SOLAR POWERED PORTABLE WATER FILTER

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Project No. 25

Contents

1 Introduction

1.1 Problem and Solution Overview

1.1.1 Problem

There are many places in the world where people do not have access to clean drinking water, and they are forced to drink contaminated water to survive. The World Health Organization estimates that 29% of the world's population does not have access to clean drinking water. It has also been reported that contaminated water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 485000 diarrhoeal deaths each year [1].

Hiring the installation of a filtration system is expensive and many people do not have enough resources to afford it. The problem is even greater in less developed countries as it cannot be installed because they obtain water directly from lakes or rivers. In addition, these undeveloped countries do not have access to electricity, so many water disinfection techniques are limited.

1.1.2 Solution

We propose the creation of a portable water filtration system capable of removing most impurities, metals, and bacteria from water. It will be a two-tank system. The first one will have our water filter and the second one will use UVC rays to disinfect the water. Our water purification system will remove heavy metals and impurities using a LifeStraw water filter. We will detect any water left in the first tank using a water level sensor. When all the introduced water is filtered and there is no water left in the first tank, ultraviolet light will be activated to disinfect the water in the second tank. That would eliminate most of the possible bacteria and viruses. An LED will indicate to the user that the ultraviolet light is active. When the LED is off, it means that the water is completely clean and perfect for drinking. Additionally, we will use a water flow sensor at the end of the water filter to know when the filter has reached the end of its lifetime and needs to be replaced. The system will automatically warn the user by turning on another LED that they need to replace the filter.

1.2 Visual aid

Figure 1. Visual aid to help interpret our product

1.3 High-level Requirements

1. The system must eliminate 99.99% of bacteria, viruses, and heavy metals present in water. We will verify this using our university labs.
2. LEDs that indicate that the filter should be replaced and that the UV lights are working should be indicating the correct things.
3. Our system should be able to operate all day long using only solar energy

2 Design

2.1 Block Diagram

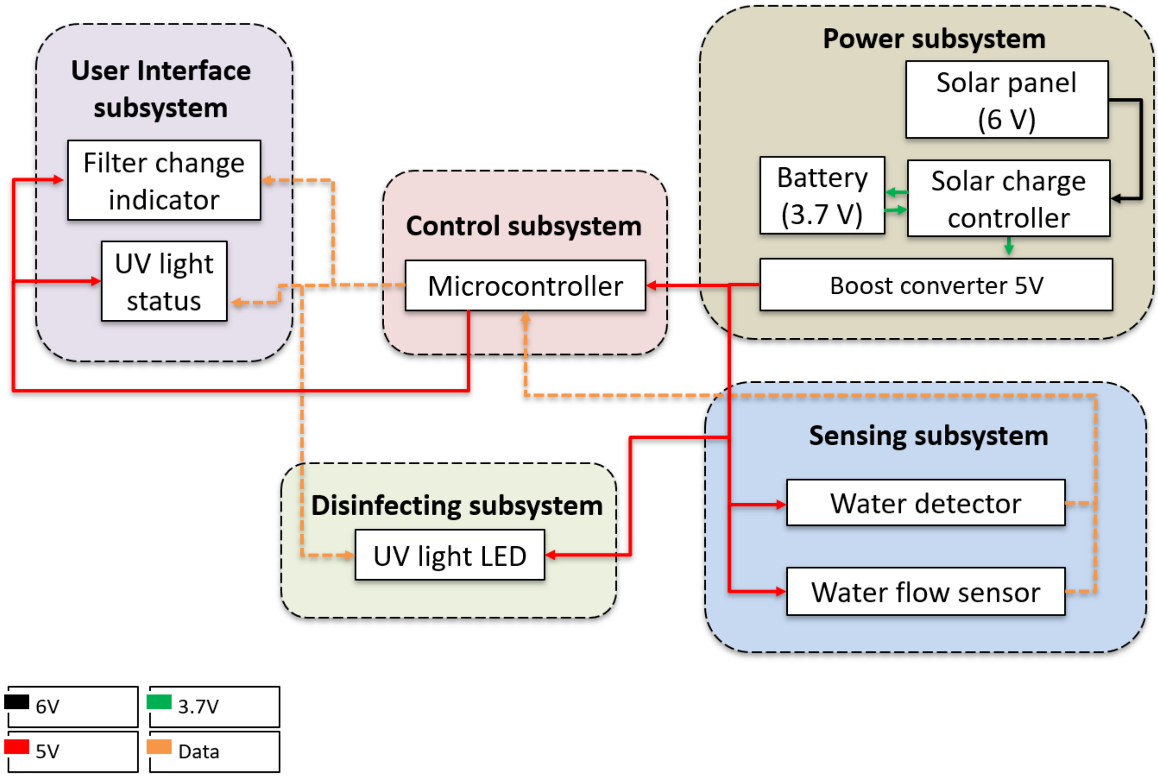

Figure 2. Block diagram of our product divided into subsystems

2.2 Physical Design

Our physical design will be very similar to the LifeStraw home dispenser. Additionally, the grey top part where the water is introduced will have a coffee filter basket inside to remove larger impurities. The PCB, microcontroller, battery, and connections will be located inside the grey container on the right. In the same block, you can see three LEDs that will constitute the user interface.

The water detection sensor will be located inside the first tank, white in the drawing. The water flow sensor and the UV light will be located on the grey ledge, just below the filter.

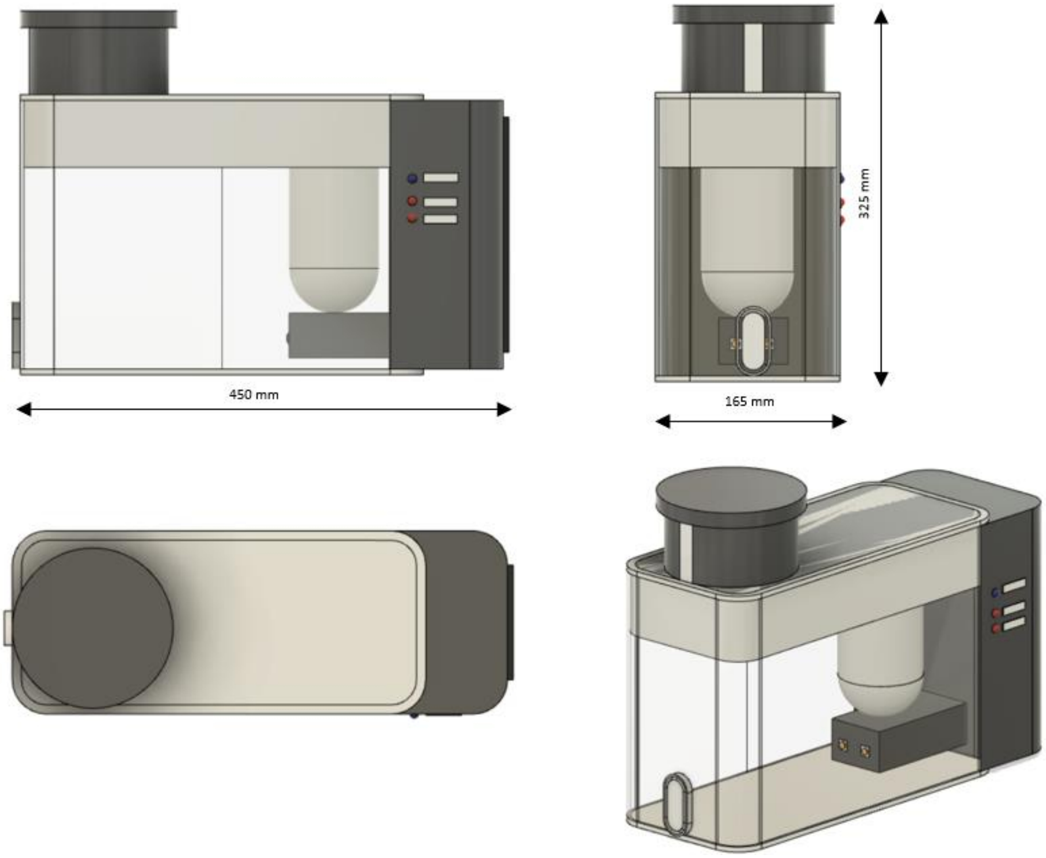

Figure 3. CAD Physical Design

2.3 Subsystem Overview

2.3.1 Power subsystem

This subsystem consists of a solar panel, a solar charge controller, a battery, and a Boost converter, which together serve as a power supply for the other subsystems. First, the photovoltaic panel converts the sun's rays into photovoltaic energy, acting as a voltage source of 6 V. Then, the energy would directly go into the solar charge controller which would be used to charge the battery when the filtering system is off.

The solar charge controller can also control whether the solar panel charges the battery because the battery cannot be charged and charge other components simultaneously, so it needs to be stopped from being charged when the whole filtering process goes on. Using as a constant power source the battery and a dc-dc boost converter we will power the rest parts of our product.

Table 1 Requirements and verification of Power Subsystem

REQUIREMENTS	VERIFICATION
1. Provide a voltage of 3.7 V +/- 0.5% from the battery to the water detector. The water detector should operate between 25-30 mA.	Measure the output voltage using a voltmeter to ensure it is within 5% of 3.7 V. Measure this subcircuit current using an ammeter to ensure it is within 25-30 mA.
2. Provide a voltage of 5 V +/- 0.5% to all the parts of the device except the water detector.	Measure the voltage of any subcircuit in operation using a voltmeter to ensure it is within 5% of 5 V.

Connector J1 is the output of the solar charge controller and has the Boost converter to 5V connected to increase the voltage from 4.4V to 5V. The other boost converter takes as input the output of the other regulator and increases the voltage to 7V.

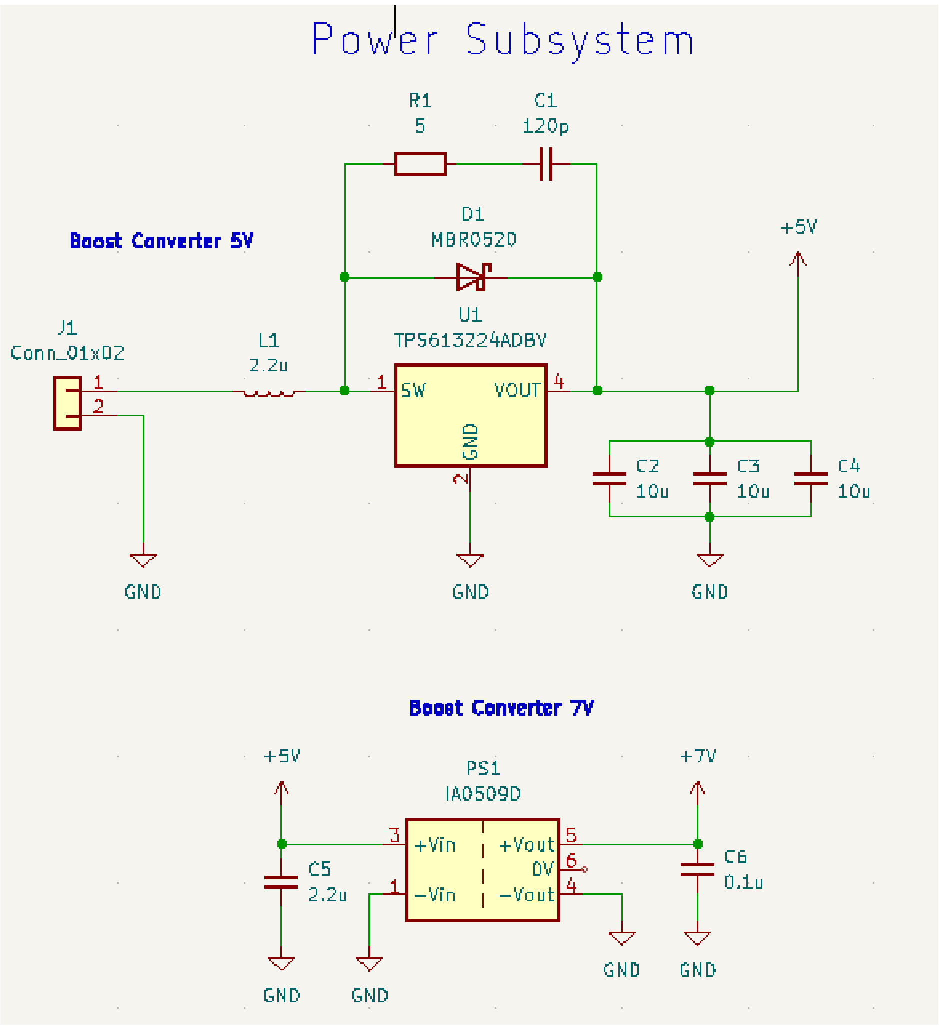

Figure 4. Power Subsystem Schematic

2.3.2 Control subsystem

We would be using an ATMEGA48-20AU - ATmega48 32-Pin 20MHz 4kb 8-bit Microcontroller as our microcontroller. This microcontroller would control when different modules are turned on and off. The following are the requirements for this subsystem -

1. It would operate at about 5 V. It would be powered from the 3.7 V battery after it has been stepped up from 3.7 V. We have chosen this voltage because it is the most convenient for us to use as most of our other modules also operate at 5 V (the microcontroller can operate at 3.3 V as well).
2. It would act as the switch to turn on all different parts of the device i.e. it would control when different modules are turned on. We would have a BJT circuit connected to each connection to make sure there is no issue with the connections.
3. It would also send signals to the LEDs to send appropriate information to the user.

Table 2 Requirements and verification of Control Subsystem

REQUIREMENTS	VERIFICATION
1. It would operate at about 5 V. That is the best voltage to operate for us as most of our other modules also operate at 5 V.	We measure the voltage provided to the microcontroller. If Vm is within 5% of 5 V, then it is working as planned.
2. Control when different modules are turned off and when they are turned on by sending a signal to switch those circuits on.	We measure the voltage between the microcontroller and the different subsystems. If Vm is within 5% of 5 V and Io (operating current) > 0 when the signal is sent, then it is working as planned. Note: Different parts of the circuit operate at different current values.
3. Send signals to the LEDs to turn on and off depending on the signals received from the sensing subsystem.	We can use visual stimuli to verify this. If the LEDs are turned on, we can clearly verify them using our eyes.

In the microcontroller schematic, it is shown the ports that we use as input for the sensors and output for the LEDs and UV lights.

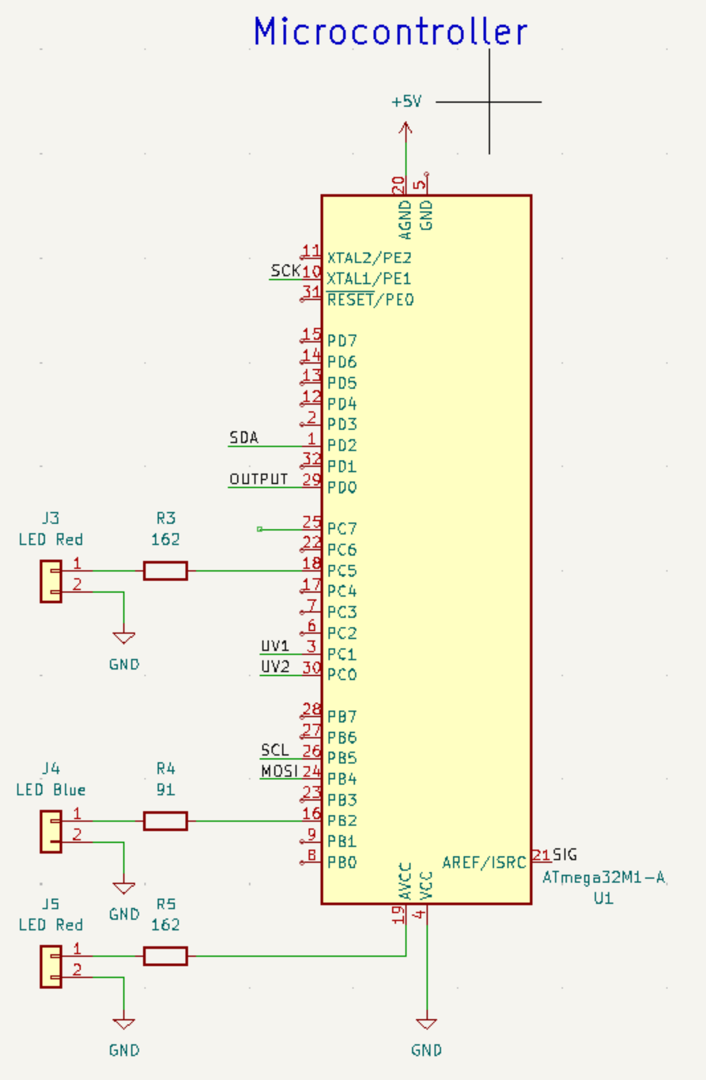

Figure 5. Control Subsystem Schematic

2.3.3 Sensing subsystem

The sensing subsystem consists of a water detector and a water flow sensor whose operation is explained below.

The water detector would detect if the tank on the top has water in it and decide if the UV lights module should be turned on based on that. It would detect if the tank had water or not using a water detector. If there is no water present in the tank, it would send a signal to the microcontroller that there is no water present in the tank. The microcontroller would then turn on the UV light module.

The following are the requirements for this part of the subsystem -

1. This water sensor operates at 3.7 V. It would get power directly from the battery after being stepped-up by the converter. This is the only voltage at which this sensor operates.
2. The microcontroller would control when the water detector is turned on. It would only be turned on during the time there is water in the first tank. It would stop as soon as the UV lights are turned on. This is done to conserve energy.

The water flow sensor would detect the flow rate of water coming from the end of the filter system. For the Carbon Filter, it would record the flow rate and the time of filtering, the total amount of water being filtered can be calculated using those two values. It is assumed that the percentage of heavy metal in normal lakes in Africa is close to that of American tap water, so when 150L (provided by the design datasheet) of water is filtered, the carbon filter should be changed. An LED would light up as an indicator.

For the Membrane Microfilter, this method cannot be used because the percentage of suspended particles in the lakes is much larger than the tap water, and it varies a lot based on how the water is collected and poured into the filter system. Moreover, the size of the holes on the membrane microfilter is fixed so the quality of water being filtered always stays the same even if the filter is clogged finally. Therefore, as avoiding waiting for too long for the filtering process is the most relevant reason a user should change the membrane filter, 50% drop of the water flow rate from the bottom of the filter system is set as the threshold value to indicate the need of changing the membrane filter. The flow rate is directly detected by the water flow sensor, so another LED would light up when the flow rate is 50% of the initial flow rate, as an indicator of changing the membrane filter.

The microcontroller would access the water flow levels and the time taken to filter and determine if the membrane filter is working properly or if we need a replacement of the two filters. If there is a need to change the filter, we would have two LEDs for each of the filters on the outside of the container that would light up. The following are the requirements for this part of the subsystem:

1. The water flow sensor would operate at about 5 V (it can operate at a voltage range of 2.7 V - 5.5 V but 5 V would be ideal for our project).
2. This water flow sensor would be powered through a 3.7 V battery that has been stepped up to 5 V.
3. The water flow sensor would be connected to the microcontroller. It would receive the signals from the water flow sensor. If the water flow levels are too low (50% of initial flow rate), that means the filter needs to be changed. This is when it would send a signal to the led to light up and it would light up outside the device. It would also control when the water flow sensor is turned on. It would only be turned on during the time there is water in the first tank. It would stop as soon as the UV lights are turned on. This is done to conserve energy.

Table 3 Requirements and verification of sensing subsystem

REQUIREMENTS	VERIFICATION
1. It should sense if there is water present in the first water tank.	This can be verified by checking what signal the water sensor sends to the microcontroller. If the sensor sends a Is > 0 to the microcontroller, then there is water present in the first tank. If there is no water present, Is = 0. This can be verified using an ammeter in the circuit between the sensor and the microcontroller.
2. This water detector will operate at 3.7 V as it is the only voltage it can operate. The water detector should operate between 25-30 mA.	We measure the voltage provided to the sub-subsystem. If Vw is within 5% of 3.7 V, then it is working as planned. Measure this subcircuit current using an ammeter to ensure it is within 25-30 mA.
3. It should sense the different flow rates of the water from the first tank to the second tank.	We can access the different flow rates of the water from the microcontroller and check them manually for the microcontroller to see if the water flow rates are being measured or not.
4. The water flow sub-subsystem should sense if the water membrane microfilter needs to be changed.	If the water flow levels are too low (50% of initial flow rate), that means the filter needs to be changed. This data would be collected by the microcontroller. It would send a signal to the led to light up and it would light up outside the device.

Continued on next page

Table 4 Continued from previous page

5. The water flow sub-subsystem should sense if the carbon filter needs to be changed.	If the filter has filtered 150L of water, the carbon filter should be changed. This information would be measured and stored by our microcontroller. When this threshold has been reached, it would send a signal to the led to light up outside the device.
6. This water flow sensor will operate at 5 V as it is the best voltage for our system.	We measure the voltage provided to the sub-subsystem. If Vf is within 5% of 5 V, then it is working as planned.

The schematic shows the connections of the two sensors used in the project.

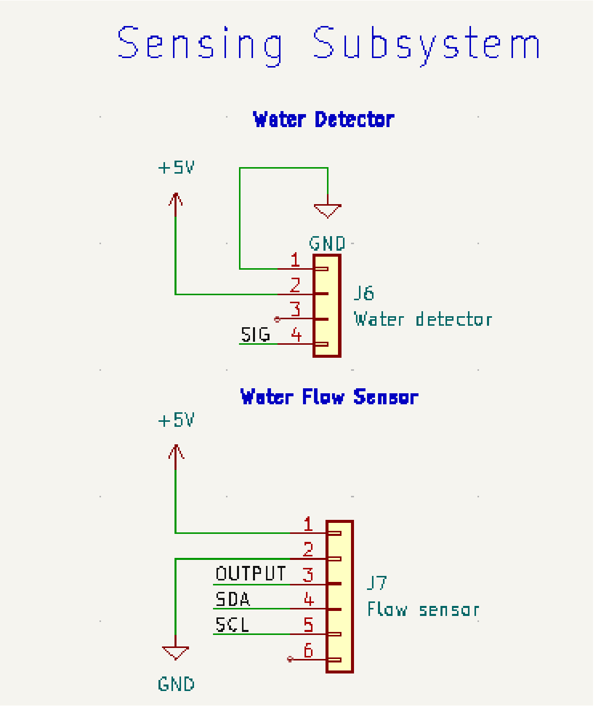

Figure 5. Control Subsystem Schematic

2.3.4 User interface subsystem

We would have four LEDs on the outside that would constitute the user interface. It would tell the user information about what kind of process is going on inside the device and when it is safe for him/her to take out the water from the device.

During the process, first, the purple LED will turn on indicating to the user that the UV light is on. Once it turns off, the water is ready to drink and the yellow light will turn on. The Red LED should light up when the carbon water filter is worn out.

Finally, the blue LED will light up indicating to the user that the microfilter is very worn out and that it is time to replace it as it may start filtering worse until it eventually does not filter at all.

Table 5 Requirements and verifications of User Interface Subsystem

REQUIREMENTS	VERIFICATION
1. The Purple LED should light up when the water is undergoing UV light treatment.	The LED should light up when the signal from the microcontroller is sent to it. We can verify this during UV light treatment by measuring the voltage between the microcontroller and UV light using a voltmeter. If it is positive and the LED light is turned on, that means our LED is working properly.
2. The Red LED should light up when the water filter is worn out.	The LED should light up when the signal from the microcontroller is sent to it. We can verify this by replacing the filter with a worn-out filter and checking if the LED light is turned on. If it is turned on, that means our LED is working properly.
3. The Blue LED should light up when the membrane microfilter should be replaced.	The LED should light up when the signal from the microcontroller is sent to it. We can verify this by replacing the filter with a worn-out microfilter and checking if the LED light is turned on. If it is turned on, that means our LED is working properly.
4. The Yellow LED should light up when the water is filtered correctly.	The LED should light up when the signal from the microcontroller is sent to it. We can verify this after UV light treatment by measuring the voltage between the microcontroller and the light using a voltmeter. If it is positive and the LED light is turned on, that means our LED is working properly.

2.2.5 Disinfecting subsystem

To perfectly purify and clean the water, we will be using a LifeStraw water filter and a UV light.

The LifeStraw water filter will start filtering the water as soon as the user puts the water into the first tank. This filter does not receive data or power from any other subsystem and that is why it is not drawn in the block diagram. But it is fundamental in the operation of the final product since it oversees removing mercury, copper, chlorine, cadmium, and zinc that may be dissolved in the water and are harmful to human health. The UV lights would get a signal from the microcontroller to turn on when the first tank has no water left and all of it has gone through the filter. We would be using a network of two UV lights. The UV lights would be turned on for about 10-12 seconds. After 10 seconds the UV light will turn off to save energy as any bacteria and viruses that may be contained in the water will have been eliminated and the water will be in good condition.

The following are the requirements for this subsystem -

1. The UV lights operate at 5V - 7V each. Each of them produces light of the wavelength of the order of 278 nm. This is required because this wavelength of light is in the range of wavelengths of UVC lights and only these ranges of wavelengths can kill bacteria and viruses to make water suitable for drinking.
2. This module would be powered through a 3.7 V battery that has been step downed to 5 V.

Table 6 Requirements and verification of Function Subsystem

REQUIREMENTS	VERIFICATION
1. The UV lights should be turned on for about 10-15 s to kill the bacteria and viruses.	We can measure the time from when the UV lights LED switches on and closes to verify this.
2. The UV lights operate at 5V each. This is the best option for our design.	We measure the voltage provided to the subsystem. If V is within 5% of 5 V, then it is working as planned.
3. The UV lights should kill the bacteria present in the water.	We will do this by collecting a water sample and measuring the bacterial content and the turbidity content of that sample in a university lab. Then we will use the same source for another water sample but this time we will filter it using our device. We will then measure the bacterial content and the turbidity content of that sample in a lab.

2.4 Tolerance Analysis

The tolerances of our system are mostly about the function of the two filters, which are used for removing suspended particles and heavy metals. It needs to be shown to the user that this device is not designed for facing extreme cases. For example, users should not use this device to filter the water coming out of the wastewater treatment plants, as our carbon filter core is designed for normal tap water. People should try to find the clearest water source they can reach when using our filter system. The activated carbon + ion exchange filter lasts 40 gallons (2 months). We will be using 40 gallons as the threshold point to remind the users to change the carbon filter, as we assume the percentage of heavy metal in natural lake water should be close to American tap water.

The tolerance of changing the membrane microfilter is more about the user experience. With a normal tap water and new microfilter, the user needs to wait for 17 minutes for all the water in the first deposit to be filtered, which is already a long time. If the water source is muddier and the microfilter is already partially clogged, the waiting time would be even longer, eventually there would be no water coming out of the filter core system. The solution is that we attach a piece of sieve at the top of the upper deposit, which would provide the function of “pre-filtering” before the water goes into the filter core. The provided data “264 gallons” is not going to be used here because the percentage of suspended particles differs so much from tap water. The threshold water flow rate to change the membrane filter is 50% of the initial water flow for a new filter and normal tap water. If the users still think the rate of filtering is too low because the filter is being partially clogged, they can choose to change the filter earlier.

3 Cost and Schedule

3.1 Cost Analysis

To estimate the cost calculation, we differentiate between the labor hours spent in the project and the cost of the products and the machine shop.

3.1.1 Labor

Based on the average internship salary of the group members ($40/hr) and estimating that we work 10 hours per person per week on the project throughout the ssemester. In addition, we add a 2.5 multiplier for all costs associated with scaling up the project to a company and the uses of university laboratories and instruments.

$$Cost_{labor} = {}^{\$}/_{Hour} * {}^{Hour}/_{Week} * weeks * members * multiplier =$$

$$= 40 * 10 * 15 * 3 * 2.5 = \$45{,}000$$

3.1.2 Parts

Table 7 Cost of parts for the Solar Powered Portable Water Filter

PART	PARTS NAME	PRICE PER UNIT	QUANTITY	PRICE
Solar Panel	MLarge 6V 3.5W Solar panel - 3.5 Watt	$45	1	$45
Solar Charge Controller	1528-1400-ND	$14.95	1	$14.95
Battery	Lithium-Ion Polymer Battery - 3.7V 10050mAh (10 Ah)	$29.95	1	$29.95
Boost Converter 7V	DCP020507	$11.31	1	$11.31
Boost Converter 5V	TPS613222ADBVR	$0.61	1	$0.61
Water Flow Sensor	FS1025-2001-DL	$58.12	1	$58.12
PHR-6	A06KR06KR26E305B	$1.72	1	$1.72
2 Pin headers male	B2B-ZR(LF)(SN)	$0.17	7	$1.19
Rectangular connectors	08CH-A-02-IDC	$0.51	7	$3.57
Microcontroller	AT89LP828-20AU	$2.76	1	$2.76
Water Detector Sensor	101020018	$3.2	1	$3.2
LED Red	WP71131ID	$0.35	1	$0.35
LED Blue	WP7113VBC/D	$0.55	1	$0.55
Deposit and Filter	Lifestraw Home Dispenser	$59.95	1	$59.95
Full Replacement Filter	Lifestraw Home Full Replacement Filter	$24.95	1	$24.95
Ion + Carbon Filter replacement	Lifestraw Home Replacement Filters	$12.95	1	$12.95
UV light	ELUC3535NUB-P7085Q15070100-S22Q	$7.08	2	$14.16
Coffe filter as pre-filter	10-12 permanent Coffe filter	$8.99	1	$8.99
			Total	$394.28

3.1.3 Machine Shop Cost

Estimated cost of the machine shop to create a compartment to adhere to the tank to place our components and coat the project with a UV light filter to prevent damage to the user.

Table 8 Other costs for the Solar Powered Portable Water Filter

PARTS	PRICE
Container	\$100
UV Light film	\$28
Labor	\$400
Total	528

3.1.4 Sum of Costs

$$= Cost_{labor} = Cost_{parts} = Cost_{others} = 45{,}000 + 294.28 + 528 = \$45{,}822.28$$

3.2 Schedule

Table 9 Distribution of the Tasks during the week

WEEK	AARNAV BHARGAVA	ALBERTO MARTINEZ	ZIHAO ZHOU
02/21	-Complete Design Document -Order first components -Finish PCB first design	-Complete Design Document -Finish PCB first design	-Complete Design Document -Finish PCB first Design
02/28	-Complete Design Review --Get PCB approved	-Complete Design Review -Get PCB approved -Start testing some components	-Complete Design Review -Star testing some components
03/07	-Order the PCB -Teamwork evaluation - Talk with the machine shop	-Order the PCB -Teamwork evaluation - Make a CAD design of our product	-Order the PCB -Teamwork evaluation -Talk with the machine shop
03/14	Spring Break	Spring Break	Spring Break
03/21	-Start programming the microcontroller -Help to complete the PCB Board assembly	-Complete PCB Board assembly with soldering and mounting -Help program the microcontroller	-Complete PCB Board soldering and mounting - Look for possible problems assembling parts and order new ones.
			Continued on next page

Table 10 Continued from the previous page

03/28	-Write Individual Progress reports -Finish programming the microcontroller and debug it	-Write Individual Progress reports -Test hardware systems and fix possible problems -Help to finish the software	-Write individual Progress reports -Test hardware systems and fix possible problems
04/04	-Implement software code -Perform full system testing with software -Fix major software problems	-Perform full system testing with software -Fix major communications between software and hardware problems	-Perform full system testing with software -Fix major hardware problems
04/11	-Test and debug the full system -Mock Demo without TA	-Test and debug the full system -Mock Demo without TA -Final assembly	-Test and debug the full system -Mock Demo without TA
04/18	-Mock Demo - Implement TA pieces of advice and prepare the demonstration to the professor -Start writing the final paper	-Mock Demo - Implement TA pieces of advice and prepare the demonstration to the professor -Start writing the final paper	-Mock Demo - Implement TA pieces of advice and prepare the demonstration to the professor -Start writing the final paper
04/25	-Demonstration to professor -Send final paper to be corrected -Elaborate on the presentation	-Demonstration to professor -Send final paper to be corrected -Elaborate on the presentation	-Demonstration to professor -Send final paper to be corrected -Elaborate on the presentation
05/02	-Deliver the final presentation -Submit final paper	-Deliver the final presentation -Submit final paper	-Deliver the final presentation -Submit final paper

4 Discussion of Ethics and Safety

4.1 Ethical requirements

1. We pledge that we would not entertain any kind of plagiarism while making this project and adhere to any copyrights that we encounter while making this device. If we do use other resources, we will cite them properly and give credit to anyone who has a hand in making our device. Hence, we comply with parts of sections 7.8.I-1, 7.8.I-3, 7.8.I-4, and 7.5.I-5 of the IEEE Code of Ethics[2].
2. Our project does not breach any ethical guidelines and strives to help people get access to clean drinking water. We aim to help every person who cannot access clean drinking water due to any reason purify their drinking water using our device. Hence, we comply with section 7.8.II-7 of the IEEE Code of Ethics[2].
3. We pledge that we will accept any kind of feedback and criticism that would help us improve our device and make it safer for its users. This is because we understand that our device has the potential to impact many people. Hence, we comply with section 7.8.II-5 of the IEEE Code of Ethics[2].
4. We pledge that we would treat all persons involved in this project with respect, entertain no kind of harassment, and avoid injuring others by adhering to strict codes of safety. Hence, we comply with parts of sections 7.8.I-7, 7.8.I-8, and 7.5.I-9 of the IEEE Code of Ethics [2].
5. We also pledge that we would follow all labs rules and regulations while using the lab and will make sure that we do not damage any equipment in the lab.

4.2 Safety requirements

While no federal regulations exist for residential water treatment filters and purification systems, we plan to adhere to a strict code of safety conduct as our device does have the potential to harm humans.

1. We pledge that we would prioritize the safety of all people working in the project as well as the safety of the user. Our project uses UVC lights to disinfect the water. These lights are harmful to our skin as well as our eyes. Hence, they are a hazard to people’s health. We will make sure we test our device and confirm that there is no leak of UVC lights outside using a UV light sensor.

2. We pledge that we would make sure that we do not harm any person present in the lab.
3. We pledge that we will always be honest about the efficiency of our device and the extent to which it can purify water as safe drinking water is one of the most important things in the world as we believe that wrong information about devices that specialize in water purification can harm a lot of people.
4. We also pledge that we will make sure our product is safe for use by other people before we try to demonstrate it working to other people.

These guidelines apply to each of our team members as individuals as well as our project, and we aim to abide by and hold each other accountable to these guidelines as specified by 7.8.III-10[2].

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