UCF Senior Design 1

Optical Chlorine Analyzer and Dechlorinator

Divide and Conquer Document

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Chapter 2 - Project Description

2.1 Project Background and Motivation

Senior design is the university's way of taking our learned theories and experiences both in classroom lectures and laboratory experiments and making us apply them in a way that can solve an existing problem. This project encompasses what engineers really do in the world: they observe complex problems and work with available resources as well as personal abilities to develop an innovative solution. Given that our group is composed of two Photonics Science Engineers (PSEs) and two Computer Engineers (CpEs), we wanted an idea that would involve gathering a great amount of data from an optical design and then process that information through well-developed software. Our project seeks to create a responsive system that can detect free chlorine content in a water source and dechlorinate it for consumption. The PSEs will be responsible for designing a system that both detects and dechlorinates the water while the CpEs will be responsible for designing the system which takes the optical signal and converts it to an electrical signal which can be processed by software. Additionally, the CpEs will also develop an application that can be used via Android phone to view information and activate the dechlorination process.

Water treatment plants often use multiple filtration systems to make water safe for consumption, and depending on the desired use can be incredibly in-depth and complex. For our system, we'll use just two steps of this process: UV dechlorination and a reverse osmosis filter. The UV light serves to break down the chlorine in water into ions which become byproducts that can be very easily removed by a reverse osmosis filter. We aim to make a product that can reduce the chlorine content in a water sample by at least 40% and remain within our desired budget.

2.2 – Current Commercial Technologies and Inspirations

2.2.1 – Previous Senior Design Project: Fish Tank Assistant

The Fish Tank Assistant is a previous senior design project which aimed to assist fish tank owners in the upkeep and care of the condition of their enclosure. By using an optical system that uses the Beer-Lambert law in tandem with a thermal camera, the project was able to detect and notify its owner of shifts in the condition of the water. Their group also consisted of two PSEs and two CpEs, which made their idea of particular interest since their documentation answered the major concern of how we'd take an optical signal and convert it to an electrical signal without an electrical engineer (EE). Their primary focus was specifically on detecting and notifying owners of algae blooms, which can occur in any water that fits the following description: warm, slow-moving, and filled with nutrients. According to them, the algae can produce a fast-acting poison known as a Cyanotoxin which can kill any marine life within. Even if this toxin isn't produced in the water, an excess of algae in the water can quickly deplete the oxygen within the tank, resulting in water incapable of supporting the pet fish within. This is the primary motivation behind their desired system.

Their final system was capable of detecting the algae with an interface that the owner could use to easily note how much algae was present and advise when to clean the fish tank. Additionally, they reached a stretch goal of being able to siphon water from a source into a test tube. While they weren't able to reach all their goals, they more than proved that their system was feasible and gave our group the idea to look into contaminants in water and seek to go one step further. That further step is to decontaminate, which is what led us to our next inspiration.

2.2.2 – Current Senior Design 2 Project: UV Light Disinfectant

One of the senior design projects currently in development is a UV light disinfectant. This group aims to detect microorganisms in water and use a specific UV wavelength to kill them. Their PSEs are currently in the process of building the optical system that will detect and kill microorganisms in the water, while their CpE works on developing software to assist the owner of the product and the EE builds the optical signal to electrical signal interface. The working principle for their project is using the UV wavelength of 254 nanometers, which is a particularly effective wavelength to destroy bacteria, parasites, and any other harmful microorganisms in a water source, to disinfect drinking water.

When initially discussing how to build off the algae project, we were made aware of and reached out to this group for information on their idea and current goals and objectives. Due to the high effectiveness of 254 nanometer UV light, most microorganisms that can be dangerous are all handled by this singular wavelength at a power of 1 watt and above. For this reason, we realized that we could not use UV light to kill biological organisms as that would have near identical goals and objectives to this current project. Thus, we researched articles online about water treatment and found that at a similar power of 1 watt and above, one could break down chlorine in water using UV light and use a filter to reduce the concentration of chlorine. For good measure, we reached out to a company which does water treatment using UV light and had them affirm our idea, which is our next section and fits into the category of current commercial technologies.

2.2.3 – Rodem: Smart Sanitary Processes

Our group looked into various companies that use UV light in their water treatment process and eventually decided to get in contact with Rodem. This company uses a variety of sanitization methods to fulfill given parameters a customer requests of them. For example, if the water needs to be used for pharmaceutical purposes, they will incorporate a complex, multi-stage water treatment process due to the necessary purity of the water. Due to their processes having multiple stages, they have experimented with and successfully incorporated various systems which utilize UV light to purify water. Some of their systems use the aforementioned 254 nanometer UV light to disinfect and deal with bacteria, but a few other systems have also used a different wavelength to reduce the concentration of chlorine in their target water sample. After a few phone calls and consistent pestering, we were able to get in contact with someone who gave us an excellent starting point and overview of how UV light dechlorination is done.

Brian Gorchowski is the contact that we eventually reached after asking various employees around Rodem how we should go about UV dechlorination. He is a regional sales manager based in Kentucky who works closely with Rodem. The company he actually works with is known as Nuvonicuv and their primary selling point is their UV-based solutions for disinfecting a variety of surfaces such as air, physical surfaces, and most importantly, water. He described to us how the UV at a certain wavelength range breaks down free chlorine in water into its ions which then reform into byproducts that are very easily removable via a reverse osmosis filter. He also gave us a better understanding of why using UV is beneficial in comparison to using other methods such as activated carbon filters. The specific drawback to activated carbon filters lies in that the damp surface of activated carbon fosters the growth of bacteria, which can easily reduce the purity of the water. While there is a variation of activated carbon which takes this into account and prevents the growth of bacteria, Gorchowski described it as very costly and usually not worth the purchase in their applications. He also gave us a very good target for the specifications of our UV light source, which is about 1200 millijoules per second to have an effect on the free chlorine we seek to deal with. 1200 millijoules per second is about 1.2 watts of power, which means we have a baseline power to ensure our UV light source reaches for our purposes. Additionally, he reaffirmed that even if the power is beneath the aforementioned target, it should remain effective as long as the wavelength is correct. After the phone call, he sent an email with valuable information to help us deduce what wavelength to use.

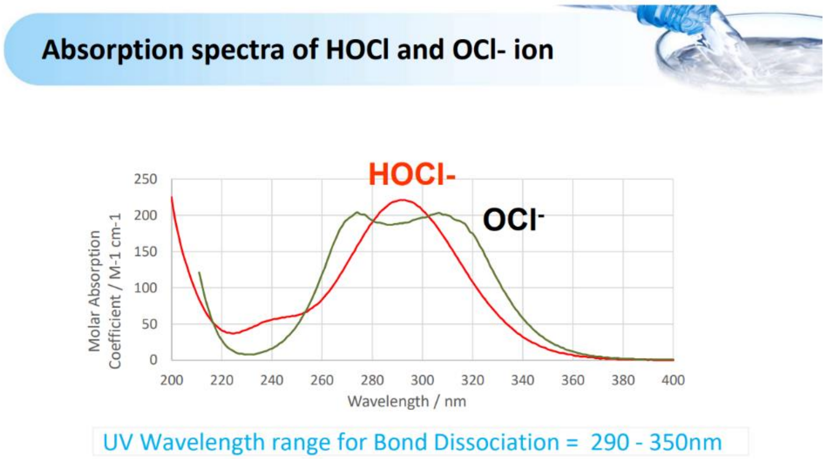

Figure 1. *Absorption spectra for free chlorine in water. Peaks indicate where dechlorination occurs.*

2.4 – Goals and Objectives

The Optical Chlorine Analyzer and Dechlorinator should at minimum do what its namesake entails: Detect free chlorine in a water sample and remove at least 40% of it. This will serve as our overall goal, with the previous senior design projects from section 2.2 serving as inspirations for our advanced and stretch goals.

2.4.1 – Basic Goals

Basic goals encompass the bare minimum of what the optical chlorine analyzer and dechlorinator should be capable of.

1. Develop an app that displays concentration of chlorine in the system and can start the dechlorination process.

2. Develop an optical system that can detect and accurately report the amount of chlorine content in water in ppm.

3. Remove at least 40% of the chlorine concentration detected.

2.4.2 – Advanced Goals

The advanced goals of our system should go beyond what the basic goals entail and should still be achievable. They encompass the fine tuning of the system and the mild expansion of certain systems within the product, giving us a path to improving the product’s performance once the bare minimum is achieved.

4. Reduce chlorine concentration in water to at or below 0.5ppm (Minimum amount of chlorine ppm in tap water).

5. Expand UV dechlorination system to be capable of reducing the chlorine content in at least 500mL of water (Approximate size of a water bottle).

2.4.3 – Stretch Goals

The stretch goals of our system are typically a path that can be taken but pose a significant challenge to the development of the product. Be it due to having to heavily expand and complicate a subsystem or due to constraints related to budget or product size, we expect to meet these goals only partially after the advanced goals are achieved.

6. Expand the system to be able to test and dechlorinate more than one water source at the same time and expand the application accordingly to give updates without impeding the understanding of the user.

Table 1. *Goals of the Project*

#	Type of Goal	Description of Goal
1	Basic	Configure an optical system involving a laser diode, a beam splitter, photodiodes, and lenses into a viable system for the detection of chlorine content in a water sample.
2	Basic	Develop a mobile application (In this case an Android Application Package for mobile phones) which can display the current status of the system, the chlorine content in the water sample it's analyzing, and start the dechlorination process.
3	Basic	Select a UV light source within the wavelength ranges of 280nm to 320nm that has enough power to cause the chlorine content in the water sample to break down and be removable via reverse osmosis filter.
4	Advanced	Refine dechlorination subsystem of project to be able to remove chlorine content in water sample down to 0.5ppm or lower. (This is lower than the ppm present in common tap water)
5	Advanced	Expand the dechlorination subsystem of the project to be able to remove the chlorine content in a water sample of at least 500mL. (This is the average quantity of water in a plastic water bottle)
6	Stretch	Expand the entire project to be able to test and dechlorinate two water sources at a time and develop the mobile application accordingly to give updates on chlorine content of both.

2.5 – Current Required Specifications

Table 2. *Requirements Specifications*

Requirements	Description	
Chlorine in Water Detection Range	The Optical Chlorine Analyzer and Dechlorinator should be able to detect chlorine concentrations.	0.5ppm -10ppm
Dechlorination	The Optical Chlorine Analyzer should be able to remove some of the initially detected chlorine in the water.	Remove 40% chlorine content
Response Time	The detector should be able to report results on the app within a minute of the initial data collection.	< 1 minute
Environmental Conditions	There should be a defined operating temperature and pH for the detector. We also want to identify any environmental conditions that could affect the detector.	Room Temperature (~293 K) pH between 6.5 to 7.5
Power Consumption	Define an acceptable power consumption for the sensor if it is deployed at a remote location.	5W-10W
Cost Constraints	We want to make sure the project does not exceed $1,000.	< $1,000
Dimensions	It should be less than 1x1x1(m) to ensure the system is portable and easy to set up in a lab setting.	< 1x1x1(M)
Accuracy	The Optical Chlorine Analyzer and Dechlorinator should give an accurate reading of the current concentration present in the water.	> 88%
Maintainability	The Optical Chlorine Analyzer and Dechlorinator should be able to run for an extended period without maintenance or supervision.	> 1 year

2.6 – House of Quality

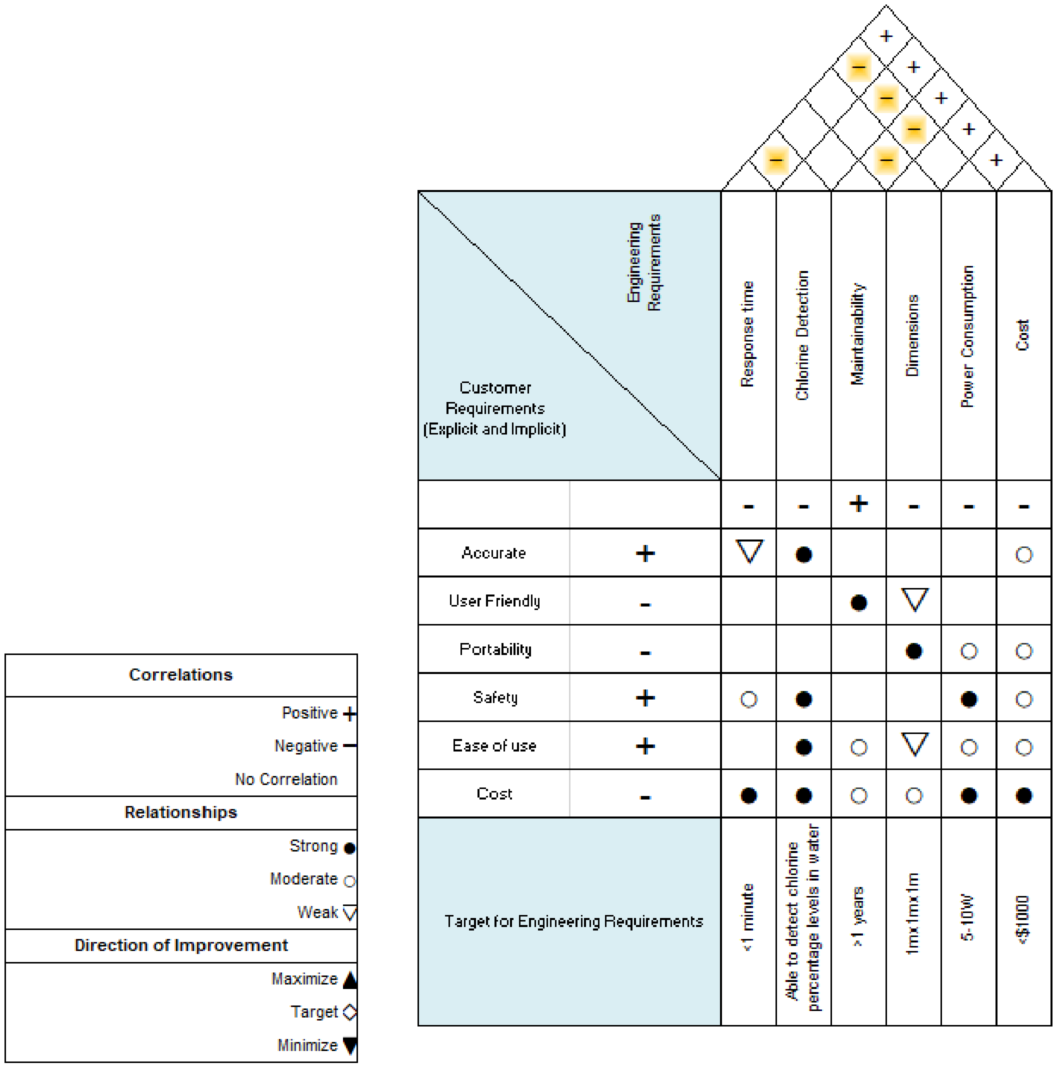

Figure 2. *House of quality*

2.7 - Hardware Block Diagram

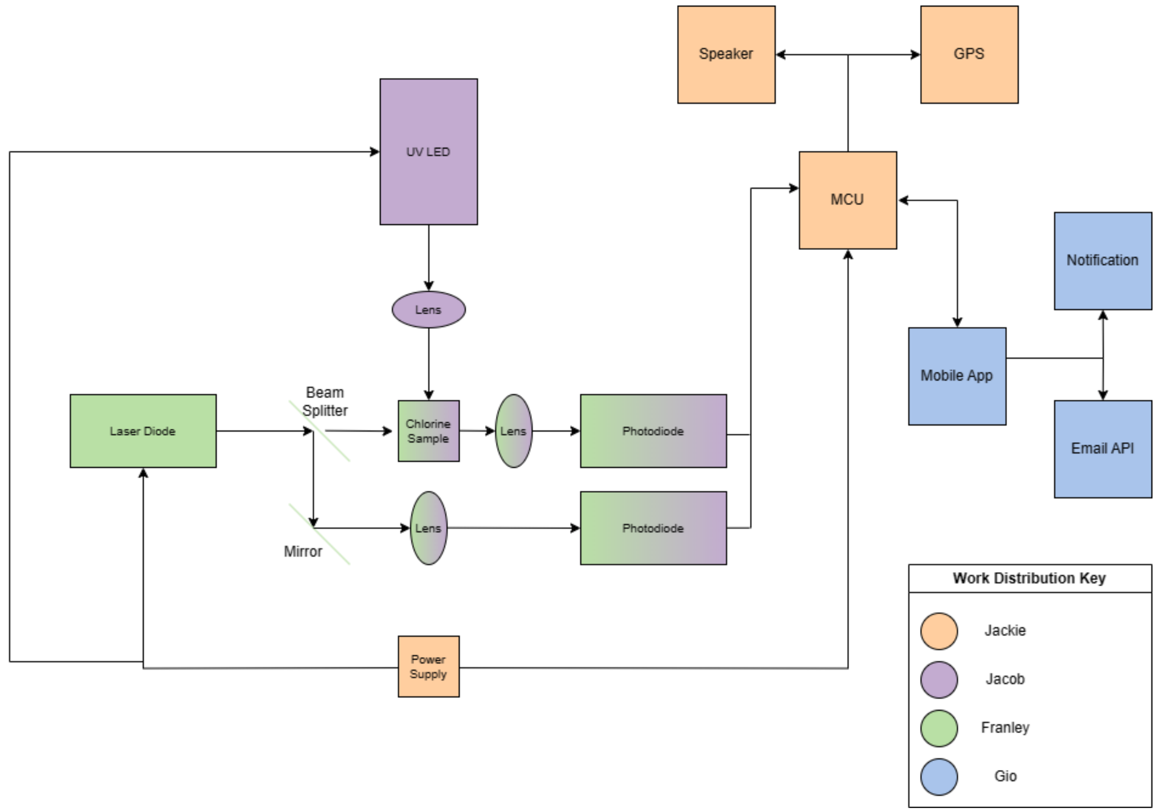

Figure 3. *Hardware Diagram*

Our hardware block diagram comprises several key components working together seamlessly. At its core, a laser diode emits a beam that is split by a beam splitter, leading to two distinct paths. The first path directs the beam towards a photodetector, facilitating the measurement of the beam's power. Meanwhile, the second path guides the beam through a chlorine sample for concentration detection. Following this, the beam encounters a UV LED, crucial for dechlorinating the chlorine sample. All these components interface with a microcontroller responsible for both laser diode control and concentration readings. Additionally, our system integrates a mobile application, providing users with convenient control and monitoring capabilities. This comprehensive setup ensures precise measurement and effective dechlorination, enhancing the usability and reliability of the system.

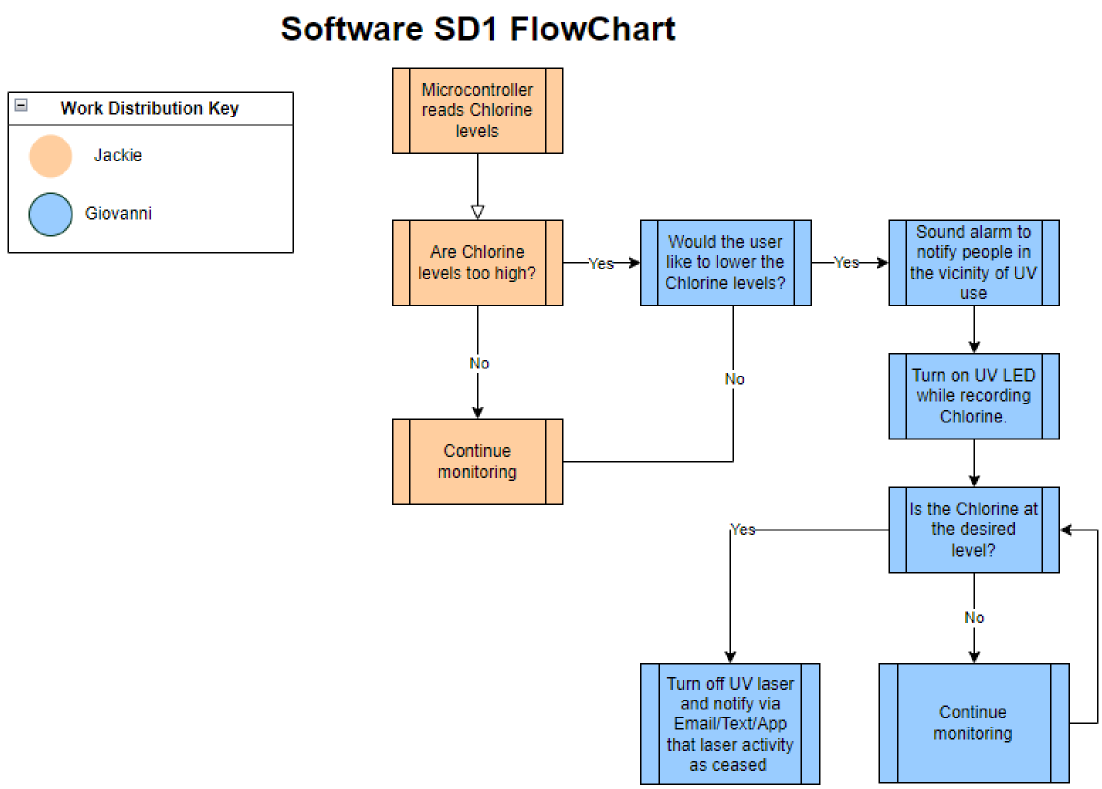

Figure 4. *Software Diagram*

Chapter 10 – Administrative Content

10.1 – Project Budgeting and Financing

The funding for our group project budget is expected to be contributed to evenly by the members within the group. The anticipated budget for this project is $1,000 to ensure the cost for each member is low. The budget is subject to change depending on the final hardware diagram (Specifically the gas detection section) and optimizing the system to achieve the parts per million or billion requirements. The budget includes a provision for replacement components that may arise throughout the project. Table 2 illustrates several key components necessary for initiating the development of an Optical Chlorine Analyzer and Dechlorinator.

Table 1. *Budget*

Component	Quantity	Unit Cost	Total
Laser Diode	1	$200	$200
Gas Cell	2	TBD	TBD

Arduino UNO Wi-Fi REV2	1	$53.80	$53.80
Microcontroller compatible speaker	1	$5.99	$5.99
GPS Module	1	$12	$12
Power Supply Adapter	1	$9.99	$9.99
Photodetector	1	TBD	TBD
Pellicle Beam Splitter	2	$188.88	$377.76
Mirrors	2	$46.59	$93.18
Collimating Lens	2	$5	$10
Focusing Lens	1	$15	$15
PCB	1	$40	$40
Total			~$817.72

10.2 – Initial project Milestones

Our group was formed within the first week of senior design 1 and we are anticipating finishing senior design 2 in the summer. The team has planned milestones to keep us ahead of schedule due to having to finish the project in less time due to the shorter summer semester. The tentative schedules for senior design 1 and senior design 2 are shown in the tables below.

Table 2. *Senior design 1 project Milestone*

Task	Start Date	Anticipated End Date	Duration
Project Brainstorming	01/09/24	01/18/24	2 weeks
Divide and Conquer	01/18/24	02/02/24	2 weeks
Buy Parts	03/15/24	04/01/24	2 weeks

30 Page Milestone	2/2/24	2/23/24	3 weeks
60 Page Milestone	2/23/24	3/15/24	3 weeks
90 Page Milestone	3/15/24	3/29/24	2 weeks
120 Page Milestone	3/29/24	4/15/24	2 weeks
Individual System Testing	4/15/24	5/7/24	3 weeks
System Integration/Testing	5/7/24	5/28/24	3 weeks

Table 3. *Senior design 2 project milestone*

Task	Start Date	Anticipated End Date	Duration
Build Prototype	TBD	TBD	TBD
Test & Redesign	TBD	TBD	TBD
Finalize Prototype	TBD	TBD	TBD
Peer Presentation	TBD	TBD	TBD
Final Report	TBD	TBD	TBD
Final Presentation	TBD	TBD	TBD