the product, create a clear set of guidelines to follow when it comes to both designing and marketing. It is sometimes difficult to bridge the gap between the information pertinent to customers and a products engineering specifications and technical jargon. The House of Quality diagram in Figure 1 lays out a clear message of what the customer wants and to what extent a product can meet those desires. Companies and organizations understand that a new and amazing product is only as good as the impact it makes on the lives of everyday people.

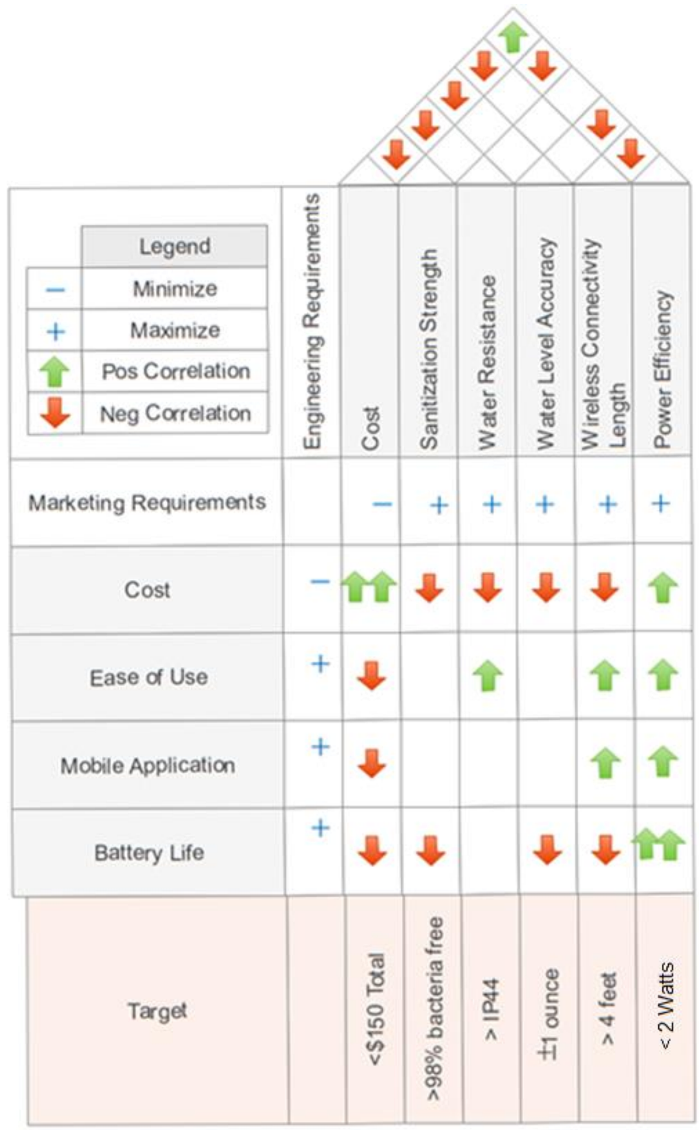

Figure 1: House of Quality

2.9.2 Breakdown

In our house of quality, we compared the engineering requirements and the marketing requirements that we estimated for our products deliverables. There are several symbols used in our house of quality to signify the relationship between different requirements. The '+' signifies the need to maximize that specific category, while the '-' signifies a need to minimize that specific category. Other symbols used are the orange and green arrows; these represent positive and negative correlation (respectively). A use of a double arrow means that the section is particularly strong for that correlation, compared to the other product requirement relations.

The main section of the 'house', located in the center region, shows the correlation between engineering and marketing requirements. To start, cost must be minimized in both the marketing/consumer side as well as the engineering side. Looking at the marketing requirements column, ease of use would need to be maximized to ensure that the customers' needs are met without any unnecessary effort. The mobile application's maneuverability and utility would need to be maximized such that the customer has zero trouble accessing the products data or interfacing with the application itself. The products battery life is a large selling point for many customers which makes this requirement receive a '+' to maximize its amount of battery life. Now looking at the engineering requirements row, the bottles sanitization strength needs to be maximized to ensure that the highest amount of sanitization has occurred. Next, the bottle needs to have high water resistance so that the electronics don't become degraded or destroyed. One of the most unique things about this water bottle is its ability to measure the water level accurately, which means we want this requirement to be maximized. Another engineering requirement that should be ideally maximized is the wireless connectivity length. The water bottle needs to send wireless updates to the user's mobile device and the more distance this can be achieved at, the better. The final requirement for the engineering section is power efficiency. Power efficiency, in this case, needs to be maximized due to the bottle having size limitations as well as its portability.

The 'roof' of the house of quality diagram was created to compare the relationship that different engineering requirements have on each other. The method to read this section is to follow the lines that cross and see where they meet, and that point signifies the relationship between the two chosen sections. The correlations shown above reflect what the product designers concluded after the research phase was completed.

Also located in the center region of the house of quality are the correlations between all the marketing requirements and the engineering requirements. Several of these categories do not have any relation at all occurring between them, thus no arrow was placed there. Starting at the cost section in marketing, the overall cost of the product will be heavily influenced by the cost of the engineering components and technology that was used; in both cases we want these values to be low. For sanitization strength, water resistance, water level accuracy, and wireless connectivity length, we have a negative correlation with marketing cost. Lastly, as the power efficiency increases, the products cost also increases, making this a positive correlation. Customers require a product to be easy to use and operate. The cost will increase as more 'user friendly' technology is implemented, making this a negative correlation due to a need to keep our product low cost. For water resistance, the user will appreciate a water bottle that is 'smart' as well as water resistant, therefore this category has a green up arrow. Wireless connectivity length definitely contributes to whether or not a customer has an easy time using a product. For this water bottle project, the connectivity length needs to be maximized in order to have a maximized ease of use for the user. Lastly, the greater the power efficiency that the bottle has the easier it is for the user to keep the bottle powered and operating successfully. In this project the quality of the mobile application depends on the cost of the engineering components, the wireless connectivity length and the power efficiency of the bottle electronics. As the length of connectivity and the power efficiency increase, the mobile application improves in utility and accuracy. As the cost of the engineering components increase, the mobile application will improve, but overall the high cost will leave a negative impact on the project. The battery life of a product is very important to consumers; many products are used every day and need a high level of reliability. Battery life and power efficiency are directly correlated, which designates the double green arrow. As for the other categories, the battery life will be degraded as sanitization strength, water level accuracy, and the wireless connectivity length increase. On the other hand, as the battery life goes up, so will the cost of the entire project which is a negative side-effect.

In the target row at the bottom, several project goals are listed. These are specific to the engineering requirement with which they are in line with. For cost, we would like to stay below $150 for the entire project. The sanitization strength needs to eliminate, at a minimum, 98% of all harmful bacteria in the drinking water. The water resistance rating for this bottle needs to be above IP44. We need the water level sensor to send data that is accurate within an ounce of the actual amount of water in the bottle. Our wireless connectivity length that we are shooting for is for it to work at greater than four feet distance from the mobile device to the bottle. The final goal that we decided on for this project is to keep the amount of power it will use to be below nine watts.

2.10 Hardware Diagram

The hardware is naturally a very critical part of designing and implementing the H-2-Ohm. This project is very modular when it comes to specific tasks, but each section has its own component and will need to send and receive logic/data from the microcontroller. Later sections go into the specific research and component selection for each of these modules, but for the purposes of the hardware block diagram shown in Figure 2, it speaks to how the system will communicate and work broadly as a whole.

The power supply will need to be able to power all of the components with focusing on powering the microcontroller and the sanitization component. The wireless communication will need to pair with a mobile device to send the data and then a mobile app will be needed to display the user's water intake. For the water level sensor, it must be able to read and send data to the microcontroller since it will be taking the water level measurements if the device was determined to be upright.

Understanding how the whole system works can be best described by looking at the microcontroller and moving out. The controller will be powered via the power supply. The water level sensor, sip detection, and sanitization will all be connected to I/O pins so data can be transferred. The controller will use code to power on and off these devices depending on their proper sequence of use, and finally once the data has been collected the controller will send it to the mobile phone via the wireless communication module selected.

Each group member started their block in the research stage where Jadyn Lalich (blue) was in charge of selection of an efficient and accurate water level sensor that will send its data to the microcontroller, accelerometer selection, and the overall power supply selection to ensure it would be strong enough to run the multiple components. Lauren Tyler (green) determined the most reliable way to detect when someone has taken a drink from the bottle so the new water level can be read, as well as researching different sanitization techniques. Matthew Peterson (red) researched an Android application that is accurate and user friendly, and transferring the data collected from the microcontroller through wireless communication. The microcontroller was researched together since it will touch every aspect of the project so group conferral and agreement was important.

As each member is now in the design stage, Jadyn Lalich is in charge of the PCB, component connections, water level sensor code, accelerometer code, and power supply. Lauren Tyler is in charge of the 3D system housing, sip detection code, and sanitization code. Matthew Peterson is in charge of the overall microcontroller code that incorporates all of the components and sends data via Bluetooth as well as the mobile application. All of the blocks have been ordered and will be subject to testing for the rest of Senior Design 1. Also, every member will be sharing the details of their parts so each person has a good understanding of how the entire project works. None of the blocks are completed as of Senior Design 1 but will be during Senior Design 2.

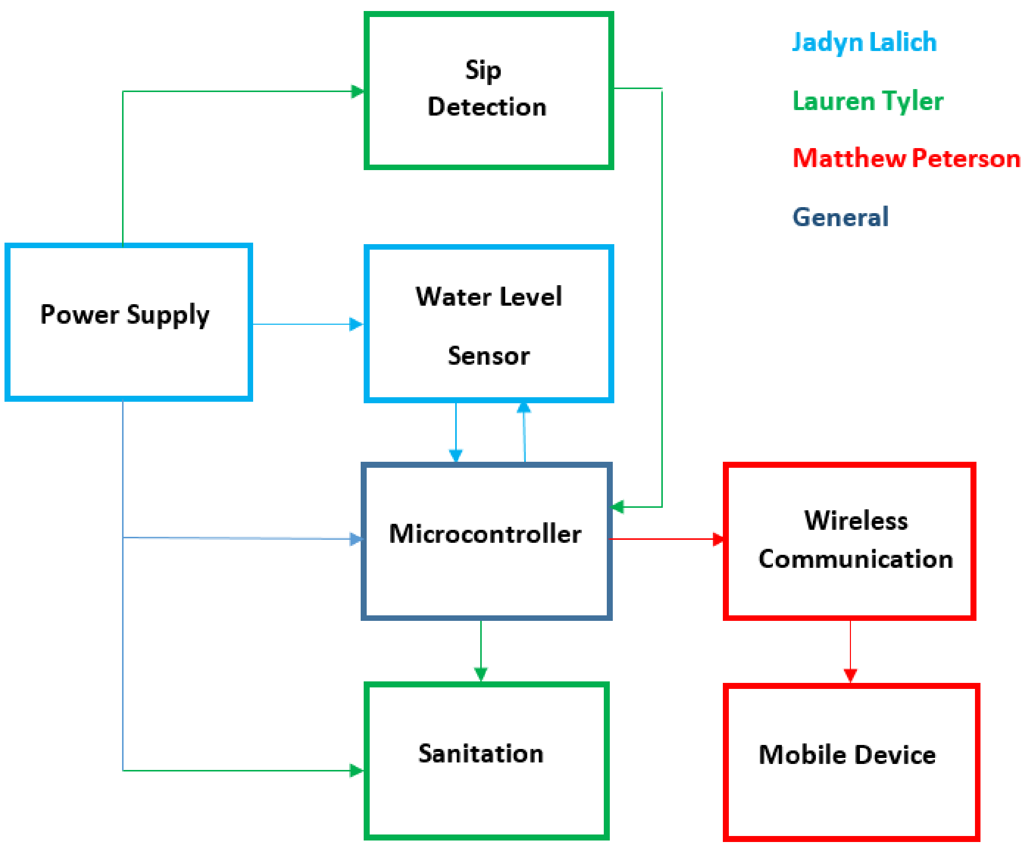

Figure 2: Hardware Diagram (Design Phase)

2.11 Software Diagram

The software diagram in Figure 3 shows the logical functionality of the H-2-Ohm module and shows how the software will function with the hardware and sensors. In the diagram, the key is shown in the top right corner which describes each item in the flow chart. Hardware describes physical components which includes the microcontroller, its memory, the pressure sensor, the accelerometer, the UV LED and the Bluetooth module. Software actions describe mostly instructions given by the microcontroller's code. If statement or test statements describe points at which the software must make a choice based on other inputs. Lastly, wireless communication shows when the Bluetooth is communicating with an external device.

For our project, the goal is to have the microcontroller sense when the lid has been opened. Upon opening, if the UV sanitization system is on, it will have its power disconnected for safety of the user. The software then waits for the next time the lid is closed via the 'Lid closed interrupt' at which time the accelerometer sensor will be activated to see if the bottle is upright. This is so that the pressure sensor can get an accurate measurement of the water level. The accelerometer will check a few times on a 10 second interval if the bottle is upright but the interval will increase to several minutes so as not to waste power. It will continue until either the lid is re-opened, cancelling this task, or it senses that the bottle is upright.

After a water measurement has been made by the pressure sensor, both the accelerometer and pressure sensor will turn off or go into low power modes until next time the 'Lid closed interrupt' occurs. The microcontroller then saves this data in its memory and compares it to the previous reading so that it can determine the amount of water consumed. This data is then sent through the Bluetooth module to the connected smart device. If no wireless device is connected, the information is stored on the microcontroller memory and will be sent once the Bluetooth is reconnected. The UV sanitization system is setup so that every few hours, it will power on the UV LED and sanitize the water. As stated earlier, this system will be configured to lose its power connection when the lid is opened so that the user is not exposed to direct UV light.

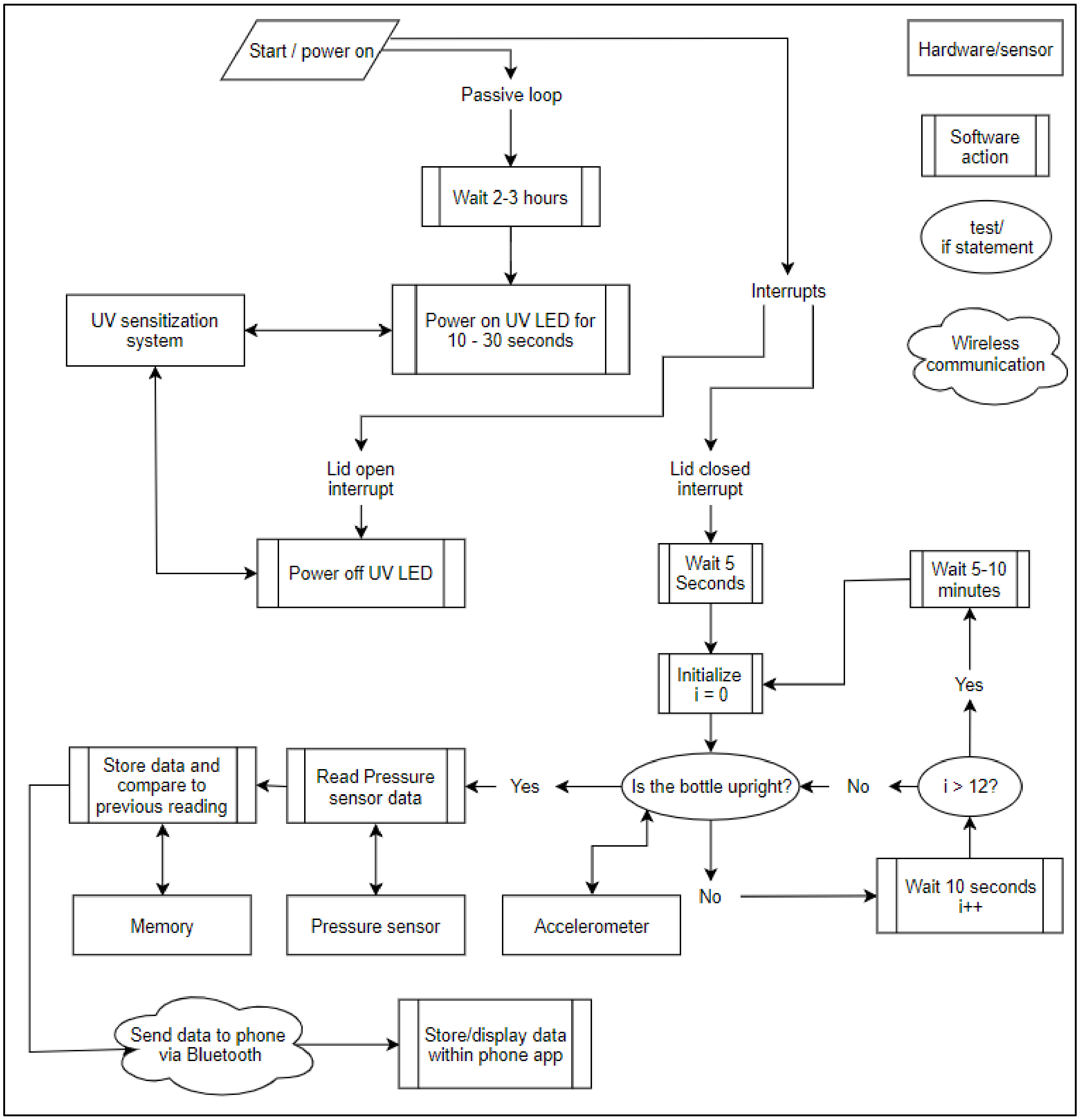

Figure 3: Software Diagram

3.0 Project Research

The research done for this project is provided in this section. An extensive gathering of information was done to provide a detailed and accurate defense of what determined the final design for this project. Several hardware and software components were explored in this research effort. The major hardware components, which are discussed below, are the water level sensor, microcontroller, sanitization module, choice of power source, and bottle cap detection module. For the software side, we are discussing which high-level programming language we decided to go with as well as the Bluetooth component used in this project.

3.1 Water Level Sensor

Selecting a water level sensor is one of the most critical design milestones for this project since this will be the way the user's water consumption is measured. There are many ways in both industrial and commercial markets to measure the water level of a contained space. However, for a small container such as the water bottle being developed for H-2-Ohm, there are constraints such as the size since the housing is limited to a regular bottle, accuracy for small level readings, complexity, and cost, as well as being in close proximity to water and the need for waterproofing. The goal is to determine the water level/consumption and send that value via wireless communication. Below are the different sensing methods being considered for this project.

3.1.1 eTape Liquid Level Sensor

The eTape liquid level sensor would be very accurate for reading the water level since it does so by the height of the fluid in contact with the tape. When the liquid is surrounding the tape at a certain level there is hydrostatic pressure [5]. The tape is then designed to have a change in resistance which can be read in by an analog to digital converter on a microcontroller to translate the resistance value to a specific water level.

In general, a low output resistance means that there is a high water level and a high output resistance means that there is a low water level. This acts like a variable resistor, to figure out the current water level the resistance is solved for using knowns. The reference voltage would be around 3-5V and the tape has a nominal resistance of 1.5kΩ. When the sensor resistance is found after using a voltage division equation the resistance gradient of 150Ω/inch can be used to find the height of the water. Important advantages and disadvantages are considered in Table 6 below.

Table 6: eTape Advantages and Disadvantages

Advantages:
Minimum accuracy is a centimeter
Ease of installation and waterproofing
Power rating of around 0.5W
Bottle would be dishwasher safe
Disadvantages:
Sensor is bulky and long
Costs upwards of $60 or more
Needs Accelerometer

Possible Implementation:
The eTape could be fixed to the lid of the water bottle so the wires can run up into the cap and be sealed off from the water. The only issue with this is that when the user goes to remove the lid to drink the eTape would have to be pulled out of the water with the cap and

that is cumbersome. With all of the components attached to the cap though this would mean that the bottle itself would be dishwasher safe.

3.1.2 Load Sensor

Much like a kitchen or bathroom scale a load sensor for the water bottle would work in a similar fashion. A load sensor would be attached at the bottom of the bottle where when the bottle is set down it will register the weight of the bottle and the liquid inside. This would require calibration of the sensor to first know the weight of the bottle with the lid on so it could subtract that from the total weight when water is in the container. After that every ounce of water has to be calibrated to a corresponding weight.

When it comes to waterproofing the electronics and power supply would have to be placed on the bottom near the sensor. This would mean careful placement for accurate weight measurements, and such that no leakage gets onto these components and also to not be too bulk that it effects the stability of the bottle to stay upright. Important advantages and disadvantages are considered in Table 7 below.

Table 7: Load Sensor Advantages and Disadvantages

Advantages:
Cost less than $20
Not bulky or in users way
Accurate to the nearest ounce
Bottle would be dishwasher safe
Disadvantages:
Water level can only be determined if the bottle is set down on a hard surface
Calibration of the different water level weights is required.
Needs Accelerometer

Possible Implementation:
As mentioned above the load cell would have to be placed at the very bottom of the water bottle which would mean that all of the other components in our project would have to be located at the bottom as well. With all of these components fixed to the bottom this would mean that the water bottle should have a false quartz glass bottom so the LED can shine through but still allows the actual electronics and sensing to be detached making the bottle easy to clean.

3.1.3 Pressure Sensor

Similar to the load sensor, a presser sensor would be attached at the bottom of the bottle. Although this sensor would have to have a hole drilled through the bottom and sealed off so it has the pressure of the water pushing down on it. An accelerometer would be needed to determine if the bottle is upright as to get a proper pressure measurement. This would require calibration of the sensor to first know how much pressure corresponds to what water level.

When it comes to waterproofing the electronics and power supply would have to be placed on the bottom near the sensor. This would mean careful placement and such that no leakage gets onto these components. Important advantages and disadvantages are considered in Table 8 below.

Table 8: Pressure Sensor Advantages and Disadvantages

Advantages:
Cost less than $30
Not bulky or in users way
Accurate to the nearest ounce
Disadvantages:
Calibration of the different water level pressures is required.
Bottle would not be dishwasher safe
Needs Accelerometer

Possible Implementation:
As mentioned above the pressure sensor would have to be placed at the very bottom of the water bottle which would mean that all of the other components in our project would have to be located at the bottom as well. With all of these components fixed to the bottom this would mean that the water bottle would not be dishwasher safe and also difficult to wash by hand.

3.1.4 Flow Meter

Rather than track water level physically through height or weight, a flow meter could be implemented to determine how much the user is actually consuming not just how much water was in the bottle but no longer in the bottle like the other mentioned methods. A flow meter would track how much water is flowing past the sensor by having a magnetic pinwheel rotate around and a Hall Effect sensor to determine how many rotations it has made [6]. Depending on the size of the straw and the diameter there would be calibration involved to understand what flow rate means in terms of water consumption. As well as when water is flowing back down the straw that amount would need to be subtracted from the earlier water consumption rate.

When it comes to waterproofing the electronics are safely out of the way since the Hall Effect sensor can gather its reading through the plastic straw. Depending on implementation the straw could be made non detachable so there would be no need for a separate MCU/wireless connection or battery. Important advantages and disadvantages are considered in Table 9 below.

Table 9: Flow Meter Advantages and Disadvantages

Advantages:
Cost less than $30
Ease of waterproofing
Not bulky or in users way
No accelerometer needed
Bottle would be dishwasher safe
Disadvantages:
Possibly only accurate to the nearest 2oz.
Calibration of the straw/Hall Effect sensor required

Possible Implementation:
A double walled straw would need to be made that has the pinwheel mechanism in the innermost cavity of the straw and the Hall Effect sensor in between the two walls securely away from water. This sensor could then have its wires run up the fixed straw into the cap so it could run on the analog to digital converter and power source located there. With this implementation only the cap would not be dishwasher safe.

3.1.5 Ultrasonic Time of Flight (TOF) Sensor

Last in terms of water sensor research is the ultrasonic TOF approach. This works via a transducer located at the bottom of the bottle (on the outside) that will pulse. This pulse then travels through the water and when it reaches the surface there is an echo, the time it takes for the echo is what determines the water level [7]. Naturally this can't be done using just a transducer so an ultrasonic sensor analog front end device is needed to control the stop and start pulses as well as calculating the time it takes to detect an echo.

When it comes to waterproofing the electronics are safely out of the way since the sensor can gather its reading through the bottom of the bottle. Like the many other approaches it will need to be calibrated and tested but in this case it would be the most labor intensive and involved. Important advantages and disadvantages are considered in Table 10 below.

Table 10: Ultrasonic TOF Advantages and Disadvantages

Advantages:
Cost less than $20
Accuracy of 1mm
Ease of waterproofing
Not bulky or in users way
Disadvantages:
Bottle would not be dishwasher safe
Extensive calibration required
Needs Accelerometer

Possible Implementation:
The transducer would be glued to the bottom of the bottle via wires connecting it back up to the cap where the other electronic components would be stored such as the power supply and ultrasonic sensor analog front end device.

3.1.6 Water Level Sensor Comparison

Selecting the water level sensor is fundamentally one of the most important decisions being made in regards to the entire project. There are many factors that go into why one method would be chosen over another some and most of these factors are prioritized based on the overarching objectives. These would be cost, accuracy, and power. Granted there are a few lower level things that need to be accounted for as well such as waterproofing, calibration, and user friendliness. In Table 11 below all of the methods from Water Level Sensor section are compared based on these criteria.

Table 11: Water Level Sensor Comparison

	eTape Liquid Level Sensor	**Load Sensor**	**Pressure Sensor**	**Flow Meter**	**Ultrasonic TOF Sensor**
Cost	< $60	< $20	< $30	< $30	< $20
Accuracy	1cm	1.0±0.1 mv/V (±5%)	0.1mbar	2oz	1mm
Power	< 0.5W	≈15mW	≈14.4µW	≈75mW	≈27.75mW
Waterproofing	Easy	Easy	Medium	Medium	Easy
Calibration	Easy	Medium	Medium	Hard	Hard
User Friendliness	Bulky	Requires hard surface	Hand wash	Dish washer safe bottle	Hand wash

3.1.7 Water Level Sensor Selection

After weighing all of the advantages and disadvantages using each of the five sensors mentioned above it became clear that for the objectives and goals of this project to be reached that the pressure sensor would be the wisest choice. It is the lowest power, high accuracy, and inexpensive. There were some things that needed to be considered such as the sensor has to be in direct contact with the water leaving waterproofing of the electronics and PCB below to be critical but even with that it was still the best choice. The user will not notice that it is there when they remove the lid to take a drink and getting the reading from the senor should be relatively intuitive.

3.2 Pressure Sensors

To measure the water level in the water bottle a pressure sensor was selected as the method of choice. The pressure sensor used for the H-2-Ohm will be mounted at the bottom of the bottle so it can read the pressure of the water in a column above it. This will utilize knows such as the density of water and the gravity of Earth [8]. With these and the pressure reading from the sensor the height of the water can be determined via the following equation:

$$P = \rho g h$$

$$h = \frac{P}{\rho g}$$

$$\rho = desity\ of\ water = 1000 kg/m^3$$
$$g = acceleration\ of\ gravity = 9.81 m/s^2$$
$$P = Pressure\ read\ from\ sensor$$

Using this equation and estimating what size bottle the H-2-Ohm will be it can be calculated that the pressure sensor would not need the ability to read anything over 30mbar since a typical 32oz water bottle is 221mm tall requiring a range of 22.1mbar. As for the accuracy of water level readings to achieve measurements per centimeter the sensor must have a minimum resolution of 1mbar/cm. Naturally the pressure sensors under consideration all need to be waterproof and low power as well as accurate to the desired range calculated. All of the pressure sensors considered for this project also measure absolute pressure meaning they are relative to a vacuum so all ranges will need to have the atmospheric pressure added to it.

3.2.1 MS5837-02BA

TE connectivity is the major developer of waterproof barometer pressure sensors and the MS5837-02BA is specially designed to be sealed off using an O-ring which is ideal since the PCB of the bottle will be resting right below. As for the electrical characteristics it runs with very low power of around 0.6µA and even lower than that when in standby [9]. This is a 24bit I^2C interface device that has temperature and pressure readings with different ranges of accuracy based on the selected bits the ADC uses to convert. Since a 1mbar minimum resolution is required the lowest ADC bit number will be fine for this project since 8 bits (OSR 265) has a resolution of 0.11mbar and a pressure range of 300-1200mbar. The supply voltage needed is 1.5-3.6V working at a typical value of 3V and the supply current during conversion is 1.25mA but coming to back down to 0.63µA for normal operations and then all the way to 0.1µA max during standby for the OSR 256 making the power consumption very low.

3.2.2 MS5803-02BA

The next sensor is the MS5803-02BA which is a lower resolution module that is also waterproof and can be sealed off with an O-ring but with more difficulty. As for the electrical characteristics it runs with very low power of around 1µA and even lower than that when in standby [10]. This is a 24bit I^2C and SPI interface device that has pressure readings with different ranges of accuracy based on the selected bits the ADC uses to convert. As mentioned before a 1mbar minimum resolution is required so the lowest ADC bit number of 8 bits (OSR 265) will be fine since it has a resolution of 0.13mbar and a pressure range of 300-1000mbar. The supply voltage needed is 1.8-3.6V working at a typical value of 3V and the supply current during conversion is 1.4mA but coming to back down to 0.9µA for normal operations and then all the way to 0.14µA max during standby for the OSR 256 making the power consumption very low.

3.2.3 MS5540C

Lastly the MS5540C which is the lowest resolution module that is also waterproof. This is a 16bit digital interface device that has pressure readings with a 0.1mbar resolution which is still higher than our minimum of 1mbar from the calculations [11]. Its pressure range is 10-1100mbar. The supply voltage needed is 2.2-3.6V working at a typical value of 3V and the supply current during conversion is 1mA but coming to back down to 4µA for normal operations and then all the way to 0.1µA max during standby. This sensor also has a temperature sensor built into the device.

3.2.4 Pressure Sensor Comparison

All three of the pressure sensor parts from above would work for this project the difficulty is choosing which one is the most efficient and accurate for our project needs. Table 12 below compares the major features and operations. It should be noted that MS5837-02BA and MS5803-02BA can have even higher resolutions than the ones listed in the table if the ADC is set to use more bits, this is not however an option for the MS5540C. Since all of their resolutions and supply voltages are typically the same the most notable differences are the prices, power, and water proofing. The MS5540C doesn't seem to make the cut because it is the most expensive, uses the most power, and doesn't have a better resolution option. Now looking between the MS5837-02A and MS5803-02BA it can be seen that the 5837 has a better accuracy, lower power, and a temperature sensor is included, it is however almost double the price of the 5803. The 5837 seems more durable and better for waterproofing and another critical feature is that it is the smallest which is the crux of this project since everything has to fit at the bottom of the bottle. The pressure sensors are pictured in Figure 4 below and the images pulled from the TE website cited in [12] and [13].

Figure 4: Pressure Sensors

MS5837-02A and MS5803-02BA (Permission to Use Requested)

Table 12: Pressure Sensor Part Comparison

	MS5837-02BA	MS5803-02BA	MS5540C
Cost	$18.72	$10.72	$22.99
Pressure Range	300-1200mbar	300-1000mbar	10-1100mbar
Resolution	0.11mbar	0.13mbar	0.1mbar
Supply Voltage	1.5-3.6V (typ. 3V)	1.8-3.6V (typ. 3V)	2.2-3.6V (typ. 3V)
Conversion Current	1.25mA	1.4mA	1mA
Normal Current	0.63µA	0.9µA	4µA
Standby Current	0.1µA	0.14µA	0.1µA
Output Type	I^2C	I^2C & SPI	Digital
Output Bits	24-bit	24-bit	16-bit
Temperature Sensing	Yes	No	Yes
Waterproofing	Easy	Medium	Medium
Size (LxWxH)	3.3x3.3x2.75mm	6.4x6.2x2.88mm	6.4x6.2x2.88mm

3.2.5 Pressure Sensor Selection

The pressure sensor selected for this project is the MS5837-02BA. When it came down to sensor selection, visualizing how the H-2-Ohm was going to be built was critical. All of the electrical components and PCB will be located at the base of the water bottle meaning, the area is very limited so automatically the smaller the part the better MS5837-02BA was able to provide over the other two. The other selling points were the minimum resolution of 0.11mbar and lowest power consumption between all of the sensors. It is not the cheapest sensor but, space and power were prioritized over cost. This sensor is designed to withstand harsh environments and even sun light which will be helpful in our implementation of the UV light to sanitize the bottle. The sanitization will also reside on the bottom and sealing off both of them will be deeply important to the protection of our electronic equipment and power source.

3.3 Accelerometers

With the pressure sensor selected as the choice method of water level sensing there is one flaw that will need to be accounted for and that flaw is measurements taken while the bottle is not in a upright position will be inaccurate. So for example if it is placed in a bag or rolling around in the trunk of a car no readings should take place since the height measurement will be wrong due to how the pressure sensor works. To ensure that the sensor values are only read while the bottle is in an upright position an accelerometer will be used. Since an accelerometer measures acceleration and it's obvious that how fast or in which direction the bottle is moving doesn't matter what will actually be used is the acceleration due to gravity (aka the bottle is leaning and not upright). The accelerometer will not need to be taking measurements constantly and will only be triggered to run after the cap has been removed and placed back on the bottle indicating a sip of water was taken. Then it will run on timed intervals until it is determined a water level measurement can be taken. Some important credentials for part selection are cost, power efficiency, and size. Ideally a cheap accelerometer can be used since it won't need all the bells and whistles that some provide. It is important that this part stays within the voltage range of our other devices as well as can stand alone without periphery components.

3.3.1 ADXL337

Up first is the ADXL337 which is a three axis accelerometer which measures with accuracy of ±3g. This device uses analog outputs so setup and use is as simple as plugging the outputs into the ADC pins of a microcontroller as well as using is 3.3V pin as the voltage supply [14]. The bandwidths are selectable so the best one for the project can be selected for use. The datasheet and other documentation say power will not be an issue but the supply current is always 300µA which may be a problem since no low power mode is stated in any of the found documentation. The size of this device is very small as well it comes in at 3x3x1.45mm. Both Adafruit and Sparkfun have lots of hookup documentation and helpful guides which would make using this in the project pretty seamless as the codes and set up would just have to be modified for the H-2-Ohm use cases.

3.3.2 LIS3DH

The next accelerometer is the LIS3DH which is three axis as well and the cheapest option out of all of the devices researched. It has selectable accuracy from ±2g/±4g/±8g/±16g and when run in ultra-low-power mode it has a current of 2µA the highest current drawn from the device however is 11µA and a supply voltage range of 1.71 to 3.6V but if used on an Arduino the 3.3V would be the selected voltage supply since a pin for that already exists [15]. This device also uses I2C communication which is what the pressure sensor uses so hooking them up to the same bus would be ideal space wise. The size of this device is very small as well it comes in at 3x3x1mm. Both Adafruit and Sparkfun have lots of hookup documentation and helpful guides which would make using this in the project pretty seamless as the codes and set up would just have to be modified for the H-2-Ohm use cases.

3.3.3 ADXL335

The ADXL335 is a three axis accelerometer which measures with accuracy of ±3g. This device uses analog outputs so setup and use is as simple as plugging the outputs into the ADC pins of a microcontroller as well as using is 3.3V pin as the voltage supply [16]. The bandwidths are selectable so the best one for the project can be selected for use. The datasheet and other documentation say power will not be an issue but the supply current is always 300μA which may be a problem since no low power mode is stated in any of the found documentation. The size of this device is very small as well it comes in at 3x3x1.45mm. Both Adafruit and Sparkfun have lots of hookup documentation and helpful guides which would make using this in the project pretty seamless as the codes and set up would just have to be modified for the H-2-Ohm use cases.

3.3.4 MMA8451 Adafruit Triple-Axis Accelerometer

Lastly the MMA8451 Adafruit Triple-Axis Accelerometer is a three-axis accelerometer which measures with selectable accuracy from ±2g/±4g/±8g. When run in low-power mode it has a min current of 6μA the highest current drawn from the device however is 165μA and a supply voltage range of 1.95 to 3.6V but if used on an Arduino the 3.3V would be the selected voltage supply since a pin for that already exists [17]. This device also uses I2C communication which is what the pressure sensor uses so hooking them up to the same bus would be ideal space wise. The size of this device is very small as well it comes in at 3x3x1mm. Since this is an Adafruit device there is lots of documentation but mostly on their website. This however will still help with hooking up the device and helpful guides which would make using this in the project pretty seamless as the codes and set up would just have to be modified for the H-2-Ohm use cases.

3.3.5 Accelerometer Comparison

All four of the accelerometers devices from above would work for this project the difficulty is choosing which one is the most efficient and cheapest for our project needs. Table 13 below compares the major features taken into consideration. It should be noted that LIS3DH and MMA8451 are I2C outputs which would mean that the utilization of the bus already being used by the pressure sensor would save space and pin as opposed the two other accelerometers which use analog outputs. Analog outputs are easier to just plug and play with so that would be ideal but their power consumption and price outweigh the short term benefits that would bring. The range and size for all of the accelerometers is pretty comparable since this project will only need limited accuracy as well as the sizes of all of them. There are periphery components for all of the devices below since most come on their own already developed breakout boards which will make testing easier. It is important that the accelerometer selected can run right off the microcontroller selected and it was apparent that all of the ones listed below had test code and recommendations from other users testing them on either Adafruit or Sparkfun so none of them will be a problem.

Table 13: Accelerometer Part Comparison

	ADXL337	LIS3DH	ADXL335	MMA8451
Cost	$9.95	$4.95	$14.95	$7.95
Range	±3g	±2g/±4g/±8g/±16g	±3g	±2g/±4g/±8g
Output	Analog	I^2C	Analog	I^2C
Supply Current	300µA	6-11µA	350µA	6-165µA
Supply Voltage	1.8V-3.6V	1.71-3.6V	1.8-3.6V	1.95-3.6V
Size (LxWxH)	3x3x1.45mm	3x3x1mm	3x3x1.45mm	3x3x1mm

3.3.6 Accelerometer Selection

The accelerometer selected for this project is the LIS3DH. When it came down to the selection price and power efficiency were the two main factors since they were all around the same size. The LIS3DH was the only one under six dollars and with extremely low current which was important because the plan is to use a microcontroller 3.3V pin for any of the accelerometers above. The I2C will take some getting used to and coding to implement but as long since it has a different address than the pressure sensor this will make the connecting them on the same bus even easier and hopefully save space and pins. Testing will be easily accomplished by using a breakout board developed by Adafruit and their prepared code just to ensure that this device will in fact be enough for this project. The selected range needed for the project will also be tested in the lab but will probably be around the ±2g or ±4g range.

3.4 Sanitization Component

There are several different methods to sanitizing water in order to make it safe for human consumption. Most sanitizations techniques involve the use of chemicals to destroy the bacteria, but other possible methods are filtration and exposure to ultraviolet light. It is commonly known that during emergency situations, in which a certain locations water supply is corrupted, it is recommended to boil water to avoid becoming infected by disease-carrying microorganisms [18]. Boiling water, and other sanitization methods, are different from filtering water to make it free of foreign particles and particulates. In this project design, we will focus on guaranteeing that the consumer's drinking water is free of bacterial microorganisms.

3.4.1 Boiling System

Boiling water is a common method of ensuring that the water is clean enough to drink, no matter the source. Depending on the altitude, the water may need to boil for a longer amount of time, high altitude, or a shorter time, lower altitude. Water should be at a rolling boil for 1 minute, at altitudes greater than 6,564 feet boil water for 3 minutes [18]. For this project, boiling the water to rid it of containments will not be the most ideal method for several reasons. Important advantages and disadvantages are considered in Table 14 below.

Table 14: Boiling System Advantages and Disadvantages

Advantages:
Will kill all pathogens
Short time to boil
Disadvantages:
The water will be too hot for the user to drink
The water bottle housing would need to be made out of a material that doesn't flex or disintegrate at high temperatures
The outer casing of the bottle may get too hot so the user cannot hold it
High amount of voltage would be required to boil water inside a portable water bottle, would require it to be plugged into the wall
Would need to incorporate an electronic method to cool the water after it has boiled

Possible Implementation:
There are commercial electric kettles available for purchase. The mechanism used in these kettles could potentially be condensed and made portable, although it may need a large battery pack to support this load. A rubber or highly insulated surrounding could be put on the bottle such that the user's hand would not be scolded by the heated metal frame of the bottle after the heating process takes place. The electronic heater would be connected to a specific timer to ensure the accuracy and consistency of each boil.

3.4.2 Chemical Treatments

There are many different chemicals that can be used to sanitize drinking water. The most common types of chemical water purifiers are chlorine, iodine, and oxidizing agents. Chlorine is a somewhat unstable chemical and has been known to leave behind a chemical residue that is associated with a small risk in cancer. Roughly 3 to 6 drops of household liquid bleach can be used, this contains 5.25% sodium hypochlorite. Iodine is another option but there are also drawbacks, it deteriorates in sunlight and leaves behind a bad taste. Nonetheless, iodine is a more effective treatment than chlorine. Hikers have been known to use iodine tablets for water treatment. Oxidizers are the fastest-acting chemical option, they leave behind the smallest amount of chemical residue, and they add the least amount of taste to the water [19]. The drawback to oxidizers is that they are more expensive compared to the other options listed here. These methods of sanitization have little to no electrical component/module that would accomplish the task and not need to be refilled/tended to frequently. Important advantages and disadvantages are considered in Table 15 below.

Table 15: Chemical Treatments Advantages and Disadvantages

Advantages:
Convenient, can buy at the store
No need for electrical power source
Disadvantages:
Varies with temperature
Varies with water pH
Small risk of cancer
Leaves a unique aftertaste
Takes a long time for chemical process to complete (~20 minutes), even longer for colder water

Possible Implementation:
In order to use chemical treatments to sanitize the water, an electronic dispenser or a periodically opening valve would need to be used. An electronic dispenser could drop in a chemical sanitization pellet or a specified number of solids into the drinking water section and dissolve in time. Another potential route, there could be a separate section to house the chemicals needed for sanitization, assuming the chemical is a liquid, it would periodically open a tiny hole at the top of its tank which would siphon a measured amount of treatment chemicals into the drinking water supply. These methods would require the user to refill the sanitizing chemicals as needed.

3.4.3 Ultraviolet-C Light

Ultraviolet (UV) light is a certain range of wavelengths located on the electromagnetic spectrum. UV light roughly spans from 10nm to 400nm, it is positioned between visible light and X-rays [20]. UV light is broken up into four general categories: vacuum UV, UVC, UVB, and UVA. The subdivision we will be focusing on is UV-C or Ultraviolet C, this has a wavelength range of 100nm to 280nm. UV-C is useful for pathogen reduction in untreated waters [21]. UV-C can be absorbed by proteins and thus, break down cell walls and cause death of organisms. The Earth's ozone layer normally protects organisms from UV-C-type exposure; 100% of the UV radiation that reaches Earth is only from UV-A and UV-B wavelength categories.

The UV-C light/LED would be attached to the top or the bottom of the water bottle in order to obtain maximum effectiveness. According to previous testing done by other researchers, the UV-C light needs to stay on for 3 minutes to kill 99.9999% of bacteria in the water [1]. Also, waterproof versions of the light are available for sale. Important advantages and disadvantages are considered in Table 16 below.

Table 16: Ultraviolet-C Light Advantages and Disadvantages

Advantages:
Requires no use of chemicals that may be corrosive/toxic
Leaves behind no residue
Environmentally friendly
Requires no human adjustment, removes human error from the sanitization process
No bottle odor from germs
Disadvantages:
Lack of testing to explore this sanitization method
Dangerous/harmful to humans if exposed
Needs to be in an enclosed bottle to be effective
Doesn't penetrate glass

Possible Implementation:
As mentioned above, the UV-C light would be located at the top or the bottom of the water bottle, this depends upon what the water sensing method will be. The UV-C light will be where the rest of the bottle's electronics are housed. A lithium ion battery cell is a possible choice to power this light.

3.4.4 Sanitization Component Comparison

After going through these different sanitization methods, it is clear that the ultraviolet-c light will be the best option for what we want our product to provide. The boiling system and chemical treatments are not feasible sanitization methods when it comes to portability and everyday use. The UV light may need to have more safety precautions to protect to user from potential exposure, but this is minor in comparison to how easy it will work with our design. Table 17 below shows how each of the sanitization components compare.

Table 17: Sanitization Component Comparison

	Boiling System	**Chemical Treatments**	**Ultraviolet-C Light**
Cost	< $20	< $20	< $50
Effectiveness	Very High	Very High	>98% pure
Power	High	Low	Medium
Waterproofing	Easy	Easy	Medium
Implementation	Hard	Hard	Easy - Medium
User Friendliness	Low, gives user too-hot water to drink	Low, needs user to refill chemicals	High, no interaction needed

3.5 UV-C LED

The following parts that are listed below are from different categories of LEDs that could have been chosen for this engineering requirement. Each of them meets the design requirement in different ways.

3.5.1 MTE280H41-UV

The MTE280H41-UV emitter is a product made by Marktech Optoelectronics. According to the parts datasheet, it is specifically designed for some of the following applications:

- UV Curing / Light Therapy / Drug Discovery
- Air and Water Disinfection / Optical Sensor
- DNA / Protein Analysis

This emitter is in a TO-46 hermetically sealed package with a special UV glass lens to prolong its performance. It has an operating temperature range of -30 ºC to +80 ºC and a typical power output of 1mW. The typical forward voltage is 7V and the maximum forward current is 40mA. It operates between 275nm and 285nm with a typical peak wavelength of 280nm, forward current must be at least 20mA [22]. The emitter has a typical viewing angle of 40º. This UV-C emitter is also a through-hole part and its largest diameter is 5.35mm ± 0.2mm. This part is $151.29.

3.5.2 RVXR-280-SB-073105

The RVXR-280-SB-073105 emitter is a product made by RayVio Corporation. This emitter is a high power and high efficiency UV-C device that can be used for disinfection and sterilization [23]. This part is on a star board mount which has a maximum diameter or roughly 19.05mm, this type of mounting is preferable for prototyping and development. It has a junction temperature of 60ºC and a typical power output of 8mW. The typical forward voltage is 7V and the max forward current is 100mA. This emitter has a typical view angle of 120º. This part costs $16.45.

3.5.3 VLMU60CL00-280-125

The VLMU60CL00-280-125 emitter is made by Vishay Semiconductor Opto Division. This emitter comes in a ceramic SMT package with a quartz lens. This is a surface mount part that is 6mm x 6mm. It has an operating temperature range of -30 ºC to +80 ºC, junction temperature of 90 ºC, and a typical output power of 2.4mW. It has a typical forward voltage of 6.2V and a maximum forward current of 20mA. The emitter ranges from 270nm to 290nm with a typical peak wavelength of 280nm. Its angle of half intensity is ±62.5º. This part costs $39.28.

3.5.4 UV-C LED Comparison

Each of these parts have their own advantages and disadvantages, overall the part best suited for this project is the one that is low cost and energy efficient. Below, Figure 5 shows the physical difference of each LED, this is important to compare because it will decide how the bottle design will look. Table 18 shows in detail how these LEDs compare.

Figure 5: UV LEDs
MTE280H41-UV, RVXR-280-SB-073105, VLMU60CL00-280-125 (left to right)

Table 18: UV-C Light Emitter Comparison

	MTE280H41-UV	**RVXR-280-SB-073105**	**VLMU60CL00-280-125**
Forward Voltage	7 V	7 V	6.2 V
Forward Current	40 mA	100 mA	40 mA
Wavelength	280 nm	280 nm	280 nm
Power Output	1 mW	8 mW	2.4 mW
Mounting Type	Through Hole	Star Board	Surface Mount
Viewing angle	40°	120°	125°
Operating Temp.	-30 ~ +80 C	60 C (JT)	-30°C ~ 80°C (TA)
Manufacturer	Marktech Optoelectronics	RayVio	Vishay
Cost	$ 151.29 (3 left on Digikey, 6 week LT)	$16.45	$39.28

3.5.5 UV-C LED Selection

The UV-C LED that was selected above had the best specifications for which our product requires. This LED has a waterproof covering and it is already in a circular 'Starboard' shape which will fit well in our water bottle design. It is also substantially cheaper compared to the other two LEDs.

3.6 Bottle Cap Detection Component

Our H-2-Ohm water bottle needs to 'know' when to take a reading of the current water level inside the bottle and when not to. Also, the bottle needs to deactivate the UV-C LED when the user is taking a drink, otherwise the users' eyes and skin could be harmed by the light. Due to these constraints, a bottle cap sensor is required. Several potential electrical mechanisms are listed below.

3.6.1 IR Sensor

Infrared sensors are electronic instruments that detect and emit infrared radiation. Passive infrared sensors only detect infrared radiation. Infrared radiation is not visible to the human eye and it has a wavelength range from 0.75μm to 1000μm [24]. There are two types of infrared sensor detection, thermal infrared and quantum infrared. Thermal IR sensors have a photo sensor on them that can detect energy as heat, which is independent of the wavelength that the emitting source has. Quantum IR sensors have a much faster response compared to the thermal IR sensor and their photo sensors are entirely dependent on the wavelength of the source. There are also infrared sensors which are capable of emitting an infrared frequency and receiving that same frequency 'echoed' back to it if an object is near enough reflect the signal. Important advantages and disadvantages are considered in Table 19 below.

Table 19: IR Sensor Advantages and Disadvantages

Advantages:
High accuracy
Disadvantages:
Larger component
Low availability
High power need
Expensive

Possible Implementation:
An infrared proximity sensor could be placed on the side of the water bottle and its emitted frequency could be echoed back after coming into contact with the cap edge. A custom cap would need to be created to ensure that the IR sensors' signal would have a close enough object to bounce back from. This is not the most viable option due to the sensors need for a high supply voltage and it is very expensive, comparably.

3.6.2 Hall Effect Sensor

Hall Effect sensors are similar to reed switches in that their output voltages change when a magnetic field is applied in close proximity. Unlike reed switches, Hall Effect sensors have no moving parts and act as a transducer when varying its output voltage [25]. The variable that affects the transducer, in this sensors case, is the applied magnetic field. Hall Effect sensors are activated by a different magnetic polarity than reed switches.

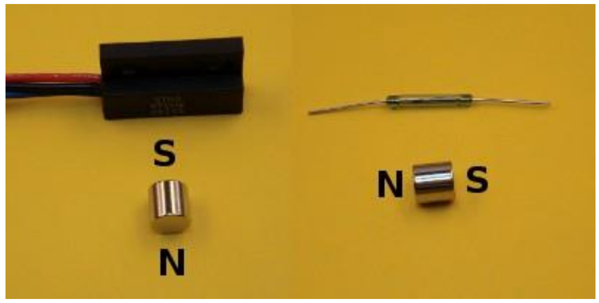

Photo courtesy of K&J Magnetics

Figure 6: Hall Effect Sensor (left) vs. Reed Switch (right)

Referring to the Figure 6 above, it is clear that Hall Effect sensors will activate when a magnetic field is perpendicular to it, usually the south side of the magnet works. On the other hand, reed switches need a magnetic field to be parallel to its body in order for it to activate. Important advantages and disadvantages are considered in Table 20 below.

Table 20: Hall Effect Sensor Advantages and Disadvantages

Advantages:
Cheap
No need for electrical power source, similar to reed switch
Only needs to 'see' one side of the magnet in order to activate
Disadvantages:
Non-ideal shaped part for the placement on the water bottle
Only activates when magnet is at a certain orientation
Larger body compared to reed switch

Possible Implementation:

The Hall Effect sensor will be placed on the side of the bottle near the edge of the cap. The cap will house a thing circular magnet which will line the bottom outer edge of it. The magnet will cover all sides of the ring of the cap such that the Hall Effect sensor will register, or close, as long as the cap is a certain tightness on the bottle. This design takes care of the problem of having to line up the cap in roughly the same spot each time the user screws it back on. This sensor requires a voltage supply in order for it to function, this is a hurdle that would need to be accounted for when it comes to power allocation.

3.6.3 Reed Switch

A reed switch is an electrical switch that is operated by an applied magnetic field [26]. The reed switch was invented at Bell Telephone Laboratories in 1936 by Walter B. Ellwood [26]. The common form of this switch includes a pair of ferromagnetic metal contacts (reeds) that are overlapping and contained in a glass sealed envelope. When there is no magnetic field being applied the metal contacts are not touching, and the circuit is open. When a magnetic field is applied, in close proximity to the metal reeds, the circuit becomes closed. This electrical component is commonly used for burglar alarms, laptop sensors and proximity sensors. There are several reed switches that are contained in a molded body instead of a glass envelope, which improves the parts durability. Important advantages and disadvantages are considered in Table 21 below.

Table 21: Reed Switch Advantages and Disadvantages

Advantages:
Cheap
No need for electrical power source, the reeds would complete the circuit
Disadvantages:
Non-ideal shaped part for the placement on the water bottle
Only activates when magnet is at a certain orientation

Possible Implementation:
A reed switch only requires the presence of a magnet to open and close the circuit. This is an excellent option for the bottle cap sensor, because the cap would require no power to make the reed switch activate. A ring-shaped magnet would be housed on the side/edge of the cap in such a way that it would come in close proximity to the reed switch located on the bottle itself. This positioning ensures that the cap is completely on when the bottle electrical components take a water level reading or initiate the UV sanitization process. The current running along the reed switch would also be low so thermal problems do not arise from the wires lining the side of the bottle, connecting the reed switch to the bottle components.

3.6.4 Bottle Cap Detection Component Comparison

Each of these bottle cap sensor mechanisms have a unique way of detecting if an object is nearby. The Hall Effect sensor and the reed switch are very similar in that they both require a magnet to be preset for their circuits to close, their difference will be shown below. In Table 22 below, they will be compared side-by-side, this way it will be easy to see which component ranks the best.

Table 22: Bottle Cap Detection Component Comparison

	IR Sensor	Hall Effect Sensor	Reed Switch
Cost	< $25	< $10	< $5
Accuracy	High	Medium	Medium
Power	<4V	<4V	None
Waterproofing	Hard	Easy	Easy
User Friendliness	Low	High	High

3.7 Reed Switch

The reed switch is the best option of the bottle cap sensor. This component doesn't require any power supply and the cap will not need any battery either. The only thing the reed switch needs to close the circuit is a magnet to come close to it.

3.7.1 MG-A2-5.0-N

The Magnasphere N-Series magnetic switch is a small metal plated magnet contact. This part is all metal and would be placed on the side of the water bottle in a 3D-printed housing to avoid having the part stick out. The operating range and release range for this reed switch is under 20mm, this is important because it needs the cap to be in close proximity for the switch to open/close. This part can also be used to detect the proximity of ferrous metals, but the distance required for detection is extremely small (< 2mm).

3.7.2 59050-030

This reed switch made by Littlefuse, Inc is encased in a 15% G.F. Nylon black body. This type of body material is preferred for the use on the water bottle in order to avoid issues with it getting wet. This component requires the smallest operating range which means it is the most reliable when it comes to verifying if the cap is properly in place such that, no UV light will escape and potentially harm the user. This reed switch is also very cheap, but there are none of them currently in stock and they have a 12-week lead time.

3.7.3 MK23-80-C-2

The Meder Electronics' MK23 reed sensor is the smallest out of the reed switch options listed here. It has a typical glass body and a medium ranged sensitivity level, 15-20 AT. This reed switch's magnetic sensitivity rating is roughly 15mm. The MK23 has a soldering temperature limit of 260◦C for 5 seconds. The glass body reed switch may not be the best option for this design due to the durability of the glass and the soldering temperature limit of the reeds. This is the cheapest option out of all three reed switches listed and it has a high contact rating.

3.7.4 Reed Switch Comparison

In the table below we compare the different reed switches that were described above. Each reed switch has a different body material which is one of the most important deciding factors in this case. The magnetic strength and distance required will be tested in later sections of this document to prove the switches effectiveness and how this will affect our bottle design. In Table 23, each of the reed switches that were mentioned above will be compared in great detail.

Table 23: Reed Switch Comparison

	MG-A2-5.0-N	**59050-030**	**MK23-80-C-2**
Manufacturer	Magnasphere Corp.	Littlefuse, Inc.	Standex-Meder Electronics
Cost	$6.53	$3.50	$1.88
Body Material	Non-ferrous metal (Gold)	Molded body	Glass body
Operating Range (distance required from magnet to close circuit)	14.4526mm	3.81mm	15 – 20 AT
Release Range (distance required from magnet to open circuit)	16.3322mm	16.51mm	-
Contact Rating	20VDC @ 250mA	5W	10W
Length	6.1976mm	22.86mm	7mm
Height	4.445mm	4.57mm	2mm

3.7.5 Reed Switch Selection

Overall the reed switch made by Standex-Meder Electronics is the best choice. It’s AT operating range is high enough that the magnet will need to be in fairly close proximity to the switch in order for it to close the circuit. Although this part has a glass body, it is the cheapest and the readily available on Digi-Key. The runner-up part was the one made by Littlefuse, Inc., this part has a plastic body but there were none in stock and the lead time was 12 weeks.

3.8 Microcontroller Module

Microcontrollers are where the ‘brains’ are located for many successful electronic projects. Typically, the development boards are what contains the microcontroller, memory, input/output pins, and other various sensors. Just about all of the electronic components that will be used in this project must be controlled by or communicate with the microcontroller. Microcontrollers are electronic devices that act as miniature computers and house the central processing unit which is where software can be uploaded. It is important to determine the individual requirements for each part that the project needs before the microcontroller component is chosen. Microcontrollers have many capabilities and it's possible to find one with the exact specifications that your project desires. In this project we are looking for a microcontroller that is capable of supporting I2C communication, compatible with the Arduino IDE, is low power, and is small enough to be housed in the bottom compartment of our water bottle of choice. This electronic component has many tiny details of what it can and cannot do, this is why researching this part is one of the most crucial steps in this research process. Our project, H-2-Ohm, will need to successfully read the amount of water in the bottle, sanitize the water with a UV-C LED, and relay all of this data to a mobile application. A microcontroller is the perfect piece to tie all of these tasks together. Specifically, the reed switch will also be connected to a pin on the microcontroller which needs to be a logic input. The reason we need a board with a login input pin is to send real-time signals whether or not the reed switch is high, bottle cap is on, or low, bottle cap is off. There are many small details such as this to consider when the design of this project takes place. It is important to account for everything going on in the system before actual physical connectivity takes place.

3.8.1 ATmega328P

The Arduino Uno is one of the most widely used development boards on the market. The microcontroller that the Arduino Uno uses is the ATmega328P. It has a 16MHz quartz crystal, USB connection, 14 digital input/output pins (6 can be used as pulse width modulation outputs), 6 analog inputs, an ICSP header and a reset button [27]. Arduinos use Arduino Software (IDE) programming language, this is a commonly used language and there are many resources available. The ATmega328P also supports I2C and SPI communication protocols. This development board has a voltage regulator on it with an input voltage supply range of 7 to 12 volts and an output regulated voltage of 5 volts. The minimum and maximum input voltage range is from 6 to 20 volts, but this may degrade the microcontroller or produce incorrect voltage readings at the 5 volts pin. There is a 3.3 volts output power pin on the Arduino Uno which can also supply a maximum DC current of 50mA. The input and output pins also supply a maximum DC current of 40mA. The length of the development board is 68.6 mm (2.7 inches) and its width is 53.4 mm (2.1 inches).

3.8.2 ATtiny85

The Adafruit Trinket is one of the smallest and most versatile development out there with a length of 27mm (1.06 in) and a width of 15mm (0.6 in). This board is equipped with the Atmel ATtiny85 microcontroller. This little chip has an 8 KB flash memory size, I2C/SPI digital communication peripherals, an operating voltage range of 1.8 to 5.5 volts and a pin count of 8 [28]. It has an internal oscillator that runs at 8 MHz but has the option to overclock it to 16 MHz by changing some settings in the software. The user can plug in this board into any computer using a USB port and program it through the Arduino IDE. Some of the normal Arduino programming functions are not present due to the boards size Another very important feature that this little board has is it's 3V logic pin which can only run at 8 MHz [29]. This chip has an on-board 3.3V power regulator with a 150mA output capability. The power regulator on this chip has a very wide range of input voltage that it can handle, 2.3 to 16 volts. Overall, the Adafruit Trinket is a powerful development board especially considering its size.

3.8.3 ATmega328V

The Lilypad Arduino is a unique development that can be easily integrated into unique electronics projects. This is the only circular board in this list, it has a diameter of 50mm (1.97 inches). This microcontroller that this board uses is the ATmega328V, this is similar to the Arduino Uno's ATmega328P. The LilyPad has 14 digital I/O pins and 6 analog input pins. Its operating voltage is 2.7 to 5.5 volts, if the board is run at a voltage higher that 5.5 volts then it will be destroyed. This board has a flash memory of 16 KB and a clock speed of 8MHz. The DC current supplied at each input and output pin is 40mA. Another perk of this development board is that it is hand-washable, but the power supply must be removed before doing this. The Lilypad Arduino is compatible with Arduino IDE software, but only with software versions 0010 and higher [30].

3.8.4 32 bit ARM Cortex-M4

The Teensy 3.2 has a wide variety of features that makes it a very impressive development board. Its microcontroller is a 32-bit ARM Cortex-M4 CPU with 256 KB of Flash Memory. It also has 34 digital input and output pins, 21 high resolution analog input pins, and several touch sensor inputs. The Teensy 3.2 is a perfectly sized board for any electronics project that requires the components to fit in a compact area, its length is 35mm (1.4 inches) and its width is 18mm (0.7 inches). The microcontroller has two I2C communication modules, which means a more efficient transfer of data. The Teensy 3.2 version is tolerant up to 5 volts of input supply voltage, it also has a current output of 10mA on it's digital I/O pins. The Teensy can be programmed with any C program editor or the Teensyduino can be installed on the board so it can also run Arduino IDE. A special feature that the Teensy 3.2 has is a 3.3 voltage pin source with a 250mA maximum current draw, as well as containing 7 timers for intervals and delays [31]. This development board has a regulator voltage input limit of 6 volts which it can regulate to be 3.3 volts typically.

3.8.5 Microcontroller Comparison

In the table below we will compare the different microcontrollers which were previously discussed. The main characteristics that our project will need is for the board to be small enough to easily fit in the base of the water bottle, the supply voltage to be within the range of our other components, and a voltage regulator to be on board. Table 24 compares the microcontrollers important characteristics that is relevant to our project.

Table 24: Microcontroller Comparison

	ATmega328P	ATtiny85	ATmega328V	32 bit ARM Cortex-M4
Development Board	Arduino Uno	Adafruit Trinket	LilyPad Arduino 328 Main Board	Teensy 3.2
Cost	$2.04	$1.16	$2.14	$3.57
Digital input/output pins	14	5	14	34
Analog input pins	6	2	6	21
Input Voltage (recommended)	7 V – 12 V	1.8 V - 5.5 V	2.7 V – 5.5 V	1.71 V – 3.6 V
Clock Speed	16 MHz	8 MHz	8 MHz	32 MHz
Flash Memory	32 KB	8 KB	16 KB	256 KB
I2C Support	YES	YES	YES	YES
IDE	Arduino	Arduino (limited)	Arduino (0010 or higher)	Arduino (must install Teensyduino)

3.8.6 Microcontroller Selection

The H-2-Ohm water bottle would be best fit with the ATmega328P microcontroller. This little microcontroller fits all of our design criteria. It has two I2C communication protocol modules, Arduino IDE compatible, and several 16-bit timers which will be used to accurately activate the sensors at given intervals. The ATmega328P does have some precautions that come with it which is common with any electronic device, these will be followed to ensure the safety of the chip. The versatility of this microcontroller will be tested in the project design section of this document.

3.9 Water Bottle Research

The largest housing for the water bottle is the bottle itself. This is what the user will be mostly concerned about since most consumers don't care how their devices work just that they do. The aesthetic and functionality of choosing a water bottle is important as well has its capacity. There is no point to having a water bottle that can only hold 12 ounces or below so this project plans to choose an 18 or 24 ounce water bottle. The base of the bottle should be wide as to hide all of the electronic components in the 3D modeled hub as well as drilling holes into the bottom for both the pressure sensor and UV-C LED components selected above. In this section both a metal water bottle and a clear water bottle will be explored.

3.9.1 Metal/Al Bottle

Metal bottles are durable and depending on how they are manufactured they do not produce condensation. This is an important quality since if there is condensation and the H-2-Ohm has to sit in a small pool of water this could potentially get in with the electronic components and damage them for future use.

Some concerns regarding the bottle being metal would be drilling holes into the base. Metal tends to be sharp once cut and we would want to make sure that this would not damage the pressure sensor or the UV-C LED. Some other options that go along with a metal bottle would be to ensure that it is grounded.

A plus for the metal bottle is that the user cannot see the contents inside the bottle when the cap is closed this is very important for the sanitization periods where the UV-C LED is active since it is harmful to the human eyes.

3.9.2 Clear bottle

There are two options when talking about clear bottles, glass and plastic. Glass bottles are aesthetically pleasing but they are not very durable where plastic bottles are very durable (arguably more than metal and glass). A few downsides to a plastic or glass bottle though are that they both produce heavy condensation which could leave the H-2-Ohm sitting in a pool of water like mentioned before.

The biggest concern for a clear bottle is the UV-C LED. When the sanitization period is active and the LED is on, this will expose the user to the rays. This is a safety hazard and the only way around it would to be to purchase a separate cover for the bottle to ensure that it is not see through. As for drilling into the base of these bottles, plastic would be no issue at all where glass would be the most unideal to drill into as that could cause the whole bottle to crack.

3.9.3 Water Bottle Comparison

Looking at both options of either a metal or clear water bottle a simple comparison of their attributes was defined and placed in Table 25. It is important to weigh all the options so the best bottle can be selected for this project.

Table 25: Accelerometer Part Comparison

	Metal/Al	**Plastic**	**Glass**
Durability	Medium	High	Low
Condensation	No	Yes	Yes
Ease of Drilling	Medium	High	Low
UV-C Eye Safe	Yes	No	No

3.9.4 Water Bottle Selection

After reviewing their characteristics above the clear choice for the H-2-Ohm is a metal water bottle. This checks the boxes when it comes to condensation, durability, and being safe for the UV-C light to be on and not worry about it harming the user. When purchasing a bottle the base width will be measured to ensure that all of our components will fit at the bottom and not interfere with the user's regular use. It is also important that the bottle have a screw top lid so that the sip detection can be implemented as well as another fail safe to keep the user from coming in contact with the UV-C LED.

3.10 Battery Research

To ensure the H-2-Ohm works at all, a strong enough power source must be selected that can one run the entire load, and two last long enough such that the user does not have to change the batteries an extreme amount of times. The idea of having a built-in charging port for the H-2-Ohm is nice but, the safety hazards alone make it not worth the headache. For instance, say the user does not empty the water bottle or does not realize there is water around the base when they are charging it, this could cause serious electrical harm not only to the H-2-Ohm but also to them if they come in contact with electrified water. So, for the purpose of this project either batteries that are disposable or rechargeable (by taking them out of the base) will be considered.

The power specifications vary based on what components are running and when. Starting with the UV-C LED, this will be powered separately from the board and requires a lot of power when it is on. Luckily it will only come on in timed three-hour increments for an interval of two minutes. The majority of the time, this is off so it only marginally effects how long the batteries will last but it does require a set voltage level. For the selected UV-C LED looking at the current vs. voltage graph it is clear that if the UV-C LED is powered with 6V it will need around 65mA, and if an even lower voltage of 5.5V is used it will need around 40mA. This will affect the brightness levels but for our sanitization purposes that will be acceptable and if needed the "on" interval can be extended. At the 6V this would have the light functioning at 60% brightness, and the 5.5V is 40% brightness [23]. It drops 20% with each half a voltage level drop. Further testing will also help define what voltage and current level the UV-C LED actually runs at and the amount of current it will draw, see the UV LED testing section for more information. The worst case scenario current draw is 100mA and that is what will be used for the battery calculations. In a 16 hour day of water bottle use case (assuming that the user gets 8 hours of sleep) the UV-C LED will have been on for a total of 10min give or take depending if the lid was opened during one of those intervals.

The microcontroller is going to be the other main power consumer since it will run all of the other periphery components. The microcontroller selected will use a voltage of 3.3V on its VIN pin to power the device and looking at forums on its power consumption based on simple code and using an 8Mhz clock rate it uses 3.6mA of current plus the components its running and for a 16Mhz clock rate it uses 6.6mA plus the components its running [32].

But for our bottle it would be mainly in sleep mode so the power source yes should be able to provide this value but in general the life of the battery will not be limited to having 6.6mA running for 16hrs.

Looking at the periphery components, the pressure sensor needs 1.25mA of current when converting but the majority of the time it will be off. The Accelerometer needs only 6-11µA, and the Bluetooth when sending data will take 13mA but in general the shutdown low power mode will only consume 2.9µA. As mentioned before the current should be added to in the unlikely extreme case the microcontroller could need 6.6mA + 1.25mA + 11µA + 13mA coming to a total of 20.86mA which should never happen since the components come on in a domino effect but for all purposes it is better to design for this case. So out of a 16 hour day of bottle use estimating that the components come on 80 times (5 sips per hour) for a duration of 1 minute then it would need to run at 20.86mA for 1.33 hours per day. It should be noted that this is the most extreme case and the actual power consumed is not expected to come close to this but the batteries looked into should be able to run these capabilities.

Power Regulation:
For the worst case scenario as mentioned before battery calculations to find the ratings take place below.

3.3V * 20.86mA * (1.33*60*60)sec = 329.6 Joules
6V * 100mA * (10*60)sec = 360 Joules
Total = 689.6 Joules

Placing a buffer of 20% depending on the voltage regulators needed to find what characteristic battery should be used will tell the minimum milliamp hours that should be selected. Ideally one voltage regulator of 3.3V will be for the microcontroller and one that's 6V for the UV-C LED will be needed. All the batteries below will be of or around 3.7V value so the following calculations can be used.

689.6J * 120% = 827.52J
827.52J/3.7V = 223.65Coulombs = 62.13mAh

The minimum milliamp hour for the battery should be 62.13mAh which will make it last one whole day since these calculations are for a 16 hour period.

3.10.1 Rechargeable Lithium Battery (Coin Cell)

For obvious reasons a Lithium coin cell battery would be an ideal choice size wise. It however is not a common rechargeable battery so the likely hood of people having a charger already in their house that could charge these after use is slim. Meaning a charger would have to come with the bottle. For a CR2450 coin cell it provides a voltage of 3.6V with a capacity of 120mAh. This means that the H-2-Ohm would have to be charged every night which is inconvenient to the user. The price range is not bad and comes in at around $3 and two will be needed.

3.10.2 Rechargeable Lithium Polymer (LiPo) Battery

Lithium Polymer batteries provide a voltage of 3.7V and come in a flat rectangular shape like the ones used in cell phones. The plus with these kinds of batteries is that they have a wide range of milliamp hours so if one with 1000mAh or 850mAh was selected then the H-2-Ohm would not have to be recharged for a minimum of a week which is more along the lines of consumer electronics these days. Their price range is a bit higher and would be around $10 per cell and two would be needed. A main concern is the size and to make sure that it stays within a few inches so it will fit under the base.

3.10.3 Rechargeable Round Lithium Ion Battery

These round batteries are the smaller counterparts to the LiPo batteries discussed in the section above. They also have a nominal voltage of 3.7V and can provide the same range of milliamp hours with the caveat that they do not have their own circuit protection. This would cause more components to be added to the board to help maintain this. After doing extensive research it was found that these are not very common to find.

3.10.4 Battery Research Comparison

After looking at these different types of batteries it was decided that every voltages range met the desired criteria, but the coin cell did not meet the desired use time of one week minimum before recharge. The milliamp hours and size played a lot into the role of this selection since all components will rest at the bottom of the bottle. In Table 26 below all three are compared against one another.

Table 26: Battery Type Comparison

	Coin Cell	**LiPo**	**Round Lithium Ion**
Voltage	3.6V	3.7V	3.7V
Milliamp Hrs	120mAh	<1000mAh	<1000mAh
Ease of Charging	Low	High	Medium
Size Estimate	24mm	2.00inx1.32in	2.72in length

3.10.5 Battery Research Selection

The Lithium Polymer battery has been selected for this project based on its size and milliamp hours. The specific model of LiPo battery going to be used is the Lithium Ion

Battery 1000mAh model from SparkFun [33]. Using the overestimated power consumption from above this would be able to power the bottle for a little less than two weeks which meets the desired range. Its size specifications are 2.00 x 1.32 x 0.23 inches meaning, our water bottle base should have a minimum diameter of 2.5 inches for wiggle room. It is important to note that a special charger would have to be included with the water bottles and the user will have to remove the batteries from the housing. For future renditions of the project the charger could be integrated onto the PCB and have micro USB charging cable.

3.11 Device Communication Research

One of the desired capabilities of the device is to send data from the H-2-Ohm module to an android mobile device. The goal of this feature is to provide feedback for the user about their water consumption and is convenient and rewarding to use. For the user, it is the primary function of the H-2-Ohm module to see water consumption and setting limits or goals on the application all through a smooth and comfortable app experience. Purely looking at the communication aspect between the module and mobile device, setting it up should be as seamless as possible and providing feedback to the app with a few seconds of the sensors detecting the changes in water level. This is important because as a user of several different phone apps, experiencing drawn out and extensive setup process can severely mar the desire to use this product.

3.11.1 Wired Connection

One option for communication is a wired connection using UART or I2C over USB. While this option is simpler and less expensive due to these features being very common in MCU's, it has the disadvantage of requiring the user to plug a wire from the phone to the module. In addition, using any wired connection with the H-2-Ohm module which will contain water can significantly increase the risk of damage either the module or mobile device. Another aspect of wired communication is the massive user inconvenience which not only requires action from the user, but also requires extra hardware as a wire is needed each time the app data needs updating. Speaking of updating, we want the app to update its information each time the H-2-Ohm bottle is used. This will occur far too often to require the user to plug the H-2-Ohm module to the mobile device to the point of it being impossible.

3.11.2 Wireless Connection (Wi-Fi)

The second option is wireless communication via Bluetooth or a Wi-Fi signal. Wireless will allow the user to easily have the information transferred between the H-2-Ohm module and the mobile device after the initial setup. If a Wi-Fi signal was used, the module would have to be sure that it is connected to the same network as the mobile device which adds more work for the user. This could be fixed by using Wi-Fi Direct in the module, allowing it to emit its own Wi-Fi signal for the mobile device to connect to but this will increase the amount of power required and in order to connect to the module, it would require the user to disconnect from other Wi-Fi networks that may provide internet. Figure 7 below shows the difference between a Wi-Fi direct connection and a connection via a local Wi-Fi Network.

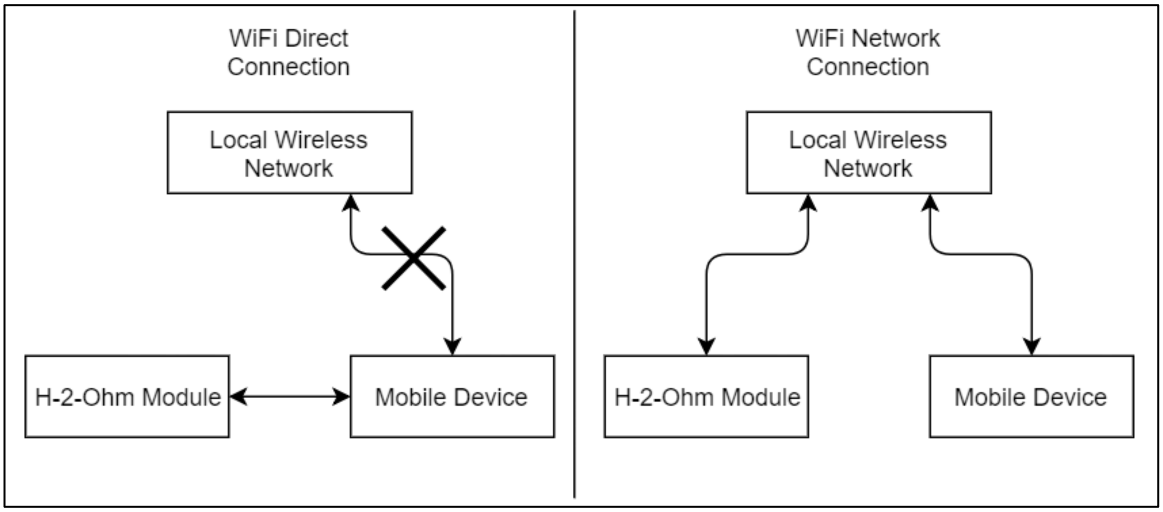

Figure 7: WiFi Direct vs. WiFi Network

3.11.3 Wireless Connection Bluetooth

Using Bluetooth on the other hand, resolves many of the problems that occur with Wi-Fi communication. Bluetooth technology has advanced to the point where it absorbs very little power and can still send data to the mobile device without interrupting its other functions. One of the few downsides to the Bluetooth option is that in using it, we increase the complexity of software design due to the proper security protocols that are used.

Overall, a wireless option will add complexity to the module as wireless communication can be less consistent than wired causing it to be more difficult to implement.

3.11.4 Device Communication Comparison

Looking at the different options for communication between the H-2-Ohm module and mobile device, we want to prioritize ease of use for the customer. The connection should be easy to setup and preferably communicate real-time changes to water levels without additional user interaction. Another focus is making sure that power consumption is minimal. A low power consumption will ensure that the device will not need a large-bulky power source which would take up more space but, it wouldn’t need to be recharged or swapped out too regularly. Table 27 shows the comparison of all the above communications.

Looking at the pros and cons of the different options, a wired communication would require the customer to connect their device to the module in order to update the mobile app. This would prevent real-time updates and require extra effort from the user. Not to mention the possibility of water damage to the mobile device or the connecting wire.

Wireless over Wi-Fi solves the issue of extra hardware but can be very inconvenient for the user to disconnect from their current Wi-Fi network to connect their device to the module. This option still would not always be able to transmit information in real-time because the user would be constantly connecting and disconnecting from the device. This option just does not provide the amount of user friendliness we are aiming for.

The final option would be wireless over Bluetooth and while new skills would be needed to configure and setup this connection, it is the most robust option due to its ability to stay connected to a mobile device within a certain range as well as the fact that after re-entering optimal range from the device, it can automatically reconnect without user input. This allows for the real-time connection desired for the H-2-Ohm module and can be much more user friendly. The only concern with this option would be power consumption but because of Bluetooth development there are Bluetooth modules that run on very low power until they are in use.

Table 27: Device Communication Comparison

	Wired	**Wireless (Wi-Fi)**	**Wireless (Bluetooth)**
User setup complexity	No setup required (plug and play)	Difficult	Simple
User accessibility	Limited by wired connection	Range of 30+ meters (Not always connected)	Range of 10-30 meters (Always connected)
Development complexity	Simple	Moderate	Difficult
Relative Power required (from H2Ω module)	≈ 0	>100mW	<100mW

3.11.5 Device Communication Selection

Because of its versatility in options for use and because using Bluetooth aligns with the set priorities for the communication device, we chose to use a Bluetooth module for communication between the H-2-Ohm module and the mobile device.

3.12 Bluetooth Module Research

Having chosen to use Bluetooth in order to connect the user’s mobile device to the H-2-Ohm module, we must do research on different modules and choose one that best suits the needs required for the H-2-Ohm module. These needs include limited power consumption, small size and several options for serial communication which will allow for higher versatility and allow us to adapt the Bluetooth module around the rest of the communication in the H-2-Ohm module.

Our main goals in choosing an optimal device are, low power consumption, small size, stable connection within 15ft and reasonable cost (< $20). Ideally the module should also be powered at around 3.3V. We were able to find several different modules that fell within these constraints, the RN4870-V/RM118, the TI CC2640R2F or BLE113. Our initial choice is the TI CC2640R2F due to its versatility as it is a microcontroller as well as its low power consumption.

3.12.1 BLE113

The BLE113 was developed by BlueGiga, owned by Silicon Labs. It uses Bluetooth v4.0 standards and supports supply voltages up between 2-3.6V and uses very little power as the maximum current flow is around 18.2mA while transmitting and 0.4uA when in sleep mode. This means that at 3.6V it consumes a maximum of only 65.52mW of power. The BLE113 also has an integrated stack and supports UART, SPI, I2C, PWM and GPI I/O interfaces as well as a 12-bit ADC. Its dimensions are 9.15 x 15.75 x 2.1 mm. This device boasts numerous applications including many different types of sensors as well as iPhone and iPad accessories [34].

3.12.2 RN4870-V/RM118

This Bluetooth module is designed and manufactured by Microchip Technology. It runs using Bluetooth v4.2 BLE standards and comes with an integrated shielded antenna. It can run on voltages ranging from 1.9-3.6V but typically uses a 3.3V supply. Tested at 3V and high operating temperatures, its maximum current while transmitting was 13mA, low power mode current is as low as 60uA and average current while connected at 18.75ms intervals is 2.13mA (at 3.3V). This means the highest power output is around 39mW and at a 18.75ms connection interval, average power output is 7mW. The RN4871 also has a 16-pin I/O configuration and its dimensions are 9 x 11.5 mm. The module also uses an ASCII command API which utilizes a BLE or smart stack allowing simple use of GPIO, I2C, PWM and UART communication [35].

3.12.3 TI CC2640R2F

The TI CC2640R2F is an interesting option as a Bluetooth communication module as it is an entire microcontroller which has a 32-bit ARM Cortex M3 and has a clock speed of up to 48MHz. It uses TI’s SimpleLink BLE technology with Bluetooth v4.2 and runs on supply voltages ranging from 1.8-3.8V. During active communication, the maximum current that it draws is 9.1mA and while on standby it draws 1.1uA. At 3.3V, the power consumption is maxed at 30mW and the minimum power consumed is 3.63uW while in standby mode [36].

3.12.4 HC-05

Due to the simplicity of its setup process, the HC-05 is widely used for Bluetooth projects that use Arduino technology. It runs on supply voltages between 3-5V and while low power operation mode is active can run on only 1.8V. Some of the disadvantages of using the HC-05 are that its only option for serial communication is via UART connection as well as the fact that it uses the much older Bluetooth version 2.0 [37].

3.12.5 Bluetooth Module Comparison

The focus of choosing the best microcontroller for our project is small size to fit in the limited space of the enclosure, low power consumption so that batteries will not need to be changed very regularly, reasonably low cost for obvious economic reasons and have a decent signal range.

Looking at all our options, the BLE113, while it does the best as far as power consumption in sleep mode, it has the highest consumption of power while active, this in conjunction with the fact that it is the second largest of the options meant that it was not our best choice.

The RN4870-V/RM118 is consistent across the board with a very low average power consumption, decently small size and the lowest cost of all the options.

The specs of the TI CC2640R2F by far look the best on paper and has the lowest power consumption and the smallest size but as a team, we decided against it due to our the desire to use a Arduino microcontroller and having two microcontrollers would be overly complicated especially alongside needing to learn SimpleLink but because TI offers this as a free sample to students, we ordered one for testing and real time comparison between it and the Arduino microcontroller.

Finally, the HC-05, it has no information from the datasheet relating to power consumption and runs Bluetooth v2.0 and while it is widely used for homemade project and there are many YouTube tutorials on how to set it up and utilize it with an Arduino microcontroller, it is too large for our project and may not have low energy options. Table 28 below shows the comparison between all these modules.

Table 28: Bluetooth Module Comparison

	BLE113	RN4870-V/RM118	TI CC2640R2F	HC-05
Bluetooth version	V4.0	V4.2	V4.2	v2.0
Size (mm)	9.15 x 15.75	9 x 11.5	7 x 7	27 x 12.7
Current(low-high)	0.4uA - 18.2mA	60uA - 13mA	1.1uA - 9.1mA	unknown
Power(low-high) (3.3V)	1.32uW- 60mW	198uW- 39mW	3.63uW- 30mW	unknown
Cost	$12.67	$7.24	$8.51	$10.57

3.12.6 Bluetooth Module Selection

After looking over all the options, we prioritized picking the one with the smallest size, lowest cost and lowest power consumption that we could use alongside our Arduino microcontroller. Therefore, the option that makes the most sense is the RN4870-V/RM118.

3.13 Mobile Application Software Tools Research

The design goals for the mobile application are simplicity, ease of use, low cost and easy integration with the Bluetooth communication. Another aspect we consider is that we are only building an application for Android devices, this means that app development software that can be used for both apple and android applications is not required. As there is little experience in app development within the team, we also want to choose and option that is not difficult to learn.

There are many tools available for android app development that could work for this project and multiple tools will probably be necessary since several of them have unique functions such as application emulators, debugging software and full development environments that can implement several of the other tools. The software tools that we researched are Android Studio, Eclipse, Microsoft's Visual Studio, AVD Manager, NimbleDroid, LeakCanary and Gradle.

3.13.1 Android Studio

Developed by Google and JetBrains, Android Studio is a free of cost app development environment. It is one of the most commonly used Android development software tools and offers numerous options for adding other crash reporting and debugging addons. It also has its own virtual device software so that app can be tested on several different device platforms. Android Studio supports the Java, C++ and Kotlin programming languages [38].

3.13.2 Eclipse

Before Android Studio was released in December 2014, Eclipse was the most commonly used IDE for Android app development. Although Android Studio is currently the preferred app development IDE for most developers, there are many who still use Eclipse. Because of this, it has many useful online resources and tutorials on how to use it. Eclipse can be used on any operating system and although it was originally created as a Java IDE, it has become extremely versatile as it now supports over twenty different programing languages.

3.13.3 Visual Studios

Made by Microsoft, Visual Studios is another IDE program with numerous tools for debugging, testing and implementation. It is an IDE that most of the team has experience working with and like Eclipse, supports many different programming languages. This is another option that has a lot of online support tutorials on how to use its different features.

3.13.4 ADV Manager

This is another piece of software that was developed by Google and is built into their Android Studio IDE. Utilizing it allows testing for how almost android device will work with the app. This means that without purchasing a bunch of different mobile phones, we can test on nearly all of them. This will allow us to test the mobile application as it is being built providing rapid feedback on what changes need to be made so that we can provide an optimal user experience.

3.13.5 NimbleDroid

NibleDroid, owned by HeadSpin, is a piece of software that analyzes mobile app performance. It searches for memory leaks, code that may cause slow app startup times and even things that make the app run slowly. NibleDroid works with both IOS and Android apps. All these things, while they may not be vital in building a functional application, can be very helpful in creating an app with a good user experience.

3.13.6 LeakCanary

This resource, produced by Square, is primarily used for identifying and tracking down memory leaks. It is a Java function that can be written into the android app code and produce a log of areas in the app which cause memory leaks and traces them to the source. Like NimbleDroid it reports which code is causing memory leaks allowing developers to quickly fix performance issues in the app [39].

3.13.7 Gradle

Gradle is an application builder tool that allows the automation of creating and developing apps. It can run on both Eclipse and Android studios as well as a couple of other popular IDEs. This type of software can be very effective for inexperienced app developers allowing them to use features that would be too advanced otherwise. Gradle was released in 2007 and is primary made to function with the Java or C++ programming languages.

3.13.8 Mobile Application Software Tools Comparison

Because we are aiming to build a simple app that can display information received over Bluetooth, we did not discuss several development tools that are used for complex social or gaming apps. After exploring the uses of the development tools previously discussed, we only need to utilize one IDE and the other software tools, while not vital, are available to make things easier when building the app. Choosing between Android Studio, Eclipse and Visual Studios as an IDE, we need to first consider what programming language we want to use and which IDEs are compatible with other listed tools. Knowing that we will likely do the app coding with Java and using C for programming the microcontroller, can choose any of these IDE options as all of them support both languages. Table 29 shows the comparison between each application development software and which one has the most capability.

Table 29: App Development Software Compatibility

	Android Studio	**Eclipse**	**Visual Studios**
AVD Manager	Yes	No	No
NimbleDroid	Yes	Yes	Yes
LeakCanary	Yes	Yes	No
Gradle	Yes	Yes	Yes

With Android Studio, we have the most flexibility when it comes to using all the available tools for troubleshooting and testing. Another advantage as mentioned before is that it has a strong community of developers which means it will not take as long to build the app and learn from mistakes.

Eclipse is another option for an IDE which has a lot of online resources but because it is used for many other things besides app development, it can be harder to search through and find posts and tutorials that will be helpful for building an app. Another downside is that Eclipse, along with Visual studios, does not support AVD manager which means that it can become more difficult to test the app in a risk free environment unless we can find other application emulation software.

Finally, Visual Studios, while it is not compatible with LeakCanary or AVD Manager is the IDE with which the team has the most experience. Taking this into account, most of this experience is related to writing Java programs rather than App development. While not useless when it comes to app development, Visual Studios does not have the same amount of versatility as the other options.

3.13.9 Mobile Application Software Tools Selection

After researching the pros and cons of the different development tools we decided on using Android Studio. This is because it offers the most support when it comes to app development and it supports far more development features like the android device emulator and the optional debugging and memory leak tools. All of this makes Android Studio an optimal choice for app development. In addition we decided to use AVD Manager, Gradle and LeakCanary as tools to optimize the app.

3.14 Serial Communication

Serial communication is going to be a large part of the H-2-Ohm project and is vital in allowing the microcontroller to send and receive data and commands from the pressure sensor, the accelerometer and the Bluetooth module. When considering which serial communication technology and protocols to use, we should look at what components we are using, what they support and what makes the most sense based on how the serial communication protocols work. This section will discuss each of the serial communication options that are available using the microcontroller that we chose and then make a decision on which one to use based on our findings from the research that we did.

3.14.1 UART

The UART acronym stands for Universal Asynchronous Receiver Transmitter and is one of the simplest applications of serial communication and is built for two wire communication between two devices. It uses TX (Transmit) and RX (Receive) ports. Because UART is asynchronous, it does not synchronize clock rates between the sending and receiving device. Therefore, UART must use a different method of determining how the data on the receiving end is interpreted without normal synchronization. This method is implemented through a start and stop bit which tells the receiving device when to start reading the data and when to stop. The way the devices synchronize the transmitted data is through a setting called baud rate. This is setting which can be set despite the clock rate of the device and has a 10% tolerance between the baud rates of the two devices. This baud rate is measured in bits per second and can be as high as 115200 but the standard rate is 9600. While UART has the potential to be unreliable, it uses parity bits in order to correct misinterpreted data. UART's advantage over other technologies is its simplicity to setup and configure as well as allowing devices with different clock frequencies to communicate. The main disadvantage of UART is the limit of only 1 slave and 1 master. Because of this, we can only have one of the external sensors connected via UART at a time and since we have two sensors, a Bluetooth module and the UV LED communicating with the microcontroller and there or limited communication ports on it, UART will be something that we should avoid if possible in order to conserve power and open ports on the microcontroller. If UART is used, we can only use it with as many devices as the microcontroller has UART ports. This means that we will need to use other serial communication technologies. [40]

3.14.2 SPI

SPI, or Serial Peripheral Interface is another serial communication option for the H-2-Ohm Module. This technology uses synchronous communication when sending data to its connected devices or peripherals. SPI is commonly used in projects like ours having a microcontroller that sends and receives data from several different sensors. SPI's synchronous clock means that all devices must read the data at the same clock rate. SPI does this by using 4 lines, two for data transmission, one for device selection and the other sends the clock signal to all connected devices so that they know when to read each bit. The two data lines are labeled MOSI (Master-Out-Slave-In) and MISO (Master-In-Slave-Out) and are connected in series from one device to the next. The master usually refers to the primary microcontroller and the slave refers to any peripheral devices. [41]

Finally, the select line which the master device uses to choose which slave device that it is communicating with. The way it is setup, SPI's protocols allows for near unlimited peripheral devices. Unique to SPI protocols is the fact that its data stream is not limited to a packet size and can send and receive data continuously. Another advantage is that SPI allows communication in full duplex allowing the selected slave to send and receive data to and from the master simultaneously. [42] The following Figure 8 [43] shows the signal flow of an SPI layout and how the master and slave devices communicate.

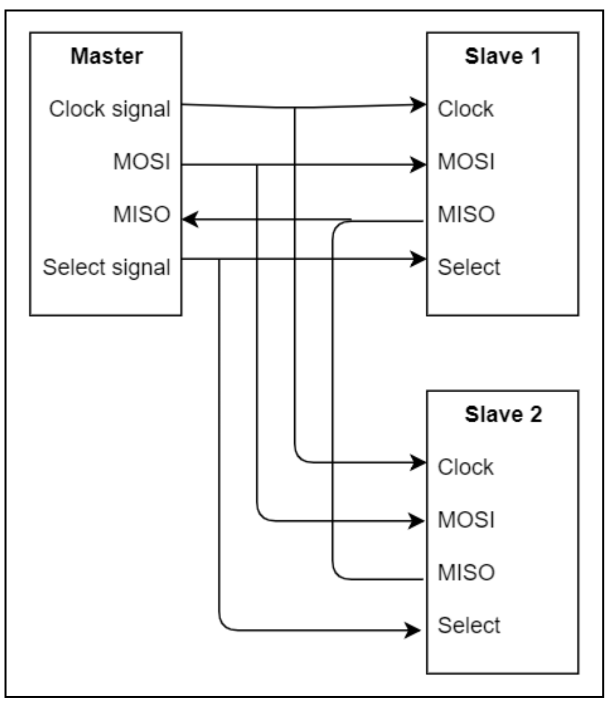

Figure 8: SPI Communication Diagram

3.14.3 I2C

Inter-Integrated Circuits or more commonly known as I2C is a serial communication protocol that has many of the advantages of both UART and SPI without as many downsides. I2C, like SPI uses a clock signal to synchronize the data transmission between the master device and the slave devices. But instead of having a third line to switch which device it is communicating with, I2C utilizes a start condition followed by the address of the device that it wants to communicate with. All connected devices check to see if the address from the master matches their own, only responding if the address is a match. In order to accomplish this the I2C protocol runs the peripherals as active low and utilize pull-up resistors to avoid sending data when the master is trying to communicate with a different device. I2C is very popular in microcontroller hardware design due to its simple scalability which allows many devices to be added in parallel limited only by address size. One concern with using this technology would be having devices that use the same address. [44]

In addition to all of this I2C allows the device to be a multi-master system. Because I2C devices can determine if the line is busy or not, multiple masters are able to be used in parallel allowing for a more complex system without adding a bunch of extra hardware, the downside to converting to a multi-master system later on as an iterative step is that the single master code will need to be adjusted so that it waits if another master device is transmitting data. The following Figure 9 shows the general concept for wiring and how the flow of information and data works when using an I2C system [43]

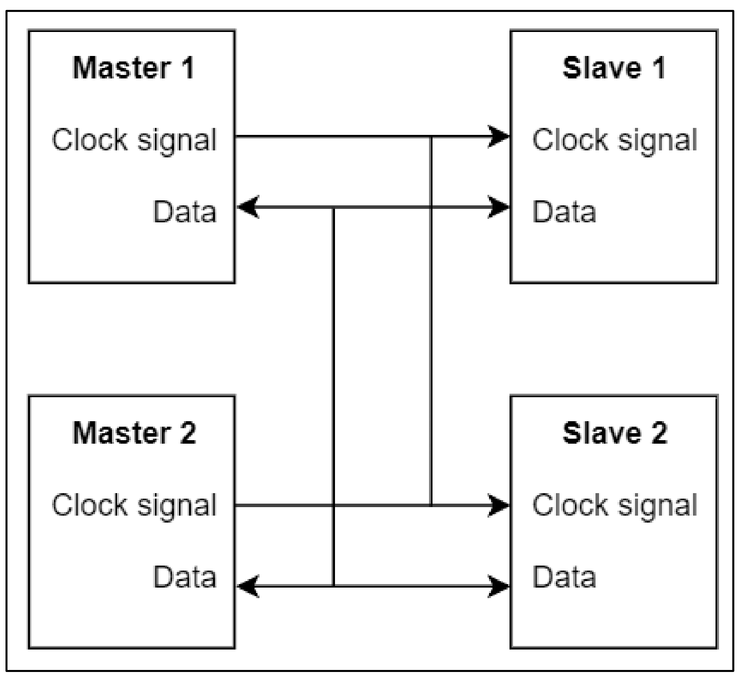

Figure 9: I2C Communication Diagram

3.14.4 Serial Communication Comparison

With the capability of the microcontroller we decided to use, we can effectively implement multiple different serial communication technologies. Since we have more than one sensor/communication device, we are unable to use only UART. Even though UART is simple and easy to setup, its slower speed makes it undesirable for communication with the Bluetooth module and the other peripherals are not compatible with UART. This could be a viable solution if future iterations of the H-2-Ohm module add a small display. Overall there is almost no advantage in using UART except for future added peripherals and the fact that it is easy to setup. It is too slow and restrictive for the use of this project.

Looking at the pure statistical advantages, SPI looks very promising because of its massive scalability and speed, its disadvantages seem to be minimal between the simple fact that it uses more wires and that the configuration is slightly more difficult to setup and understand but because of our project direction and goals, we don't need a massive amount of peripherals and while 10Mbps speeds are impressive, they are quite unnecessary for the scale of the H-2-Ohm module. Due to the fact that we cannot fully utilize the advantages of SPI, it may not be the best option.

The last option for serial communications that we should consider is I2C. I2C is incredibly popular for use in designs similar to ours due to the ease of setup for numerous sensors and external devices. Due to its versatility in application and our circumstance as far as the fact that some of the sensors that we are using in our project only support I2C, we should consider using it for some of our other peripherals as well. Thankfully, I2C is supported on every peripheral connected to the device and can therefore be a one and done solution for serial communication in our project. Table 30 shows the comparisons of all of these different communication options.

Table 30: Serial Communication Comparison

	UART	**SPI**	**I2C**
Speed	Up to 115.2Kbps	10Mbps+	Up to 3.4Mbps
Complexity	Simple	Difficult	Moderate
Scalability	Only 1 device per UART port	Theoretically unlimited	Limited by address size
Required Wires	2	4	2

3.14.5 Serial Communication Selection

After considering all of the serial communication options and protocols I2C is our most balanced choice. It allows all of the sensors to function using the same communication protocols. SPI, while it gives more freedom at the cost of increased complexity, is beyond the scope of what we need. I2C provides plenty of speed and scalability for what our project needs. If needed, we can choose later on if we want to use UART for communication to the Bluetooth module since it is a simple change and is not difficult to implement later on. For the time being, we plan to use the I2C option for all of the connected peripherals.

4.0 Standards and Constraints

This section will detail all product standards and constraints that we choose to abide by in the design and decision making process of the H-2Ohm project. Constraints will detail design goals and restrictions when it comes to specific aspects of the project, how we would like it to work and how it will affect the world directly and indirectly. Standards will list general protocols and procedures that our design will follow and abide by when it is functional as well as following them in the way we design the H-2-Ohm module.

4.1 Realistic Project Constraints

There are many different possible uses for the H-2-Ohm project and we do not know who will use it. One goal in considering constraints is that it should be as versitile as possible. In our design we try to consider as many different purposes for use as we can. Fitness is likely on of the most common uses for our project allowing users to make sure they have a healthy amount of daily water consumption. Another possible use is limiting water intake. While this is a small group of people, there are a few medical imparements that may require users may need to limit water consumption and we want to accomidate this usage as well. The other usage which is similar to fitness would be for users who know they are not drinking enough water and want to set goals and want the ability to see how they are improving.

4.1.1 Economic Constraints

Many Senior design projects are supported by either UCF or a large company like Lockheed Martin, Siemens, Harris Coorperation or Texas instruments. Our project however is being financially supported internally by the members of the group and therefore we must stay within the cost that we can afford as a group but we must also consider large scale production of the H-2-Ohm module as a product. While it may not go that far, we feel we should keep it within a resonable cost range compared to other similar products that already exsist.

Looking at other products that have measure water consumption and intake, we found that they are purchasable for $40-50 but these do not have the UV sanitization system and are made using plastic bottles rather than our design using a metal bottle. However, bottles containing only a sanitization system cost upwards of $95. Because our project will obtain both functionalities we aim to get all of the parts and build it for less than those two products combined which total between $130 and $150. Considering this, we think that around or under $150 is a reasonable budget for the project.

4.1.2 Environmental Constraints

Any project created in this day and age must consider all possible options at our disposal to minimize the negative environmental impact on the planet and increase possible positive impact as murphy's law works against the environmental health of the planet. As we consider constraints for our design, it is important to put effort into minimizing environmental effects by choosing components that can be recycled once they have run their life-cycle of use for our project.

In choosing a bottle to build around, we need to make sure that it can be recycled or re-usable. For other parts such as the PCB and circuitry used for the project, another reason to minimize the size of the parts is that these materials have extremely limited recyclability as of this time even though they are comprised of recyclable materials, they are extremely difficult to filter once they are in the waste system. Sadly, all we can do is minimize and not completely eliminate these components which are restricted in their level of recycleability.

4.1.3 Social and Political Constraints

Considering social constraints we not only have to look at the use and availablity price wall that may restrict people from being able to afford the H-2-Ohm product as well as making sure that most people arent unable to use it because they may not have a smart android device according to a research done in early 2018, in the united states over 70% of adults own smart phones and while a little over half of united states adults own iOS devices over 70% of smart phones sold worldwide run on the Android OS. While owning a smart phone will have little chance of being an obsticle, we must decide if the application we build to connect to the H-2-Ohm module will be for Android or iOS. Looking at the US only, it is easy to think that iOS is the obvious choice but, taking into consideration the price wall associated with purchasing an iOS smart phone, we should prioritize building an Android app in order to be accesible to a wider range of people. Not to mention that internationally, Android is overwhelmingly more popular because of its price point. We can consider creating an iOS application for this product upon further iterations based on the desirability and success of the H-2-Ohm module if it were to be mass produced and sold as a product. [45]

4.1.4 Legal Constraints

In working out this project, legal constraints must be taken into account. This includes carefully considering patents for similar products as well as making sure we patent any new ideas of our own so that the intellectual property of our group is protected legally from anyone who might take ideas that this group came up with and claim them as their own. Another legal aspect that we will consider in the development of the H-2-Ohm project is to carefully and thoroughly test each aspect of the product for physical hazards or danger. Things that we could consider as physical hazards in our project would be the flow of electricity as high amounts of power can cause over-heating or electrical shock. Another danger could be any chemical reactions to the metal bottle or even physical damage due to UV light exposure to the skin or eyes.

All of these physical threats must considered and in the design of the H-2-Ohm module, we will either create proper countermeasures that vastly minimize the risk of any of these things happening or appropriatly warn the customer against improper use that would increase any of these risks. Doing so will ensure that no legal action can be taken against us in a court of law. Doing such testing should take place in controlled environments where extreme circumstances can be tested to ensure that the user is safe from harm.

4.1.5 Health and Safety Constraints

The topic of health and safety of the product that is build flows across every constraint as so almost all of the constraints have been covered in other sections such as the ethical and legal constraints. This section is here to reference those sections for further details and provide a outline of our goals when it comes to health and safety.

This project should of little to no danger to the general user. The using this product for its appropriate application, it should bring no risk of danger to the user or anyone else. In cases where the product is misused and mishandled we will do our best to predict potential problems and minimize the amount of potential harm its misuse could cause for the user or others that are nearby.

4.1.6 Manufacturability Constraints

For constraints involving the manufacturing of this as a product, there are a few things that be well-thought-out. These things include but are not limited to using up-to-date components, using components that are not limited in supply, choosing parts that fit together without being exsesive in size and making sure the chosen parts are either manufactured within the US or have low cost shipping.

First, we want to make sure all the components that we use are up-to-date and are the latest design. While standards do not encounter significant changes regularly, we want to make sure that we use parts that use more recent technology so that as things change, the product we build is still relevant for a longer period of time without being forced to make major adjustments. One example is the Bluetooth technology. One of our options for a Bluetooth module that is commonly seen in youtube DIY videos runs using Bluetooth v2.0. The latest version is Bluetooth v5.0 and while they are backwards compatible, using a module running on later versions allows future iterations of the product to use more features as well as run faster at lower power.

Secondly, we must consider the limited quantity of different components when deciding on a specific part, this is partially connected to the last point about using up-to-date parts because using older parts can severly limit the supply of components if the manufacturer has stopped making a specific part. Sometimes even newer models are so niche that they only manufacture a set amount of them before ending production. This means that even newer components can have limited supply and we must take this into account when determining which parts we use for the project.

The next constraint to consider when looking at the viability of manufacturing our design on a larger scale all of the parts and electronic components must fit into the limited size constraints. These size constraints are determined by how large the bottle we decide to use for the project is. It also must be big enough to house all of the necessary components while still being comfortable for a customer to use it. This is an aspect of manufacturing a product that is easily overlooked and we should definiitely take it into consideration.

Lastly, when choosing design components, we should attempt to save on cost by trying to find United States manufacturers or at the very least, making sure that shipping costs are competitive and reasonable. Another option to consider manufacturing the product overseas but this option can sometimes create more issues than it solves. It is a great solution when considering cost, but then it is easy to go outside the bounds of our ethical constraints when it comes to labor outside the United States.

All of these things are important to go over when choosing parts for manufacuring a product like this. However, we also realize that the perfect solution does not always exsist for every one of these issues simultaneously. We seek to find a good balance of cost, size and up-to-date technology all while keeping in mind the previously stated legal and ethical constraints.

4.1.7 Sustainability Constraints

The H-2-Ohm module should be able to endure every day use for extended periods of time, in many different situations and in different climates or temperatures. Things such as durability and longevity of the product are important because as a customer, spending $100 plus on a bottle just to have it wear down in a few months is ridiculous. Generally, water bottles like this may not last indefinetaly due to the internal electronic components but when it comes to metal water bottles, most of the compitition have products with the potential to last indefinately other than the plastic lid which will eventually wear down.

Because this product uses electronic components, not only is it more of a challenge to implement the longevity of the H-2-Ohm product, but it will also require some sort of power. Any device that requires power has inate sustainability constraints because from a customer perspective it would be unacceptabled should the power module need charging more than once per week. If we decide to use replacable batteries for our design, the standard is even higher because even replacing batteries once per week is way too often and can become very expensive. This topic also pours into environmental constraints that were mentioned ealier as all power that is wasted has potential to negatively affect the planets general health. This is why many people are focused on generating and using renewable energy.

4.1.8 Ethical Constraints

Similar to legal constraints where it was discussed that the product should be thoroughly tested, when considering ethical constraints it is important to make sure safety and ethical standards are met when testing. Therefore, when testing different extreme conditions, we will not use unethical test subjects such as people or animals. Chemical tests and UV light tests will be conducted using accurate sensors and refer to research that has already been done with similar materials and components.

It is also important to think about possible mass production of this product and labor ethics in the United States as well as other countries should this product be manufactured outside of the United States. It is very important that as we move forward, all of these ethical constraints are carefully considered in order to create a product that does not benefit some people at the detriment to other people or animals who either need active protection or are at a disadvantage compared to the majority.

4.1.9 Application Constraints

For the numerous models of andoid phones that exsist we will use all the resources at our disposel to ensure that as many different hardware and software android versions as possible support the application we are building. Because we are using Android Studio, we are able to easily create and develop and application that has a wide range of compatibility for the different devices that might be used.

4.2 Project Standards

This section lists the different standards that we decided to use and implement into the H-2-Ohm project. Standards in this project could be used for many different reasons. These include compatibility with future technology, safety, user comfort and convenience and many other reasons. The purpose of a standard is to have a set protocol or procedure that is trusted and followed by many different manufacturers and product desigers in order to create something that is safe and benefits both the consumer and the developers.

4.2.1 Battery Standards

Concerning standards regarding the battery charge cycle, battery material and all safety standards when it comes the type of batteries used, our project would rely on the IEEE standard 1679.1-2017 which specifically standardizes the usage of the lithium-based battery but once again it is unavailable to view without purchase. Therefore, we will use the general standards that are publicly accessible. These should provide a baseline of safety and reliability to work from when working with the battery's charge cycle and materials as well as how this relates to safety in using a lithium polymer battery.

First when obtaining a new battery, one should confirm that it is fully charged before first time use. Also, when charging this type of battery, the rate of charge should be limited depending on its capacity so as not to cause the battery to fail or create safety risks. This type of battery is not without temperature constraints as well as even under non-extreme conditions, being left without use for prolonged time periods can also cause degradation to the battery. When storing a Lithium Polymer battery, it should be kept at a charge of around 60-70% for maximum lifetime.

All of these are valuable to recognize when utilizing the type of battery our project requires and allows for a longer lifetime while ensuring user safety and reliability. [46]

4.2.2 PCB Standards

For our Printed circuit board, all standards are maintained by the Institute for Printed Circuits (IPC). While it is not within our budget to purchase any of the standards, this section will cover generally accepted standards when it comes to designing and building a PCB. These standards effect our designs PCB materials used, layer thickness and solderability. All of these will ensure the safety and functionality of the PCB that we design as well as minimize costs.

For PCB materials, there are a couple different options that are generally utilized. The first and most frequently used material is FR-4 which is a reinforced glass epoxy. It is extremely useful as the epoxy material is strong for its weight as well as fire and water resistant. These features make it highly versatile and durable for multiple applications. The second option is PTFE and is primarily used when high speeds or frequencies are required as well as high accuracy functions. It also is flame resistant and very durable. For conductive materials, there is a wide array of different metals that are utilized like copper, aluminum and iron, each with a specific purpose to prolong the lifetime of the PCB. [47]

The thickness of each PCB layer and its total thickness will also have a drastic effect on the PCB functionality and reliability. For PCBs with single and double layers, they only utilize a core substrate PCB layer and the copper foil around it while multilayered PCBs have an additional type of layer for insulation called a prepreg layer which allows more copper foil layers to be used. While an average PCB have a total thickness of around 1.4 to 2.8mm. This will rely on if the PCB is multilayered or not as well as how thick each layer is. There are many ways of determining how thick each layer should be but this is heavily reliant on how many layers are needed for the design

Solderability refers to the consistency at which you expect each solder to be successful. There are many different things that can cause issues to arise such failing to apply proper amounts of copper coating to the pins. These standards ensure that when it comes to large scale production, the resulted solder is consistent and reliably successful.

Looking through the available documentation provided by IPC, we can use performance class 1 standards since it will be a consumer product. These IPC standards detail how a PCB is to be built, which materials are used and how it is soldered together. [48]

4.2.3 IEEE 802.15.1 Bluetooth

For our project we will abide by the Bluetooth standard 802.15.1 set by IEEE. This standard describes the network layers, transport protocols, channel and frequency restrictions as well as the standard range, performance and consistency of a Bluetooth device.

4.2.4 Android Application Standards

While Android is a relatively flexible system for app development and it doesn't have strict design requirements or standards. When building the application for the H-2-Ohm module we decided to look to Android's development design and quality documentation which details design guidelines as far as quality, style, usability and several other application components related to design. We use these for direction when building the app so that the application meets Android development standards for the Google Play store.

4.2.5 RoHS Standards

RoHS is an acronym for Restriction of Hazardous Substances. RoHS standards impact the electronics industry and the electrical products that are produced every day. These standards were originally formed in the European Union in 2002 in order to restrict manufacturers from using the following hazardous materials, listed in Table 31, commonly found in some electronics parts. All applicable products in the EU market since July 1, 2006 must pass RoHS compliance [49].

Table 31: RoHS Hazardous Materials Maximum Allowable Concentrations

Material	**Concentration**
Cadmium (Cd)	< 100 ppm
Lead (Pb)	< 1000 ppm
Mercury (Hg)	< 1000 ppm
Hexavalent Chromium (Cr VI)	< 1000 ppm
Polybrominated Biphenyls (PBB)	< 1000 ppm
Polybrominated Diphenyl Ethers (PBDE)	< 1000 ppm
Bis(2-Ethylhexyl) phthalate (DEHP)	< 1000 ppm
Benzyl butyl phthalate (BBP)	< 1000 ppm
Dibutyl phthalate (DBP)	< 1000 ppm
Disobutyl phthalate (DIBP)	< 1000 ppm

RoHS is put into place and frequently updated in order to perturb the amount of electronic toxic waste in the world. The turn over frequency of electronic devices is only increasing which makes standards like RoHS even more necessary to promote a toxic free world.

4.2.6 BPA Food Contact Standards

BPA, bisphenol A., is a chemical used in industry to create certain types of plastics and resin [50]. It can also be found in some metal-based food and beverage containers because it is sometimes used as a protective lining. The FDA, Food and Drug Administration, gives the approval premarket for any food contact substances. Currently, the FDA claims that BPA is safe at that which it occurs in foods.

When different foods and beverages, that we frequently eat and drink, come into contact with any type of packaging material tiny particles from that packaging material can be transferred to the food and drink substances. The FDA has regulations in place that protect consumers from any dangerously packaged products. Some of the affects from these packaging materials are difficult to be studied and require a lot of time to see the real adverse effects that may occur. For this reason, the FDA will update their stance on whether or not certain packaging is safe for consumers. Recently, the use of BPA-based materials in infant food and beverage products is no longer supported by the FDA due to petitions by the public.

Many water bottles on the market openly advertise that they are BPA free, even though the FDA does not currently object to the use of BPA (besides for infant products). In the past the FDA has done studies on the affects that BPA has on the body and how long it takes our bodies to dispose of it. A study was done on pregnant rodents who were given 100 to 1000 times more BPA than people are exposed to through food and this BPA could not be detected in the fetus's 8 hours later [50]. Even though a study could be done as extreme as this one there is still a public consensus that BPA is bad for your health and must be avoided, this is why many products claim they are BPA free.

5.0 Project Design

In the following sections both the hardware and software designs will be explored and explicitly laid out. This will help with PCB design, general schematic flows, code flow, and mobile application. In the hardware section, schematic design will show pin connections for each of the devices selected as well as how they will connect to other devices. The software design lays out how the overall code of all these devices will be handled as well as the creation of the mobile application.

5.1 Hardware Design

For the hardware design each component is broken up into its own section where its pins, connections, and general design is laid out. Schematic designs have been included as well and these are how the devices will be wired to test as well as connected on the PCB. It is important that all of these devices have the proper configurations as any improper wiring can lead to damage of the device as well as many hours trouble shooting or having the device working improperly. These designs will be reviewed after testing to ensure they are safe and that they can be integrated into the project as a whole.

It is important that a final schematic has all of the correct parts and connections because using a PCB software the schematic will be converted to a PCB file and this will pull all of the footprints over for each component. The sizing of these are critical because this is what the part will be soldered to as well as what the actual routed connections are made to. For the H-2-Ohm the components used will ideally be large enough for ease of soldering so specifically 0805 and 1206 footprints for the resistors and capacitors will be used. There is not much that can be done about the other components selected as their footprints are not standardized. In the end the bill of materials will be pulled from the schematic and all of the miscellaneous components that have not been ordered yet will be then purchased. Since I2C was the selected serial communication method the main hardware design is centered around the major components using an SDA bus and SCL bus where each component has a bus entry connection and can wire straight to it.

The entire hardware design can be seen in Figure 10 which shows all of the connections and components used for the H-2-Ohm. This is not the final schematic and will be a work in progress while going through the schematic design process and PCB layout in Senior Design 2 next semester. Each section will then be broken up and explained in the sections below.

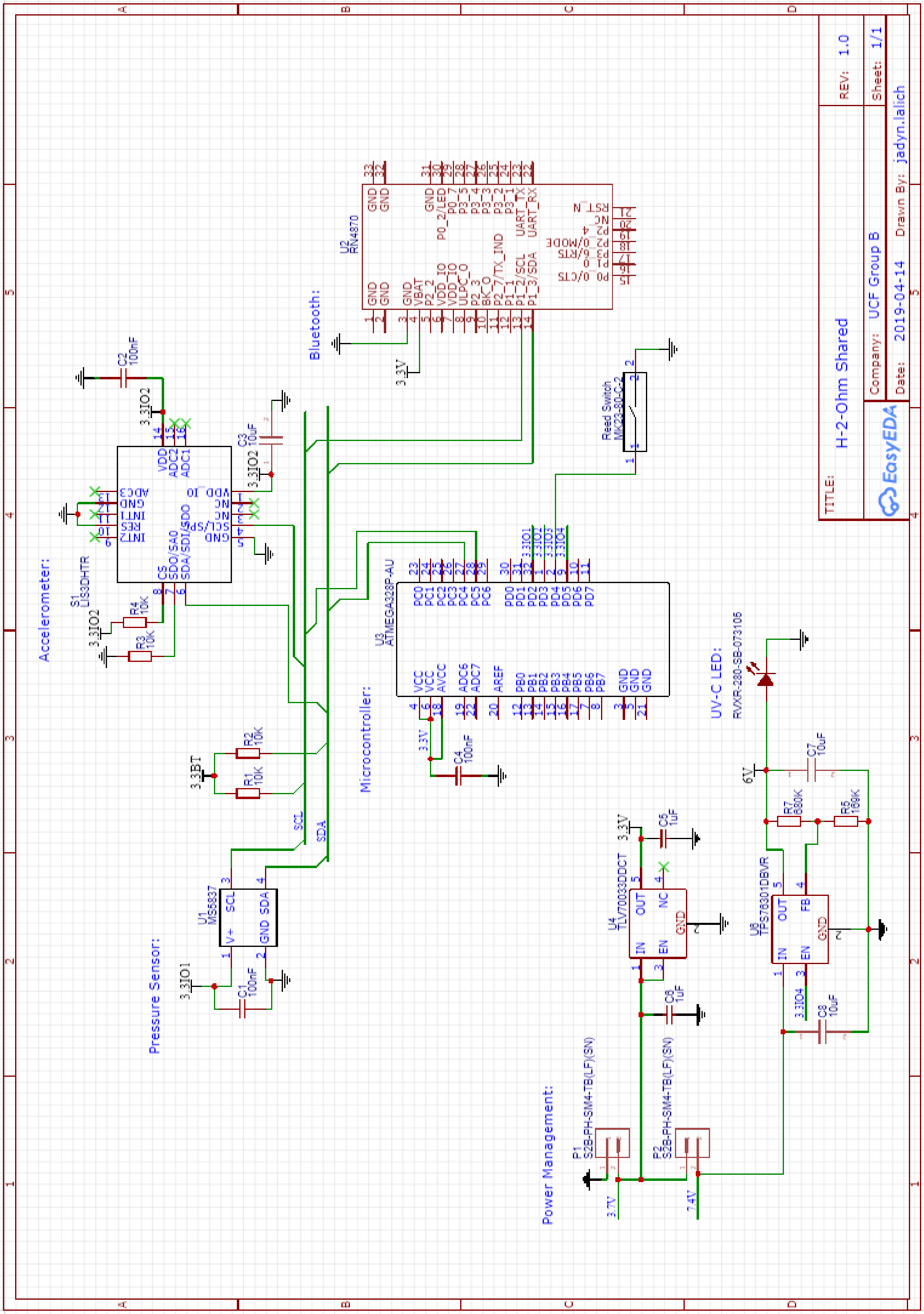

Figure 10: H-2-Ohm Hardware Design Schematic

5.1.1 Pressure Sensor Design

The MS583702-BA21 pressure sensor selected for this project has a relatively simple layout as seen in Figure 11 below. As far as hardware design this sensor has four main pins GND, VDD, SCL, and SDA. This makes the schematic layout moderately easier. The microcontroller has a SCL and SDA bus that the pressure sensor will have its SCL and SDA pins respectively routed to. SCL is the I2C clock and the SDA is the I2C data.

The power supply (VDD) will be connected to one of the microcontrollers I/O pins since it can provide the 3.3V needed as well as the current. The datasheet recommends that a 100nF ceramic capacitor or larger is connected from the VDD pin to GND but as close to the VDD as possible [9]. Also recommended in the shown application circuit are two 10kΩ pull up resistors for the I2C bus. These will be connected to the 3.3V pin of the microcontroller rather than an I/O pin since there is no need to have this turn on and off.

The last design note for the pressure sensor is that having it directly mounted to the main PCB is not wise do to its size and the waterproofing that needs to take place. Ideally a daughter card will have this four pin layout and connect to the main PCB via headers which will then have the routing to all the microcontroller pins.

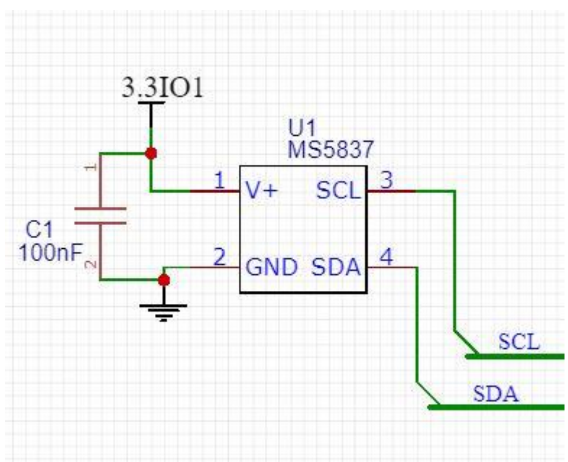

Figure 11: Pressure Sensor Schematic

5.1.2 Accelerometer Design

Schematic design for the LIS3DH accelerometer will go directly on the main PCB. Like the pressure sensor its SDA and SCL pins will be connected to the I2C bus that gets fed to the microcontroller. The VDD_IO pin and the VDD pin will both be tied to an I/O pin of the microcontroller with the addition of two external 10µF aluminum capacitors each placed close to their respective pin. Since I2C will be exclusively used for this project the CS pin will be set high via 10kΩ connected to VDD.

The SD0 pin selects the last bit of the I2C address for the accelerometer and for this project the last bit will be set to zero by pulling the pin to ground using another 10kΩ resistor. The entire accelerometer design will us both the datasheet and Adafruit design documents and schematics to help. The initial design for the accelerometer schematic can be seen below in Figure 12.

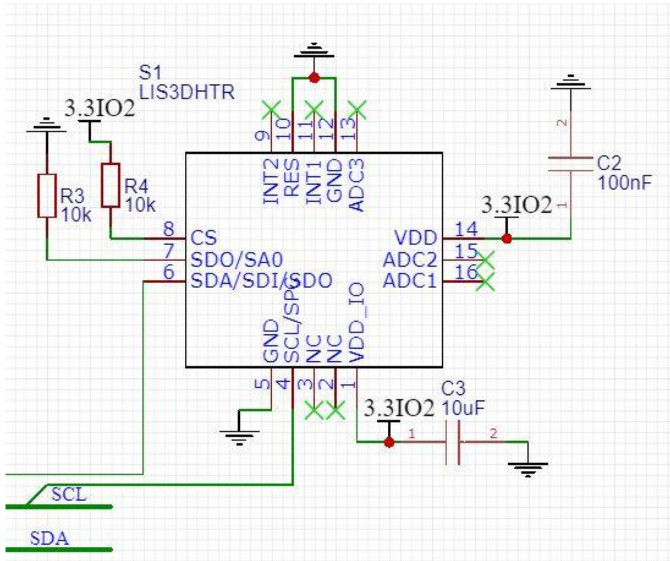

Figure 12: Accelerometer Schematic

5.1.3 Power Design

The whole bottle will not function without a proper power supply. Two 3.7V LiPo batteries have been selected for this project that will connect to the PCB using two JST connectors. Since the microcontroller will need to be powered via a steady 3.3V a LDO voltage regulator will be used to step down the voltage from one of these batteries and feed the 3.3V directly to the controller. The LDO selected for this project is the TLV70033DDCT which will always be enabled and has the desired 3.3V output. As for the UV LED it needs a minimum of 6V so a separate voltage regulator will come from the node of the two batteries in series to step the 7.4V to this value. The TPS76301DBVR is a variable LDO so the resistor values selected to get the desired 6V output are 680kΩ and 169kΩ. The enable pin will go off to an I/O pin on the microcontroller that will control when the UV LED comes on and off based on the timer and the reed switch. The general schematic design can be seen in Figure 13 below. A DPDT switch will also be implemented in this design to turn on and off the device and isolate all of the electronic components from the two batteries. The headers will be pulled from the 3.7V node before the microcontroller LDO and at the 7.4V node before the UV LDO and run to the switch mounted on the side of the bottle.

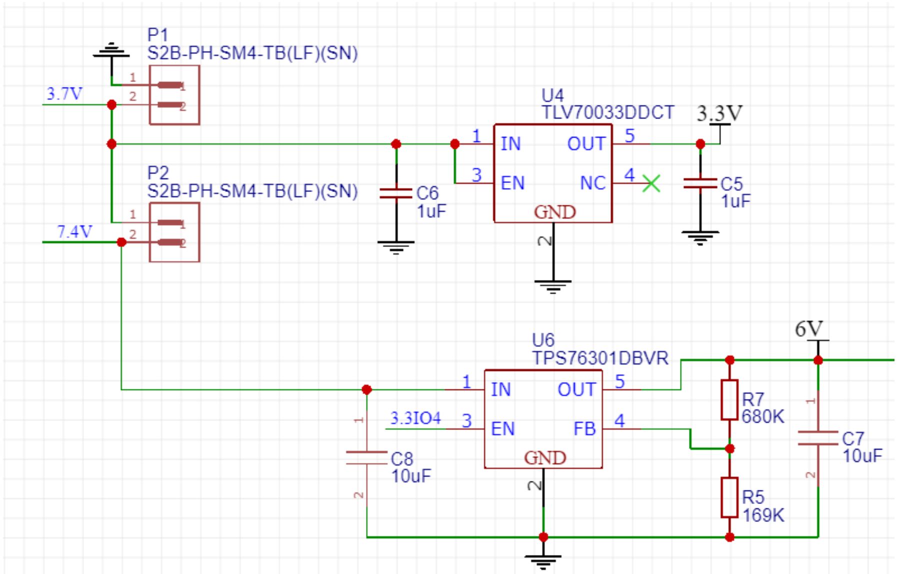

Figure 13: Power Schematic

5.1.4 UV LED Design

The RVXR-280-SB-073105 UV-C LED is a high-powered device that we will use to sanitize the water at certain timing intervals. The light will activate for 120 seconds every 3 hours, this will be an ongoing timer which will only be interrupted when the bottle cap is removed. The UV-C LED that was chosen for this project has a minimum forward voltage of 5V to a maximum voltage of 7.5V, the typical amount is 6.5V.

In order to reach the proper amount of UV-C exposure that's needed to sanitize the water, we need the wavelength to at least be between 275nm and 285nm. Looking at Figure 15, we can see that the light-frequency range requires a minimum of roughly 50% relative power. 50% relative power is at the 50mA current point which is almost 6V forward voltage. This is one of the deciding factors when we chose 6V for the UV-C LED. The affect that these forward voltage values have on the output of UV-C light can be seen in Figures 14 and 15, which were found in the data sheet for RVXR-280-SB-073105 [23]:

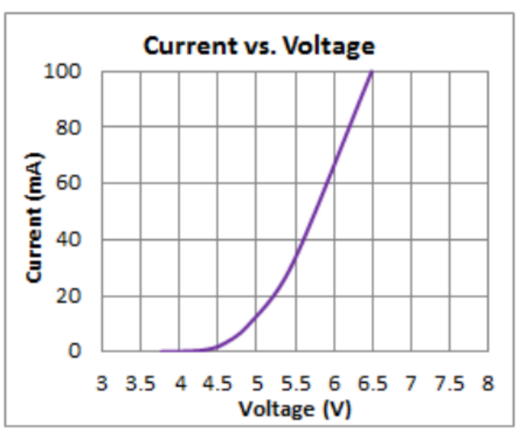

Figure 14: UV-C LED Current vs. Forward Voltage

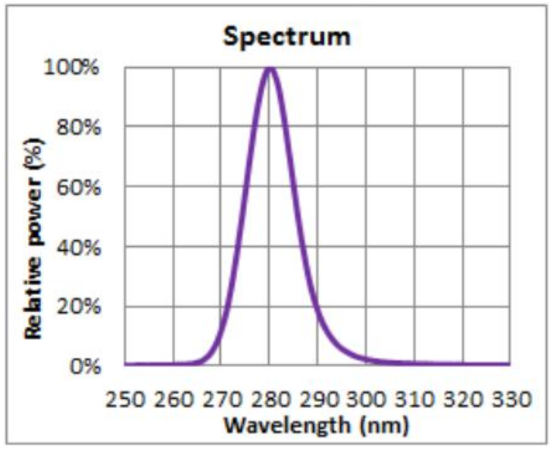

Figure 15: UV-C LED Relative Power (%) vs. Output Light Wavelenght

The schematic shown in Figure 16 shows a basic outline of how we plan on powering the LED as well as controlling it's on and off times. A low dropout regulator will need to be used in order to convert the 7.4V incoming from the power supply to 6 V for the UV-C LED. The UV-C LED is a higher wavelength compared to the UV-A and UV-B which we are exposed to while being outside, for this reason there needs to be a hard safety in place to protect the consumers. This is where the reed switch comes in, the reed switch's logic reading will trigger an interrupt in the UV's timer if the cap is off (zero reading).

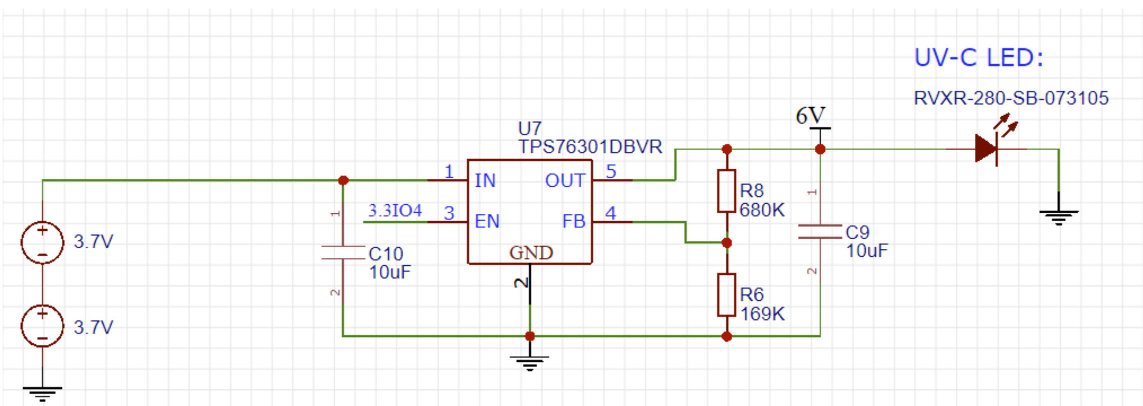

Figure 16: UV-C LED Schematic

5.1.5 Reed Switch Design

The reed switch is a very simple, yet important controlling component for the H-2-Ohm's overall function. This part doesn't require any power for it to work, only the proximity of a magnet will make it close the circuit.

When the magnet is close to the reed switch the circuit will close thus, sending a logic '0' value to the microcontroller unit. The microcontroller will only run the pressure sensor as well as the UV-C LED as long at the reed switch pin is reading a '0' or a low value, otherwise the pin is reading a '1' and an interrupt is occurring.

On PIN 1 of the reed switch design diagram below, Figure 17, the switch will be connected to a logic input pin, which would then connect to the 3.3IO3 on the MCU. PIN 1 needs to be a connected to a logic input pin in order to keep the power requirements low and the design simple. PIN 2 will be connected to ground so that it will read as 'low' to the microcontroller thus, not causing an interrupt.

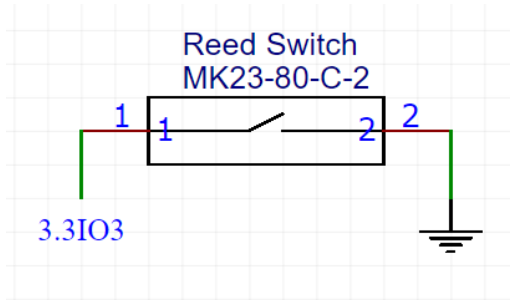

Figure 17: Reed Switch Schematic

5.1.6 Microcontroller Design

The heart of the whole design is the microcontroller since it decides what to power on, read data from, and shut off. All of the previous design sections will feed to the microcontroller in some way. Pins PC4 and PC5 are used for the I2C communication where PC4 connects to the SDA bus and PC5 to the SCL bus. The microcontroller will then use these busses to address the individual components and receive their data.

As for powering each device and determining what comes on, the I/O ports will be used. PD2 will power 3.3IO1 which turns on the pressure sensor. The code implemented on the microcontroller will ensure that this pin only comes on when a sip has been taken and the accelerometer has determined that the bottle is upright. PD3 powers the accelerometer through the 3.3IO2 connection. The accelerometer will be triggered to turn on after a sip has been detected. PD4 runs the 3.3IO3 connection that goes off to the reed switch, this will trigger an interrupt for the UV LED if it is currently on as well as start a domino effect starting with the accelerometer checking to see if the bottle is in the upright position. Lastly PD5 has the 3.3IO4 connection to the enable pin of the UV LED LDO which will power on and off the LED based on a timer from the microcontroller and an interrupt from the reed switch. All of these I/O pins will have to be thoroughly tested since the code implemented by the microcontroller will have them working in specific orders and turning different components on and off.

Dealing with the microcontroller as a whole it will be powered using the regulated 3.3V output from the power management stage directly to its VCC pins where a 100nF ceramic capacitor will also be placed to ensure the source is as smooth as possible. Other research is being done on how to flash the code to the microcontroller while it is on the designed PCB and there will also be a stage of design where the Arduino bootloader is burned to the device so code can be properly uploaded via the Arduino Uno. More components and connections will be added as the design matures but the ones shown in Figure 18 below are the main connections in regards to this project.

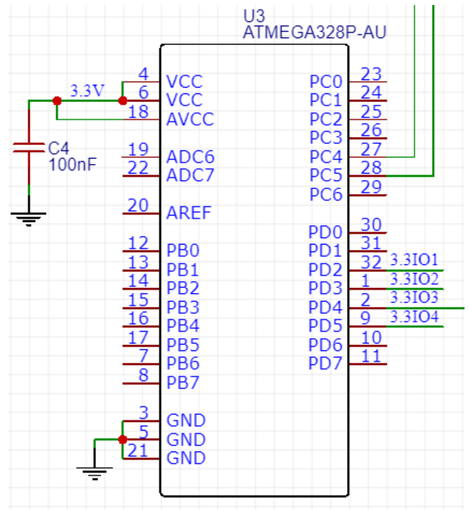

Figure 18: Microcontroller Schematic

5.1.7 Bluetooth Design

When designing the setup and wiring for the RN4870 Bluetooth module, there are several points that we need to research using the Bluetooth modules datasheet which will tell us what our options are for powering the module and allowing it to communicate with the microcontroller. The option we decided on for the communication aspect of the design is to use a simple 2-wire I2C connction. From the datasheet we also determined that the best option for powering the module was through the VBAT port. The only other connections that would be needed are the ground connection and the oprional LED connection to show whether the module is powered on or not. Table 32 shows the I2C connctions, power connections and the LED connection as well as which pin on the Bluetooth module they connect from and which node they connect to.

Table 32: Bluetooth Design I2C Connections

	Power	Ground	Serial clock	Serial Data	LED
Pin	4	1-3	13	14	30
Port	VBAT	GND	P1_2	P1_3	P0_2
Node	Vcc	Ground	SCL	SDA	Vcc

Using this information we decided to connect the power using the VBAT port on pin 4 and connecting it to +Vcc, the optional LED would also be connected to the +Vcc in series with a resistor which will run to P0_2 at pin 30 but for now we chose not to use this function as it only shows the bluetooth status. The LED that we will use will show that the entire H-2-Ohm module is powered on but this may change in future iterations. We will run a wire from pin 3 at the module's ground port to the ground node of the PCB. The last two connections will be the serial data and serial clock for I2C that need to connect to the clack and data nodes at the microcontroller. The serial clock will run out from P1_2 at pin 13 to the SCL node and the serial data will go from P1_3 at pin 14 to the SDA node [51]. The connections can be seen in Figure 19.

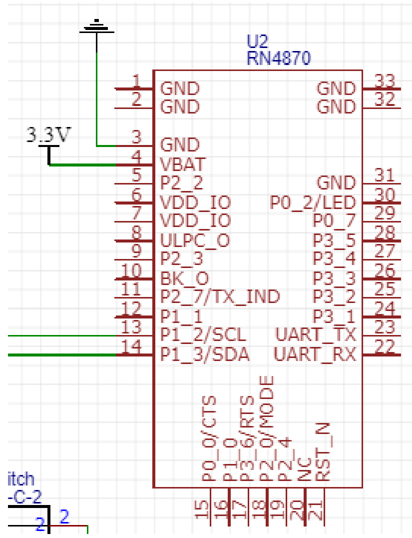

Figure 19: Bluetooth Schematic

5.2 Software Design

The software design is composed of the component code and the mobile application. These sections below dive into how the H-2-Ohm system will run over all and what information is run through the microcontroller as well as setting up the different timers needed to accomplish all the required tasks. As for the mobile application this shows the beginning stages of what it will look like and its functionalities.

5.2.1 Component Code Design

When starting on component code design, the main things to consider will be utilizing good documentation within the code, code organization and attempting to minimize the microcontrollers CPU active time. As far as actual coding is concerned, the layers that we need to consider are, the number of clock timers, the number of interrupts, the different counters that are used within the code to obtain the smallest Big-O function possible. Because the Big-O function determines the general scale of time that the software needs to run for, this will directly impact how long the H-2-Ohm module's microcontroller will be out of low-power modes, thus increasing power consumption.

Our microcontroller has only one 16-bit clock which can be used for measuring times longer than 8 seconds while in low-power mode and because we may need to utilize a real-time clock in order to run the 2-hour timer which activates the LED. Another option would be to save all of the 16-bit timer settings in the CPU or memory registers, then after all of the shorter timers have completed, restore the stored information, modifying it to account for the time that it was not running. This solution, however, would make it so that the LED sanitization system cannot run until the H-2-Ohm module has gotten a reading which can take some time if the bottle is not upright for an extended period. Because of this, we will either adjust how the sanitization timer is implemented or use a RTC module to resolve this issue.

There are three interrupts that will be implemented into the code. The primary interrupt that will take precedence will be the lid open interrupt which will cause the LED sanitization system to power off and also interrupt any measurements being taken, resetting the process for when the lid is closed again. This lid closed interrupt is the secondary interrupt which will activate the process of taking a water level measurement and sending the information to the mobile device via Bluetooth. The last and lowest priority interrupt is the LED sanitization system which will activate periodically on a longer timer up to 2 hours.

For the counters that will be used in the code design, there are only a few but each clock timer that needs to count for longer than 34 minutes will need at least one counter because this is the longest time frame that a 16-bit timer can count on a 32kHz clock. The other counters that will be used will be implemented as shown in the project flowchart as ways to minimize the time the microcontroller is out of low power mode by changing the amount of time waiting for water level measurements to be taken. This wait time is used to ensure that the H-2-Ohm bottle is upright when taking a water level measurement. We realize that sometimes a user will put the bottle in their backpack where it will not be perfectly upright in order to take a measurement. If the bottle is left in this position for extended periods of time, we don't want to be taking the microcontroller out of low-power mode every 10-15 seconds as this will consume more power than is necessary. The way we are implementing the code, counter incrementations are rarely done multiple times for each time the microcontroller leaves low power mode. Because of this, the Big-O function will likely be O(n) or O(1). The only other counters that may be used are those that are used for redundancies in communicating with the I2C peripherals.

We believe that using this design we can achieve the goals of the project while minimizing power usage from the microcontroller. Determining these aspects of the code ahead of time will also improve code organization and documentation allowing it to easily accommodate future improvements.

5.2.2 Mobile Application Design

Although we have been previously spoken about design goals for the H-2-Ohm mobile application, in this section, we look to turn those design goals into an actual prototype design and try to show and explain the design choices that we made.

The first and simplest design choice for the application is the color profile. Because our project relates to water and water consumption habits, we decided that a soft blue color should be the primary tone of the app. We thought about using some sort of water droplet design to further reinforce the connection to water or liquid but decided against using it outside of the app’s icon and loading screen because having it as a menu background can be very distracting to the user and doesn’t add a lot to the experience.

The next design choices that we discussed are related to style. We want the application to look modern with soft rounded edges and very little extreme contrast. We also want everything to be visible on the screen without having to scroll up and down or search through menus in order to find the desired information. Another style choice that is small but can make a big difference when it comes to user experience is the font. From a wide selection, we chose Bahnschrift Bold Semi-Condensed as it has a modern feel but is also very simple and easy to read. For the font size, we decided to have the height of our text to be 4-5% of the mobile device’s screen. This design can be important for those who either have issues with vision or regular headaches from trying to read off of a screen.

In order to make a simple, user friendly design, we want to display all of the data on a single sccreen. This data should include current H-2-Ohm module water levels, display daily goals and progress and also show past water consumption in order to provide motivation based on past progress. The only interaction other that displaying the data to the user will be the menu button. This button will take the user to he settings menu which will display notification option, allow the user to reset the data as well as other various application settings. Figure 20 below show a sample and prototype of what the app design should look.

The last design element of the application is the data that it will receive from the H-2-Ohm module, how it interprets the data and where it stores that information. Data sent to the app over bluetooth will include not only the most recent reading, but also the one before, this will help the app to compare the received data to its stored data to determine if it has missing information to due to lost bluetooth signal or other issues. The incoming data will then be taken, looking at the water level readings and subtract the current reading from the last reading and adding it to the current amount of water consumed. It will also use the current water level to update the on-screen graphic which displays the percentage of water remaining in the H-2-Ohm module. Because we want the app to function quickly and because it is unnecessary for it to access the internet, all of the data required for the app will be stored locally on the mobile device. This will allow quick access and it will not force the user into having a constant internet connection in order for it to function and communicate with the H-2-Ohm module.

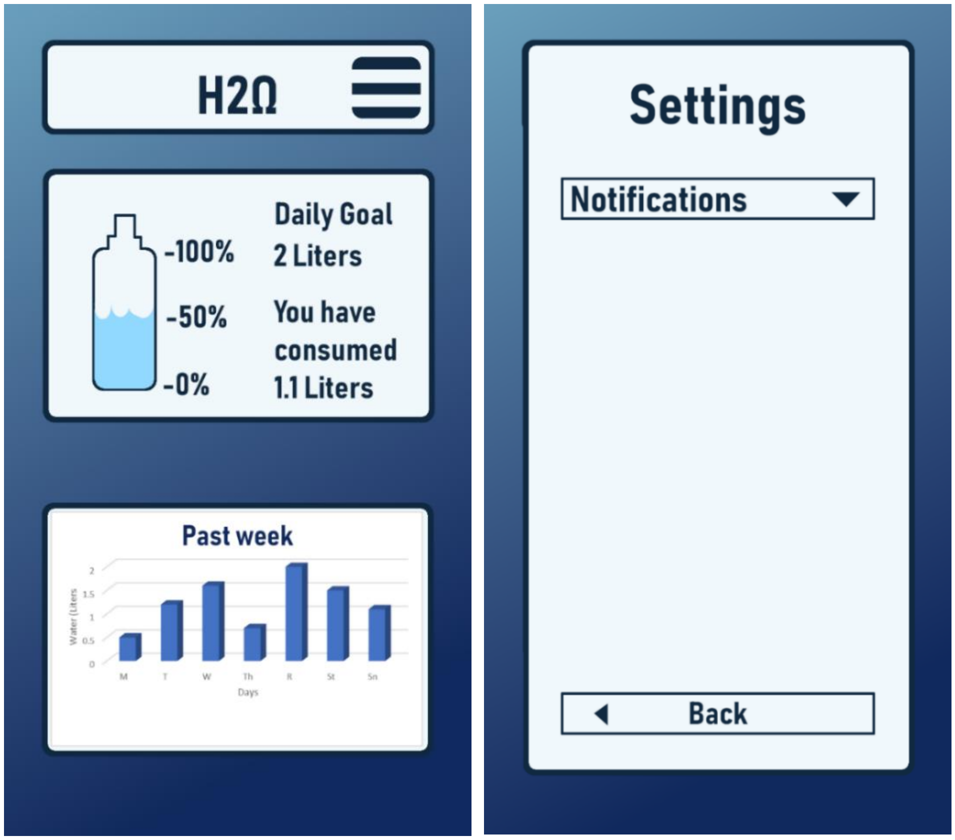

Figure 20: Mobile Application Design

5.3 Printed Circuit Board (PCB)

One of the largest requirements for Senior Design 2 is substantial PCB design. The H-2-Ohm will have a particular challenge with this as the PCB will need to be rather small. The desired size would be a maximum length of 2 inches and a maximum width of 1.5 inches. If necessary as the project progresses it can be determined if a second PCB specifically dedicated to charging the batteries should be created. This would be an ideal feature to implement if time permits.

Overall team designed PCBs are what make the projects organized and more compact since they are created specifically with one project in mind rather than breakout boards that can be purchased pre-made to fit all sorts of designs. The PCB will have to be designed and created using a selected software as well as ordered from a manufacturer. This section will walk through both of these processes as well as the overall PCB design.

5.3.1 Schematic and PCB Software

The project will have to work on something like a breadboard before a PCB should be designed or purchased and the easiest way to translate breadboard work into something understandable is through schematic design. It is important that the software used can translate a schematic into a PCB design. Naturally the routing and general layout of the PCB will be done by our team but it is easier when the schematic nets transfer over nicely and the component footprints are the correct size and design.

The software that will be used to start the project is EasyEDA, it was easily downloaded for free via the internet and so far has been very user friendly. An account can be created where your projects are saved and it has a searchable library with all the parts this project uses already uploaded in it. Another feature is that a project can be shared between team members so anyone can make changes. The schematic design tool is very simple and many YouTube videos exist to help if troubles arises. As for the PCB design all of the components from the schematic will be pulled over with the correct footprints which is ideal since that leaves layout and routing as the main issues to tackle. If EasyEDA proves unsuccessful EagleCad will used but after talking with other senior design teams the consensus is that EagleCad is less user friendly and importing parts to libraries is not as simple.

5.3.2 PCB Manufacturing and Soldering

Once the PCB design has been finalized and a gerber file is created and the board will need to be sent out and made. There are many manufactures to consider and in general the ones in the United States are much more expensive than China. If this project stays on schedule timing should not be an issue even with the long distance shipping. Narrowing it down to two manufacturers JLCPCB and PCBWay both are Chinese manufactures that are cheap and relatively quick. Most boards will be printed and received in a week. Table 33 shows the different quotes for these two PCB manufactures.

Table 33: PCB Manufacturer Comparison

	JLCPCB	**PCBWay**
Size	50.8x38.1mm	50.8x38.1mm
Layers	2	2
Country	China	China
Price	$8	$5
Shipping	$16.67	$17

PCBWay will be used for this project based on price and the general layout of the website was easier to understand. It should also be noted that past senior design groups have used them with success and recommended them for this project.

After the board is received the components will have to be soldered on. Depending on how everything goes the team would like to try our best attempt first since it will save money but it also runs the risk of us wrecking our components beyond reuse and/or accidentally shorting pins together. Another option would be to have the board professionally soldered by a company in the area. In class it was discussed that Quality Manufacturing Services in Lake Mary could assemble the PCB with all the proper equipment and more professionally than our team could ever achieve. The only downside to using them would be the price, each team member is not charging for labor where as their services would have to be paid for and built into the self-funded budget. As of right now the plan is to solder on all the components ourselves and turn to Quality Manufacturing Services if outside help is needed.

5.3.3 PCB Design

The PCB design will have to be done in the most compact and efficient way possible. There are a few standard design sets what will need to be accommodated in order to stay within a proper design. With a compact design it will be important that the board has two layers that way routing will not overlap and both the top and bottom sides of the board can be utilized. With multiple layers there will be need for vias which are holes through the PCB that connect the two different layers so routing can be completed. The dimensions used for the estimated final design would be around 2 x 1.5 inches since the PCB will need to fit under the bottle and be less than the diameter. If more space is needed this will be achieved by having multiple PCBs and stacking them vertically. As for general PCB design the standard thickness is 1.6mm on PCBWay's website and the surface finished selected will be HASL-lead free because of the RoHS standard and staying environmentally friendly.

With routing and soldering being considered, the majority of the selected components will be surface mount devices (SMD) and the copper weight of the routes will not need to be very think since the amount of current flowing through them should never exceed more than an amp. In Figure 21 below a general layout of the PCB has been created to estimate space and what components will actually lay on the PCB instead of jumpering to it. The sensor and the UV LED will be jumpered to the PCB since they need to be sealed and fixed to the bottle itself. The only other things not on the PCB will be the two LiPo batteries which will connect to the JST connectors as shown to the left and the reed switch which will just require a normal wire soldered to the board.

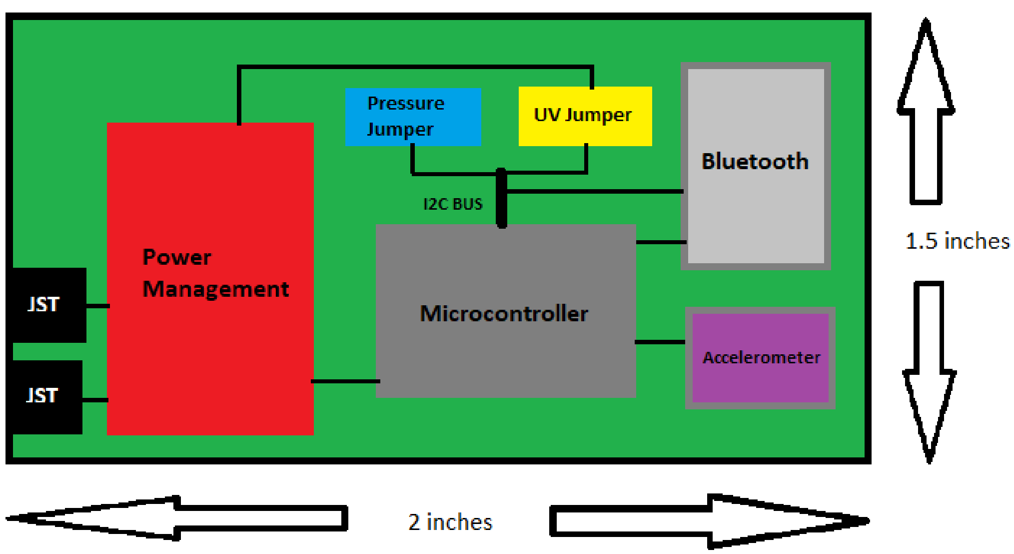

Figure 21: General PCB Design

5.4 System Housing Design

H-2-Ohm will be designed for functionality and be aesthetically satisfying at the same time. Any water bottle that someone uses throughout the day needs to be lightweight, durable, and ideally be small enough to fit in convenient holders. The H-2-Ohm water bottle will be able to meet all of those needs and more. Its main purpose is to subtly measure the amount of water in the bottle after the cap has been screwed on, as well as turn on the UV-C LED at occasional intervals without affecting the user's day to day activity.

The bottle will need to be made out of some sort of metal so the UV-C light will not escape the container and so that the electronics will be protected by the durable shell. The best type of material to use for this is stainless steel because there are already so many water bottles already available on the market. We would need a stainless-steel bottle that is single-walled because we will be drilling two small holes in the bottom of the bottle for the UV-C LED and the pressure sensor. There will be rubber O-rings and other sealant material placed around the sensor edges to ensure that no water will leak through to the electronic components on the other side. Both sensors are very small and will need to be connected to the PCB via female jumper wires such that the sensors can reach the cut-out holes of the stainless-steel bottles bottom.

The entire electronics portion of H-2-Ohm will be housed in a 3D-Printed base section. This bottom section will either be sealed to the base of the stainless-steel water bottle or we will build a latch mechanism on either side of the bottle to make sure the base portion stays attached. We will use an epoxy glue mixture to fuse the plastic base and the metal base together, a large clamp will hold each piece to each other until the glue has confidently set each part in place. For experimenting and testing purposes, we will leave the bottom side of the electronics housing completely open/exposed. The actual product will not be in this configuration, this initial product is a prototype and having the ability to test components is essential.

When emitting, the UV-C LED can be dangerous to the human eye, there will be two safety measures put in place to prevent this from happening. The most crucial safety design element incorporated in this bottle is the reed switch. The reed switch will be placed right below the bottom of the cap, there will be magnets lining the edge of the cap. The magnets of the cap will ensure that the reed switch is closed once the cap in locked in place on the bottle thus, protecting the user from the UV-C LEDs lights. If the reed switch is closed then the electronics for the two sensors will run as normal if there is no magnet near the reed switch then it will be open and current will not flow thus, signaling to the sensors to standby and cease operations. A timing program may be put in place to ensure that the UV-C LED does not activate during the user's manual water level reading time period, such as forcing 5 minutes to elapse before the UV-C LED switches on. The second safety measure will be the four regular LEDs placed on the sides of the base component of the bottle. These lights will turn on while the UV-C LED is doing an exposure period, this will warn the user to not open the cap during these times. Although the UV-C LED will instantly shut off once the cap is unscrewed from the bottle because of the reed switch.

The magnet located on the tassel is in place for the user to manually hold up against the reed switch to 'force' the presser sensor to turn on and take a new water level reading. Even though we will be using a water bottle that is made out of stainless steel, we have verified that the stainless steel that this bottle is made out of is austenitic stainless steel which is not magnetic. It helps having a non-magnetic water bottle body so that the magnet on the tassel won't constantly be attached to the side, this may cause some magnetic interference with the components down below or it could inadvertently close the reed switch.

There will be a power switch located on the side of the lower part of the bottle, where the other electronics are housed. As mentioned in the user manual section, the products user will need to turn the bottle off when they go to sleep and on when they wake up. These directions are in place in order to conserve as much power as possible and let the user choose when they want the electronics to be on. It's assumed that the user won't be picking up the bottle and drinking from it or filling it up while they sleep so there is no reason for the UV-C LED to turn on or the microcontroller to be on.

The 3D printed material that will be used must be strong enough to withstand any accidental bottle drops or bumps into solid surfaces as well as be waterproof. We will be using PLA or Nylon 3D-Printing filament with the Creality Ender 3 3D-Printer. PLA stands for Polylactic Acid, this is one of the most widely used 3D-Printing filaments. If this filament is used to build the compartment, then the 100% fill setting will be on to ensure the material doesn't have any hollow aspect to it and increase its strength. PLA is more brittle than Nylon but it is an easier filament to use because of its low temperature requirements. Nylon is the best option for this project's needs due to its high durability. It will be determined in the actual implementation phase if this material will be used. Figure 22 shows the H-2-Ohm concept design.

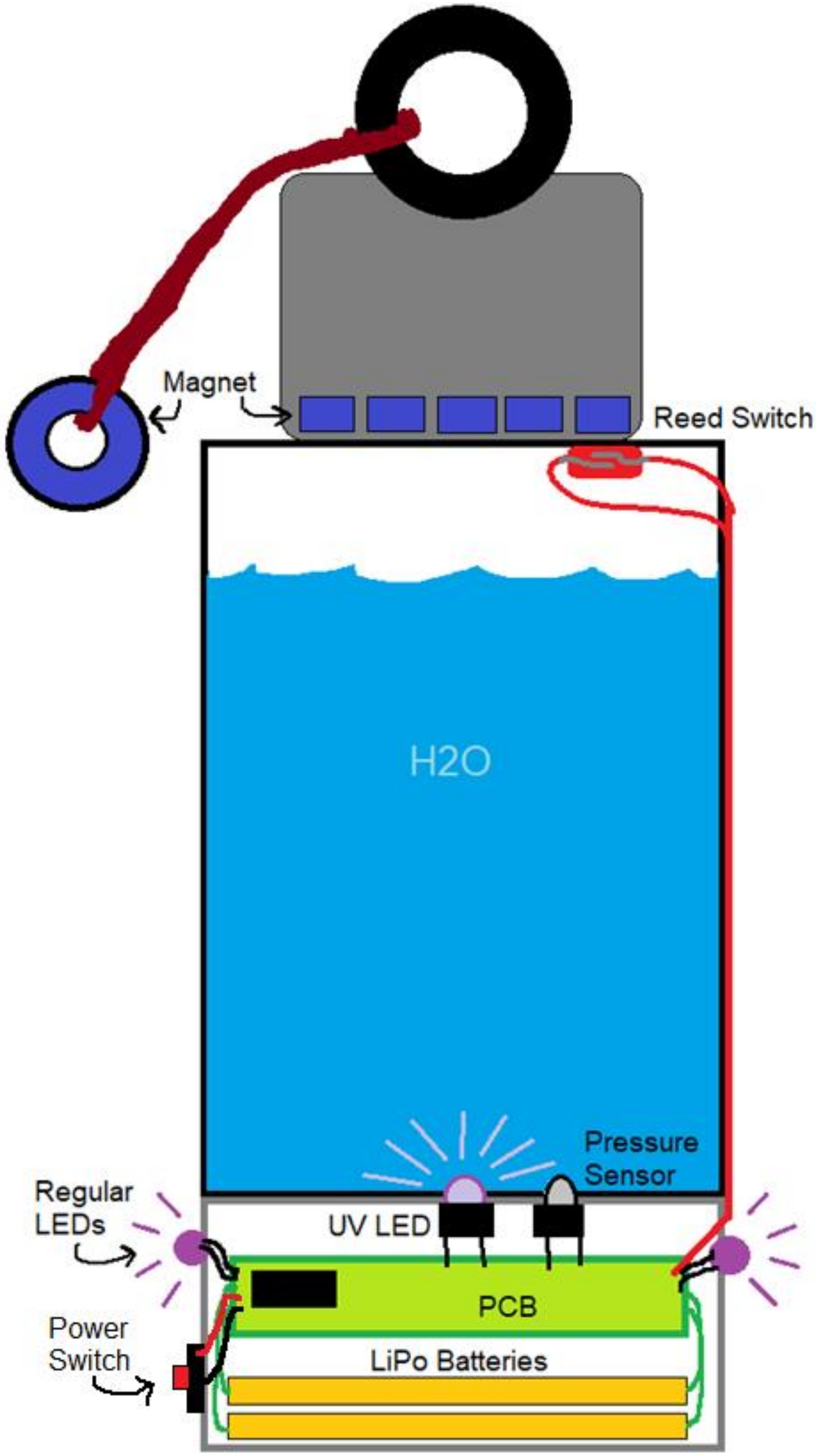

Figure 22: H-2-Ohm Concept Design

5.4.1 Materials

The following materials will need to be used in the building stages of the project. The body and design aspects of the project are the big steps that will ultimately bring the product to completion. Table 34 below gives a rough estimate of what we will need to accomplish the design parameters listed above.

Table 34: Bottle Design Materials

Stainless Steel Single-Walled Bottle (64oz)	3D-Printing Filament
Drill	Regular LEDs
Ring Magnet	Waterproof Sealant
Small Rectangular Magnets	Waterproof Electrical Tape
Rope Tassel	Electrical Tape
Rubber O-rings	Wires
3D-Printer	Epoxy

The Bottle manufacturing company, Klean Kanteen, makes a 64oz stainless-steel single-walled water bottle [52]. This bottle fits our project design needs due to its durability, body material, and size. One of the most important characteristics of this bottle is its large base, 4.3 inches diameter. The large base will ensure that all of the electronic components being used will fit within that area with room to spare. Table 35 below shows the bottles dimensions in detail.

Table 35: Water Bottle Dimensions

Capacity	64 fluid ounces (1900 ml)
Weight (w/loop cap)	13.2 ounces (374.1 g)
Size (w/loop cap)	10.4" H x 4.3" W (264 mm H x 110 mm W)
Opening Diameter	2.125" (54 mm)

5.4.2 Modeling Software

We will be using the Ultimaker Cura 3D-modeling software. This is a widely used 3D-Printing software so there are plenty of online tutorial tools available for us to learn from and make the design process run as smooth as possible. This is also a free software and has been known to be quite easy to use. Ultimaker Cura works with STL, OBJ, X3D or 3MF file formats. The Creality Ender 3 works perfectly with STL file format. For this project we will need to 3D-Print and design the bottom housing section for all the electronics as well as build a snap-fit enclosure to easily remove the bottom section and access the parts. Also there needs to be four holes evenly spaced on the outer ring of the compartment to fit the LEDs through.

5.4.3 Potential H-2-Ohm Product Upgrades

Charging Capability: Ideally, this product would not have a removable bottom piece. Instead it would only have a small port for a charging cable to be connected to, along with a tough rubber sealing attached to it so this port could stay dry and maintain the integrity of the internal components. This would greatly increase the bottles convenience and simplicity.

LED indicators: The pressure sensor is already going to send the water level readings data to the mobile application via Bluetooth communication. A possible product upgrade could be the incorporation of LED indicators lining one side of the bottle. These LEDs will illuminate in congruence with the actual water level readings inside the bottle and easily inform the user what water level they are currently at. These lights could be activated via the bottle cap being placed back on the lid or an option to turn the lights on within the mobile application. Another potential LED indicator could be an RGB LED located at the lower side of the bottle to indicate what the bottles battery level was at.

6.1 Component Testing

Since the H-2-Ohm is so modular each component will be tested individually before combining them as a whole. The tests in the following sections are not the complete final operational tests such as adding everything together and having them work via a domino effect or like the final working product. These tests are simply to determine the validity of the component for this project and to ensure that each works the way the team envisioned.

The main components that need to be tested are the pressure sensor, accelerometer, UV LED, reed switch, microcontroller, Bluetooth, and mobile application. After all of the components are tested individually the process of putting everything together on a breadboard will help with schematic design and the end game PCB layout. Another advantage of testing each component individually is that when they are combined if anything doesn't work the team will know it must be something to do with the actual layout of the design rather than the part. It is important the these tests are run as efficiently as possible that way there will be time to select a new component should one turn out to work differently than expected. Lead times for electronic components can be an issue for projects such as Senior Design 1 and Senior Design 2 so it is important that the components be selected and tested in a timely manner so there can be a smooth completion of the project.

6.1.1 Pressure Sensor Testing

The pressure sensor is quite frankly one of the most important components to be tested. The entire crux of the project rests on an accurate water level measurement from this sensor. Testing it will be critical to ensure that our prototype can actually be realized. To start out, measurements will take place to ensure that the wiring of the sensor and code is working properly. To do this a hole will be drilled in the lid of a disposable water bottle and the pressure sensor will be secured and placed to read the measurements from inside.

When the bottle is squeezed the data from the sensor should change indicating that measurements are taking place. Once this has been performed the pressure sensor will be then be mounted in the actual water bottle selected for this project and sealed off as to be water tight using an o-ring and sealant. Preliminary testing will just have wires coming off the sensor until an appropriate daughter card can be made that will connect it to the projects PCB.

With the wires attached and the sensor ready to read values this is when the main testing will take place. A measuring cup will be used to add water to the bottle one ounce at a time since that is the desired accuracy of the H-2-Ohm and the values from the pressure sensor will be stored and read. With these values captured they can be used in the overarching code that will be in the final design that way the exact water consumption of the user will be accurate. It was noted before that the pressure sensor will give values of pressure based on height and since the bottle size is not changing this will give an exact height level for a certain number of ounces. As the data received from the sensor is grabbed and finalized other test will be run where water will be poured out of the bottle into a measuring cup and the level will be then again read by the sensor. This will ensure that the code is reliable if the value produced is the subtraction of the amount in the measuring cup.

The last test will be to ensure that the sensor can come on and off via the I/O pins of the microcontroller and send its data through the I2C bus as described in the hardware design section. It is critical that the device does not have any issues running in this set up since the flow of the project is to have different devices turn on and off in sequence.

6.1.2 Accelerometer Testing

Determining whether the bottle is upright is the only objective the accelerometer is concerned with so the tests run on this component do not need to be in depth or too complex. The code will be loaded onto the microcontroller and the accelerometer will be run. The tests will take measurements of the board sitting upright and then slowly start to tilt it in every direction. With this calibration taking place a small range of values will be noted since the code later on will need to be looking in that range to determine if the bottle is indeed upright.

Final testing for the accelerometer will happen when the device is mounted on the PCB this may change its orientation and the same calibration tests as above should be used. The calibration only needs to be done once since the PCB will be fixed to the bottle for the completed project. And lastly just like the pressure sensor the accelerometer will need to be tested to see if it can come on and off via the I/O pins on the microcontroller and send its data through the I2C bus. Both the accelerometer and pressure sensor should go to the same I2C bus and be tested since this will be critical for the PCB design.

6.1.3 Power Testing

The two LiPo batteries will be tested to ensure that they are producing the expected 3.7V as well as to make sure that in their series configuration the second node has a voltage of 7.4V. All of this will be tested with a multimeter and after the layout is confirmed it will be tested to make sure both voltage regulators are giving their desired output of a steady 3.3V for the microcontroller and a steady 6V for the UV LED. These test will not be complex but they are essential to ensuring that the proper voltages are attained before connecting the power to our components and possibly ruining them if the power management is incorrect.

Once this has been proven and the circuit is connected different currents will be measured to make sure that the battery life (time before next charge) as estimated in the research section will be a week of use minimum. As mentioned before if the feature of using a USB to charge the water bottle is added there will need to be further test to make sure that the proper charging is taking place as well as more connections to ensure everything is working fine.

6.1.4 UV LED Testing

The UV-C LED is a key component in this projects design, and we need to be certain that it works accurately and consistently. At typical operating forward voltage, this LED emits a wavelength that is roughly 280 nm. This wavelength has a high enough frequency that it is dangerous to the human eye as well as our skin. The following safety measures were taken, LED was placed in a plastic-coated cardboard box before it was turned on and UV safety glasses were worn. The LED emits a very soft, purple glow, this glow is a byproduct of the down-conversion that takes place in the emitter.

LEDs are diodes, of course, so that means that we need to plug the cathode (-) into the negative voltage supply terminal and the anode (+) into the positive voltage supply terminal for the component to work. According to the datasheet, the typical forward voltage for this UV-C LED is 6.5V, this value was set in the power supply which made the power supply automatically switch to constant current mode. We want to power the LED with a constant current instead of a constant voltage because the turn-on voltage varies between each manufactured LED. The power efficiency was calculated by taking the ratio of the power dissipated and the input power. When we varied the current from 0mA to 100mA we noted the following forward voltage and output power values in Table 36.

Table 36: UV-C LED Measured Current and Forward Voltage

Current (mA)	Forward Voltage (V)	Power Dissipated (mW)	Power Efficiency (%)
0	3.48	0	0
10	4.65	46.5	71.53846
20	4.81	96.2	74
30	4.96	148.8	76.30769
40	5.11	204.4	78.61538
50	5.18	259	79.69231
60	5.29	317.4	81.38462
70	5.36	375.2	82.46154
80	5.42	433.6	83.38462
90	5.48	493.2	84.30769
100	5.55	555	85.38462

According to the datasheet, the maximum power that can be dissipated across the LED is 750mW. This particular LED that we tested only requires 5.55V forward voltage at its nominal current (100mA), that's almost 1V lower than what was expected. It's important to note that the UV-C LED acts as a constant current load, this means that it will draw a constant amount of current but the voltage going to the load will vary. The batteries being used for this project will be two 3.7V 1000mAh Lithium Ion batteries placed in series. Which means the 7.4V being supplied to the LED needs to be regulated down to about 5.5V to 6V, but it will have 1000mAh being supplied to it as well.

Based on the equation above, we will have a maximum of 10 hours before our batteries need to be rechanged. This calculation is not accounting for the other components of this project so this battery lifetime, but the UV-C LED will on turn on every 3 hours for a 120 second period, so the equation for the amount of power used in a day of regular use would look like the ones mentioned in the battery research section.

Because of the LED's small exposure time each day, it will not drain the battery as quickly as it would it is was on for a constant period (10 hours of use maximum). Overall this is great news for our portable water bottle, the long battery life increases the products convivence and its ease of use.

6.1.5 Reed Switch Testing

The Reed Switch will be tested in order to verify that the circuit with close, in the presence of a strong enough magnet, and open once that magnet has been moved a reasonable distance away. The reed switch needs to function accurately and quickly to ensure it is reliable to send the correct 'statuses' to the microcontroller. The microcontroller will have a pin dedicated to receiving the logic high/low of the reed switch. The status of the reed switch, if the circuit is closed, is what will allow the UV-C LED to turn on when necessary and the accelerometer to check for bottles position.

This switch is unique in that it only needs a magnet to make it activate. To test this function, two wires will be soldered to each leg of the reed switch. Next, each side of the reed switch will be connected to a Fluke 117 Multimeter, the multimeter will check for continuity. The magnets will be brought gradually closer to the reed switch until ~ 0 Ω is achieved. In Figure 23 we can see that the magnets needed to be at least 0.5 cm from the reed switch in order to close the switch.

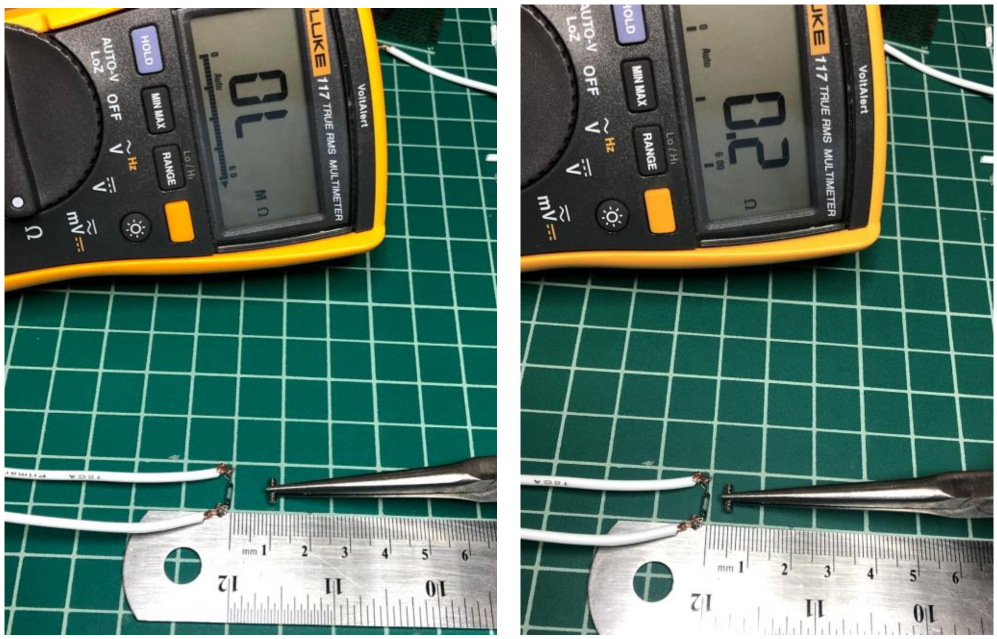

Figure 23: Magnet is 1 cm away from reed switch and the circuit is open (left), Magnet is 0.5 cm away from reed switch and the circuit is closed (right)

By having the magnets distance measured that leads to designing the bottle cap to meet these needs. The small magnets will line the edge of the bottle cap which will make them be in close enough proximity to the reed switch when the cap is tightened sufficiently.

6.1.6 Microcontroller Testing

To start out testing the microcontroller simply connecting it to the 3.3V power supply and making sure it powers on correctly will be the best first step. After that simple codes will be sent to ensure that everything is set up and a good connection is made. Then comes the part by part testing of the I/O pins starting with the reed switch to see if it can understand its readings, then power the accelerometer, pressure sensor, and the UV LED enable pin. After the voltage levels are check to ensure these devices can indeed be powered by the I/O pins, each of the I2C connections will be tested device by device to read the data from each of the components connected to the bus. Once it is confirmed that each component can communicate and run using the microcontroller and the I/O pins the Bluetooth will be checked. The Bluetooth will run directly off the microcontroller's VCC and get the data sent to it via the microcontroller so it can then be sent off to the mobile device. It is critical that the microcontroller sends the data to the Bluetooth module.

The final testing will include running the code that sets up all the components in sequences and to ensure that the microcontroller clocks keep track of when to power the UV LED as well has how long the accelerometer should continue to check if the bottle is upright. While the components are running the power levels should be compared to the expected values to see how much voltage and current they are drawing from the microcontroller.

6.1.7 Bluetooth Testing

When testing to make sure that the Bluetooth is working correctly, we want to make sure that the Bluetooth module responds appropriately to the microcontroller instructions, stays connected within its range, connects to paired devices within a reasonable amount of time and correctly transmits data to the paired device.

The first thing to test will be making sure that the Bluetooth module pairs correctly with an Android phone with no major issues. While, making sure this very basic function works correctly, we will also confirm that the time it takes to pair with a smart phone and then connect to it, is short and does not take too long as this could severely harm the user's overall experience with the H-2-Ohm module.

Next, we will make sure that the data sent from the microcontroller for transmission is able to be seen by the mobile device being used. We will test using several different data values including extreme values that have a higher chance of being miss-interpreted during its transmission to the user's mobile device.

Thirdly, after confirming that data is able to be sent by the module and received by the user's smart phone, we will test to confirm that it meets our standards for connection range. This can be tested by sending a steady stream of data to the smart phone as we slowly move the smart phone further and further away from the module until either the connection is lost or the data starts to become miss-understood by the receiving mobile device due to information that might have been lost on the way. Another way we will test the connection range of the module is finding out how close the paired mobile device must be before an automated connection is able to be established between the two devices.

The last thing that we will test is how the Bluetooth module responds to all of the different commands we might use from the microcontroller. These commands would include things like resending the data after a failed connection, telling the Bluetooth module to pair or connect as well as other various commands that we might utilize in the project.

6.1.8 Mobile Application Testing

There are numerous options for testing Android mobile apps depending on the design goals of the app. As stated previously, the main design goal is ease of use such that the app is quick to open, run and display the desired data. With the design of the H-2-Ohm module we envision very little required navigation when checking in and using the app other than the initial setup and applying a few different options for preferences. Other than these things, the design should be very simple with only one main page to display the necessary information.

For testing this type of app we will likely want to use notifications so that the user knows when the water consumption information has been updated. In testing this function we will want to make sure that the mobile device doesn't receive notifications too regularly to the point of annoyance but also updates the information quickly after the sensors have read and transmitted the data. It should also be noted that when opening the app for the first time, there should be a prompt so that the app can determine if it is being used for medical reasons as this will determine the urgency/priority level of certain notifications.

Another test will be the speed at which the app can be opened and begin user interactions. Because of its goal of being a simplistic design, there should be no issues or extended load times when attempting to open the app.

The third test will be making sure that desirable customizations to the app are available and fully functional. Because there are many different people who could use this application, we want to accommodate, allowing for a couple customizations for color and lighting styles as well as being able to either set goals for H2O consumption or limitations on water consumption due to medical reasons.

Finally, and most importantly is basic functionality. We must test to confirm that the application properly interprets and displays the data even in strange circumstances, therefore, it is necessary to test sending extreme data values so that we make sure the application properly responds with error messages if needed.

6.2 Prototype Testing

Prototype testing can be the most exciting, and at the same time, disappointing parts of any product development. This section of the design process will outline how each individual component will be brought together and tested, as well as some of the precautions that need to be accounted for when doing these tests. Several different types of equipment will be needed to perform these tests such as a Fluke 117 multimeter, a TP3005T DC regulated power supply, banana/alligator clip cables, soldering station, solder, flux, hot glue gun, and various other small parts.

When testing the H-2-Ohm prototype, the process involves repeating all of the other testing steps except with one important difference. Prototype testing not only makes sure that all of the systems work together correctly but also tests the device's limitations making sure that things continue to work consistently within reasonable extremes. These extremes include, water resistance testing, temperature testing, safety and durability testing and testing in different extreme software scenarios that may cause the device to malfunction or transmit erroneous data. The first test will consist of the team putting the bottle in ideal conditions and confirm that all components work and communicate with each other correctly.

Testing for water resistance is of primary importance since there is a constant risk of water damage if the H-2-Ohm module is not properly sealed. In testing this, we will also take note of situations where the module might be more vulnerable than normal such as changing or recharging the devices batteries. This test will start with ideal cases in which the bottle is filled without spillage. After confirming that the module continues to work correctly, we can continue by running more strenuous tests such as shaking the module while it is full, half-full and mostly empty to make sure this impulse pressure on the inside of the bottle does not cause issues. Then as a final test for water proofing, fill the bottle, allowing it to overflow and let water run down the outside of the bottle. After each of these steps, it is important to make sure that the module continues to work as expected within an error close to 0. These tests will confirm that the H-2-Ohm module is reasonable water resistant allowing us to move on to further tests.

The next phase of prototype testing is temperature changes. After having tested with ideal temperatures, the next test is to make sure all of the bottle's components work in temperatures less than 50°F. Another thing to keep in mind is that some may use this bottle in freezing temperatures so it is also important to test extremely low temperatures, confirming that not only do the electrical components function, but also that the expansion of the water getting colder and eventually freezing does not compromise the bottle's structural integrity.

The safety of the device is directly related to its resilience against water entering the module that contains the electronic components. Therefore, testing its safety is mostly covered in properly confirming that it is versatile in different situations involving water and electronics coming into contact with each other. The durability of the device can be tested by making sure various directional and impulse forces exerted upon it don't compromise the H-2-Ohm modules integrity and functionality.

Finally, this last phase of testing involves simply making sure all of the software works correctly and displays the proper error messages when extreme values are obtained. This includes inputting 0 and maximum values for each of the different software variables and making sure that in doing so, accurate error messages get displayed on the app. This is important to allow for easy troubleshooting whenever software or firmware updates are needed, whether it be for general application improvements or continued hardware iterations that may require additional code to be added to the H-2-Ohm's microcontroller programming.

Running these tests will guarantee that all features and device functions fall within the set parameters for device usage as well as give us data regarding its possible limitations. These tests will also show us where future iterations of the H-2-Ohm module could use valuable improvement whether it be for a better user experience or improved design features that add versatility overall end product.

For each test we will document any voltage, current, and any other form of measurement that we observe. After each part is successfully tested and verified that they are in proper working condition, the more advanced prototype testing phase of this projects build will take place. The following hardware and software areas of this project will be tested as it is outlined below.

6.2.1 Hardware Testing

Testing the hardware components for this project is extremely important, especially when they are connected and controlled by the microcontroller. For this process of testing, we will be connecting each part to controlled via the microcontroller and testing their connectivity by seeing if the parts power on and operate as predicted.

First, the microcontroller will be connected to the power supply, 3.7V, through a voltage regulator. The voltage regulator will step down the voltage to 3.3V, which is what the microcontroller requires to power itself on. Basically, every component will be connected to the MCU located on the PCB that we have designed.

The UV-C LED will not be directly connected to the MCU. There will be a MOSFET that has the source connected to the output wire of the LDO voltage regulator, the drain connected to the anode lead of the LED, and the gate will be connected to a pin located on the microcontroller. This pin on the microcontroller will read either high or low based on the status of the reed switch, it is necessary to let the reed switch activate/deactivate the UV-C LED for safety reasons as mentioned earlier. There will also be four small normal LEDs, visible light, which will poke out of the sides of the lower section of the bottle that will turn on with the UV-C LED, these LEDs will draw their voltage from the MCU.

The reed switch will be connected to an I/O pin on the microcontroller. The UV-C LED's MOSTFET gate will be connected to a different pin on the MCU that will send different signals based on the status of the reed switch I/O pin. The accelerometer will also depend on the reed switch, this is so the accelerometer only runs when it 'knows' the bottle cap is closed.

The accelerometer needs to be connected to the I2C pins on the MCU in order to be programmed and send their appropriate data to the controller. The bottle needs to verify that it is sitting on level ground before it signals the pressure sensor to take a measurement. Initially, the UV-C LED and the accelerometer will be tested after they are each connected to the MCU, as well as the reed switch. To ensure these components work as planned, they will be turned on or off based on the status of the reed switch.

The component that will be tested next is the pressure sensor. The pressure sensor is the crux of this project's success, we need to isolate this part so we are certain it has minimal sources of issue. We cannot be fully certain that the pressure sensor works until we can see its data on the computer/mobile application. The pressure sensor, like the accelerometer, will be connected to the I2C bus through which it will transport its data. The Arduino Uno development board has Tx/Rx LEDs that indicate if data has been sent over the I2C bus. This component will only be fully determined if it is working through software testing.

Finally, the Bluetooth component’s hardware will be tested once it is connected to the I2C bus pins, SDA and SCL. The Bluetooth piece is only connected to a 3.3V power supply and the MCU. We can verify that this part is working once we are able to have the pressure sensor send its data to the input pins of the Bluetooth module via the I2C bus.

The ultimate test will be if we first remove the bottle cap, which opens the reed switch, and then reapply the bottle cap, closing the switch. After putting the cap back on, the accelerometer will check if the bottle is flat and upright, if it is then we move on to the pressure sensor. The pressure sensor will activate, take a measurement, and send this data to the Bluetooth module over the I2C bus. If we see the Tx/Rx LEDs on the Arduino Uno board illuminate at this stage, then we know something has been transferred. The overall hardware prototype layout that we will follow is outlined below in Figure 24.

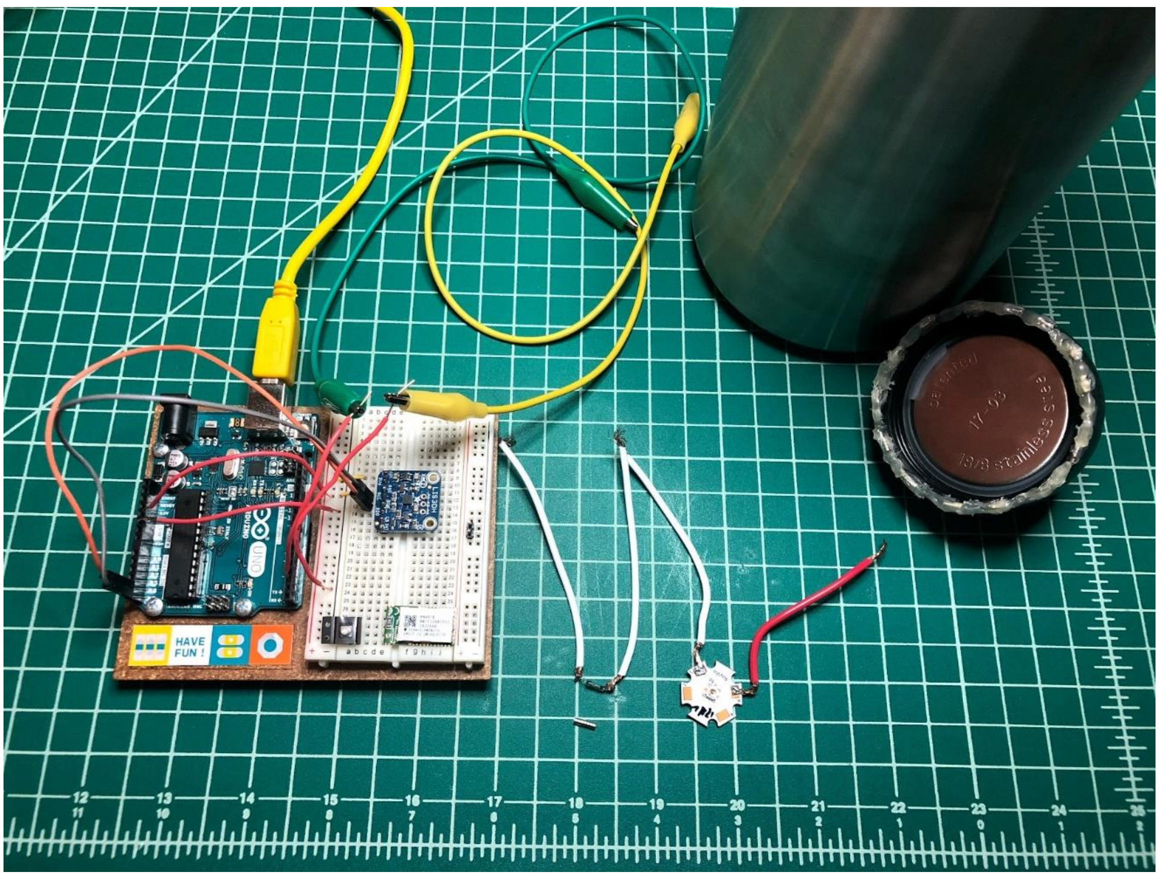

Figure 24: Prototype Testing

6.2.2 Software Testing

When testing the H-2-Ohm module software there will be several things to consider, most of them stemming from the way the microcontroller is programed and confirming that everything works as expected as shown by the software block flowchart. This will include making sure all of the interrupts work and properly activate with the correct timers. We need to confirm that the UV LED turns on upon the correct time intervals, the accelerometer properly takes accurate measurements upon closing the bottle's lid, and that the pressure sensor activates correctly after determining that the H-2-Ohm bottle is in an upright position, then the microcontroller needs to store the collected data and finally make sure that it is correctly communicated through Bluetooth to the Android mobile application. When all of these things have been tested and working correctly, we can be relatively sure that all of the microcontroller software works correctly and only minor corrections are needed for future versions.

The first thing to test is the UV LED, making sure that the long intervals of 2-3 hours work correctly. Because the 16-bit timer limitations in the microcontroller, we will need to use a variable counter that increments a certain number of times each time the timer resets to 0. We will test this function on a smaller scale by using no clock dividers for the timer. This means that while the interval will be much shorter, we will be able to confirm that the code works correctly and will properly scale to the correct time interval for when we want it to wait a full 2-3 hours.

The next software test will be making sure the lid close interrupt properly edge activated upon the lid closing and doesn't set off the interrupt in an infinite loop while it is closed. Because this interrupt activates on the rising edge, another thing to confirm is that there is no bouncing of the signal. If any bounce is detected, de-bouncing must be implemented into the software so that repeated interrupts will not occur. This lid close action should then trigger the accelerometer to turn on and take a measurement after a few seconds. The testing should make sure that it properly turns on and takes a reading repeatedly until it detects that the H-2-Ohm bottle is upright. This testing will mostly utilize the timers to make sure the accelerometer doesn't consume a lot of power trying to take measurements if it is not set upright for an extended period of time, only turning on periodically to see if it is upright or not.

After the accelerometer detects that the bottle is upright, we must then test to make sure that the pressure sensor correctly powers on and gets accurate measurements within a reasonable error. Since the accelerometer does the work in order to make sure the bottle is upright when taking a pressure sensor measurement, no extra timers are needed.

Lastly, once all the data from the sensors is read from the microcontroller, we must make sure that the data is properly stored on the microcontroller and correctly sent to the mobile application through the Bluetooth connection. This will be tested by storing the data to the microcontroller, reading it to make sure there are no errors and that the data didn't change, then sending it over Bluetooth and confirming that all data is consistent between the microcontroller and the mobile application.

7.0 Conclusion

Starting out with a simple idea of how to improve people's health by improving their water intake has led this team down a long path to perfecting an innovative and interactive solution. Creating the H-2-Ohm will not be done overnight and after the extensive research completed this semester in Senior Design 1 there is a sense that this is only the beginning.

This design will be put to the test come Senior Design 2 as well as all of the features the H-2-Ohm plans on incorporating.

Water level measurement techniques were analyzed and compared against each other to land on implementing a pressure sensor to detect how much water a user has consumed. This design discussion then led to needing an accelerometer to determine when the bottle is upright due to how the sensor gets its height readings. So the proper 3-axis device was selected. Powering all of these components as well as controlling them all came down to digging deep into the datasheets and selecting two LiPo batteries to power the system and a small microcontroller to be the heart beat and control center for all of the peripherals.

As mentioned in the existing products section, the concept of incorporating a UV-C LED with a portable water bottle is not novel, but we decided to take it a step further and measure the water levels as well. It was interesting to learn how UV lights affect our bodies and other microorganisms. The subtle differences between UV-A, B and C mattered when it came to the need to sanitize water effectively. Small challenges arose when it came to testing this LED, referring back to fundamental lectures on diodes helped greatly during this time.

Before embarking on this project we had little knowledge about the Hall Effect or what a reed switch even was. Researching little-known topics such as this gave us a greater appreciation for how vast these fields of engineering are. The reed switch was an excellent find for this project, it requires zero power and works extremely well with our bottle-cap requirements.

In researching the app development and communication aspect of the H-2-Ohm module design, it was interesting to see all of the different areas that are often overlooked as a consumer or user. When working on a project like this we can see how each tiny aspect of the design is of vital importance can cause delays in the build process when proper research is not conducted. One example is considering how even the type of serial or wireless communication we use will vastly effect how many of the other items in the design operate. In researching the app development process, it is easy to overlook how design elements like color, contrast and font can effect the overall application experience for the user. Where the functionality of the app is concerned, it was valuable to consider how the data would be stored and shared between the app and the microcontroller memory and how this decision can increase or decrease the amount of data needing to be transmitted over bluetooth.

Overall, this design process has been a huge learning experience for everyone on the team. For the most part, the first piece of the project has consisted of research, concept designs, minimal testing, and explanations of what we plan to do in the near to come future. Working well with a team is an important skill to have when it comes to being successful in any professional setting. Engineering is about using your knowledge to simplify complex ideas and issues, into something that can work successfully in the real world. H-2-Ohm was an original idea developed by our team, the steps that we took to make it become a real product were priceless experiences.

8.0 Appendix

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8.2 Technical Assistance

RE: University Student - Need help testing UV LED

Robert Walker <rwalker@rayvio.com>

Sat 4/13/2019 4:24 PM

To: Lauren Tyler <Laurentyler@Knights.ucf.edu>;

See below.

Dr. Robert C. Walker
President & CEO
rwalker@rayvio.com
+1-650-796-9598

RayVio

RayVio Corporation
3980 Trust Way
Hayward, CA 94545 USA
Google Maps: https://goo.gl/maps/8MqT6
Website: www.rayvio.com
LinkedIn: Click here

From: Lauren Tyler [mailto:Laurentyler@Knights.ucf.edu]
Sent: Friday, April 12, 2019 8:42 PM
To: Robert Walker
Subject: Re: University Student - Need help testing UV LED

Dr. Walker,

Thank you for the assistance, I apologize for not realizing that I've already emailed you before requesting usage of the LED photos.

I'm using this voltage supply:

Okay, so I set the voltage threshold level to be 6.5 V and then the c.c. light turned on and I slowly turned up the current until I saw the LED get brighter (I had safety glasses on). I stopped at 100mA and my power supply showed that it was pulling 5.5 V. I also realized that before this I had the Cathode side of the diode plugged into my GND (oops). So that explains why it wasn't working earlier.

It started to glow at around 30mA, really neat to watch it work thanks for your help!
[RCW] Glad it worked!

Quick Question:
When I was changing the current value, this was also changing the constant current value to the diode correct?
[RCW] Yes.
Also, why didn't the voltage go to 6.5 V when I reached 100mA? Does this mean I only need 5.5mW to power the diode?
[RCW] Different LEDs will have slightly different voltages @ 100 mA. According to the data sheet, the "typical" voltage is 6.5V; but it can range from 5 (min) – 7.5V (max). You happen to have one with 5.5V (we keep working to bring the voltage down – lower is better). So you need 5.5V * 100 mA = 550 mW to power the diode (at 100 mA).

Referring to the table below, my forward current was 100mA but I wasn't at 8mW. Was this because I set a 6.5V threshold and not an 8V one?
[RCW] The table below shows the UV OPTICAL OUTPUT power of the LED (e.g. how much light it emits) – it has nothing to do with the ELECTRICAL INPUT power (which was above). At 100 mA, the LED will put out 6-9 mW of UVC power.

Table 2. Radiant Flux vs. Forward Current at T_a= 25˚C

Part Number	Radiant Output @ 25°C vs. Forward Current			
	Forward Current (mA)	Min. (mW)	Typ. (mW)	Max. (mW)
RVXR-280-S(x)-073105	50	3	4	4.5
RVXR-280-S(x)-073105	70	4	5.5	6.5
RVXR-280-S(x)-073105	100	6	8	9
RVXR-280-S(x)-073605	50	4.5	5	6
RVXR-280-S(x)-073605	70	6	7	8.5
RVXR-280-S(x)-073605	100	9	10	12

Thank you!
[RCW] Hope that helps.

-Lauren

From: Robert Walker <rwalker@rayvio.com>
Sent: Friday, April 12, 2019 5:00:46 PM
To: Lauren Tyler
Subject: RE: University Student - Need help testing UV LED

Lauren:

Thanks for your email. I'm sorry you are having difficulties.

For operating the LEDs, the ideal thing to do is to operated them in a **constant current mode** (they are diodes), rather than a constant voltage mode, as the Vf (essentially the turn-on voltage) can vary a bit from LED to LED. Is that something you could do? And, when you had the LED at a constant 6.5V, was it drawing any current from the power supply? How much?

If so, when you operate the UV LED at several 10s of mA (the rated current is 100 mA, but you can operate it below this or slightly above as well), you should see a very light, purplish glow (this is an artifact of some of the UV light getting down converted to purple). It is not bright, but it is visible. Please wear safety goggles or UV protected glasses (most plastics and glass will 100% absorb UVC light) when looking at it, so you don't damage your eyes.

Please let me know if that helps. Thanks.

-Bob

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3980 Trust Way
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LinkedIn: Click here

From: Lauren Tyler [mailto:Laurentyler@Knights.ucf.edu]
Sent: Friday, April 12, 2019 1:39 PM
To: Robert Walker
Subject: University Student - Need help testing UV LED

Hi Mr. Walker,

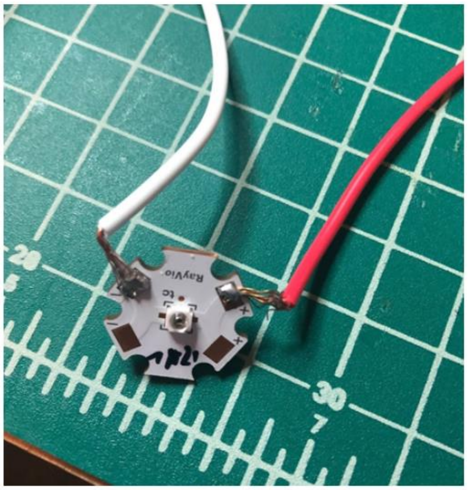
My name's Lauren Tyler and I'm an Electrical Engineering student at the University of Central Florida. I'm currently doing a senior design project and need some guidance on testing the UV-C LED that I bought from RayVio.

Part #: RVXR-280-SB-073105

We had it in a box for safety before we attempted to power it on.
Next we applied 6.5 V to the positive terminal and we didn't see any indicators that it was working/on.

Should I be connecting voltage to the other terminals as well? I
didn't think I needed to because they were shorted together. (pos + pos, neg +neg)

Set Up:



Please email or call,
Email:
laurentyler@knights.ucf.edu
Phone:
(386)
569-9423

Thanks,
Lauren Tyler

8.3 Permissions

Pressure Sensor Image Request:

TE Connectivity

Your question has been received. You should expect a response from us within 8 business hours.

You may also update this question by replying to this message.

Question Reference #06344830
Subject: Image Permission Request
Product Category:
Date Created: 3/25/2019
Part Number:

Customer:
Description: My name is Jadyn Lalich and I am an electrical engineering student at the University of Central Florida. I would like to request the use of images of two of your pressure sensors. They will be used in a design paper for a project I am working on for school. The images would be of the MS5837-02BA and MS5803-02BA taken from your web-page https://www.te.com/usa-en/product-CAT-BLPS0059.html and https://www.te.com/usa-en/product-CAT-BLPS0010.html respectively. All images and information will be cited. Thank you for your time.

ref:_00DE0Hkve._5000L1FuRDX:ref

Reed Switch & Hall Effect Sensor Image:

Hall Sensor & Reed Switch Photo Use

KM K&J Magnetics <contactus@kjmagnetics.com>
Today, 9:51 AM
Lauren Tyler

Reply all

Lauren,

It is OK for you to use that image in your document. Though the images and text on our website is copyrighted material, you're free to use them as long as you include attribution.

Good luck with your report!

Best Regards,

Michael Paul
K&J Magnetics, Inc.
www.kjmagnetics.com

Thank you so much for your feedback. | Thank you so much for your input. | Thank you for the kind feedback.

Report inappropriate text

On 3/23/2019 7:52 PM, K&J Magnetics, Inc. wrote:

> From: laurentyler@knights.ucf.edu
>
> Message:
> Hello,
> My name's Lauren Tyler and I am a senior electrical engineering student at the University of Central Florida. I would like to ask for permission to use the image titled: Proper Magnet Orientation: A Hall effect sensor (left) vs. a reed switch (right) in my senior research document. I would like to use this imagine to assist in an explanation of how these electronic components operate.
> Thank you Lauren Tyler

Rayvio UV-C LED Image:

RE: Rayvio "General Inquiry"

Robert Walker <rwalker@rayvio.com>

Sun 3/24/2019 8:58 PM

To:Lauren Tyler <Laurentyler@Knights.ucf.edu>;

Approved.

Dr. Robert C. Walker
President & CEO
rwalker@rayvio.com
+1-650-796-9598

RayVio

RayVio Corporation
3980 Trust Way
Hayward, CA 94545 USA
Google Maps: https://goo.gl/maps/8MqT6
Website: www.rayvio.com
LinkedIn: Click here

This e-mail message, including any attachments and previous email messages sent with it, contains CONFIDENTIAL and PROPRIETARY information of RayVio Corp. and may be legally PRIVILEGED. You may not use, disclose, reproduce or distribute such information without RayVio's authorization. If you have received this message in error, please notify the sender immediately by reply email or by telephone, and permanently delete the original message, its attachments and any copies thereof

From: Lauren Tyler [mailto:Laurentyler@Knights.ucf.edu]
Sent: Sunday, March 24, 2019 5:49 PM
To: Robert Walker
Subject: Re: Rayvio "General Inquiry"

Hi Bob,
I would like to use it for academic purposes. It's for my ECE senior design project paper.

Thank you,
Lauren Tyler

On Mar 24, 2019, at 7:56 PM, Robert Walker <rwalker@rayvio.com> wrote:

Lauren:

Thanks for reaching out. I appreciate the care and respect.

Can you tell what purpose you are using the image for? An academic paper, a web site, a ???

Thank you!

-Bob

Dr. Robert C. Walker
President & CEO
rwalker@rayvio.com
+1-650-796-9598
<image001.png>

RayVio Corporation
3980 Trust Way
Hayward, CA 94545 USA
Google Maps: https://goo.gl/maps/8MqT6
Website: www.rayvio.com
LinkedIn: Click here

From: Lauren Tyler [mailto:wordpress@rayvio.com]
Sent: Saturday, March 23, 2019 5:02 PM
To: info
Subject: Rayvio "General Inquiry"

From: Lauren Tyler
Subject: General Inquiry

Message Body:
Hello,
My name's Lauren Tyler and I am a senior electrical engineering student at the University of Central Florida. I would like to ask for permission to use an image of this part:

Part Number: RVXR-280-SB-073105

I would like to use this imagine to show the difference between UV LEDs.

Thank you,

Lauren Tyler

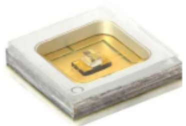
--
This e-mail was sent from a contact form on Rayvio (http://rayvio.com)

Vishay UV-C LED Image:

REQUEST to use an image from Vishay

1

AA Aurand, Andrew <Andrew.Aurand@vishay.com>
Today, 3:16 PM



Download Save to OneDrive - Knights - University of Central Florida

Dear Ms. Tyler,

Please accept this email as consent to use the attached image ("Work") for educational use only subject to the following conditions. Your use of the Work constitutes acceptance of the terms contained in this email.

- Consent is granted for publication of the Work for educational purposes only. No other consent or permission is granted with respect to the Work or any Vishay property other than the Work. No consent is granted for any use that constitutes commercial use.
- Vishay remains the sole owner of the Work. No transfer of intellectual property is made by this email or any other communication.
- No challenge to Vishay's ownership of the Work will be made by you or your organization.
- Credit will be given to Vishay when the Work is printed or displayed in any media with this text, in legible type: "Copyright Vishay Intertechnology, Inc. 2019. All rights reserved."
- No action will be taken by you or your organization that might dilute, tarnish, disparage, or reflect adversely on Vishay or the Work or diminish the value or goodwill associated therewith.

Please contact me with any questions.

Best,
Andrew Aurand
Sr. Director, IP

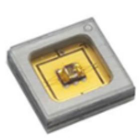
andrew.aurand@vishay.com
(o) 610.251.5268
(f) 610.889.0965

Vishay Intertechnology, Inc.
63 Lancaster Avenue
Malvern, PA, 19355

LT Lauren Tyler
Sat 3/23, 8:05 PM
LED@vishay.com

Reply all

Hello,
My name's Lauren Tyler and I am a senior electrical engineering student at the University of Central Florida. I would like to ask for permission to use this image:



Part Number: VLMU60CL00-280-125

I would like to use this imagine to show the difference between UV LEDs.

Thank you,
Lauren Tyler

Marktech UV-C LED Image:

REQUEST to use an image from Marktech Optoelectronics

KW Kevin Ward <K.Ward@marktechopto.com>
Today, 2:10 PM

Hello Lauren,

Yes and sorry for the loss against Duke, they deserved to win, they played a great game.

Best Regards,
Kevin Ward
Sales Manager
Marktech Optoelectronics
3 Northway Lane North
Latham, New York 12110
518-956-2980 ext 208
518-785-4725 fax
k.ward@marktechopto.com
www.marktechopto.com
Marktech
Optoelectronics

It was a great game. | Thanks for the game. | It was very sad.

Report inappropriate text

LT Lauren Tyler
Sat 3/23, 8:00 PM

EDIT:
Part Number: MTE280H41-UV

LT Lauren Tyler
Sat 3/23, 7:59 PM
info@marktechopto.com

Hello,
My name's Lauren Tyler and I am a senior electrical engineering student at the University of Central Florida. I would like to ask for permission to use this image:

Part Number:

I would like to use this imagine to show the difference between UV LEDs.

Thank you,
Lauren Tyler

Cover Page Image Request:

Permission to use image

Lauren Tyler

Mon 4/15/2019 12:11 PM

To:news@knightnews.com <news@knightnews.com>;

Hello,

My name's Lauren Tyler and I am a fellow knight at UCF. My team and I are doing an Electrical & Computer Engineering senior design project. We are making a 'smart' water bottle and would like to use this image as our cover page:

I believe this image was taken that this event in 2015: http://knightnews.com/2015/04/ucf-fills-reflecting-pond-with-250k-water-bottles-for-reflect-on-sustainability/

Thank you,
Lauren Tyler