SOLAR POWERED PORTABLE WATER FILTER

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Abstract

Our project aims to help people around the world purify their water cheaply and inexpensively. Our main target is people from underdeveloped countries who do not have access to clean drinking water. While our device did succeed in achieving basic functionality based on our designs, it is still some ways away from what we have envisioned. We aim to make it more automated so that we can limit human interaction as much as possible and make the overall project cheap for mass production.

Contents

1. Introduction

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. To put this in perspective, 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. In less developed countries, the problem is even greater as water is used directly from lakes or rivers, which tend to be contaminated with pollutants. In addition, it is common for these countries do not have regular access to electricity. Hence, the water disinfection techniques that they can use are also limited.

1.2 Solution

We proposed the creation of a portable water filtration system capable of removing most impurities, metals, and bacteria from water. It is a two-tank system. The first one filters the water and the second one uses UVC rays to disinfect the water. Our water purification system removes heavy metals and impurities using a prefilter and a LifeStraw water filter. The prefilter has a size of 20 microns and is used to remove large contaminants like mud. The LifeStraw filter has two parts - a microfilter with a size of 0.2 microns and a Carbon + Ion filter that removes heavy metals. 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 filters have reached the end of their lifetime and need to be replaced. The system will also automatically warn the user that they need to replace the microfilter or the Carbon + Ion filter through dedicated LEDs.

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 by filtering muddy water through our filter.
2. The LEDs must indicate if we should replace the micro filter or the Carbon + Ion filter. They should also indicate that the UV lights are in use.
3. Our system should be able to operate using only solar energy.

2 Design

2.1 Physical Design

Our project consists of two tanks connected by the filters. The reason for this design is that we need our project to be fully automatic, which means the user just needs to pour water and wait for the finish of the disinfection. Because the UV lights are power consuming, we designed that they should only light up when the filtering process is done. The way we achieved this goal is that we placed a water sensor at the bottom of the upper tank, so when all the water is being filtered and the water level drops below the sensor, it would catch this signal and the microcontroller would turn on the UV lights.

The whole system was powered by the solar panel, which we placed at the side of our project. It would cooperate with the components in the power subsystem to supply appropriate voltages to the whole circuit. The UV lights are placed at the bottom of the lower tank for maximum efficiency, and we covered the lower tank with aluminum foil to protect the user from harmful UV light.

The pre-filter on the top of our design is used to remove the large impurities in the water. The microfilter at the bottom of the upper tank is removing bacteria, parasites, and microplastics. The carbon + ion filter under the microfilter is removing heavy metals, chemical contaminants, and chlorine. After those three filters and the disinfection of the UV light, the water coming out from our project is safe for drinking.

Figure 1 shows a CAD design of what we would like the final physical design to look like for commercialization.

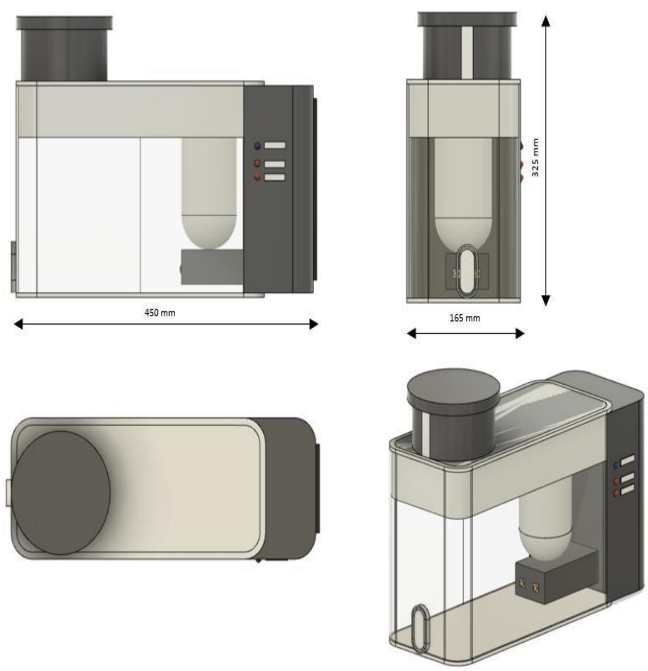

Figure 1 CAD Physical Design

2.2 Hardware Design

For the hardware design, we have divided the circuit into 5 distinct subsystems as shown in the schematic in Figure 2 below.

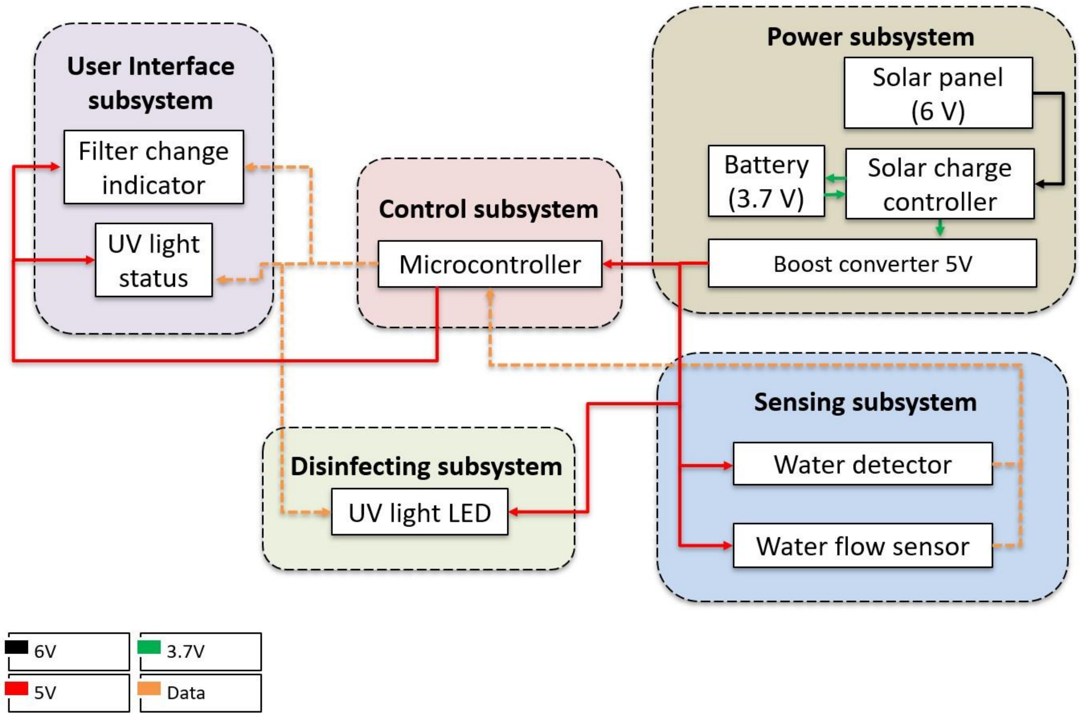

Figure 2 Subsystem Diagram

2.2.1 Power Subsystem

The power subsystem consists of the solar panel, the battery, the solar charge controller, and the boost converters to 5V and 7V in charge of generating the voltages required by the rest of the components. Figure 3 shows the schematic used for the power subsystem.

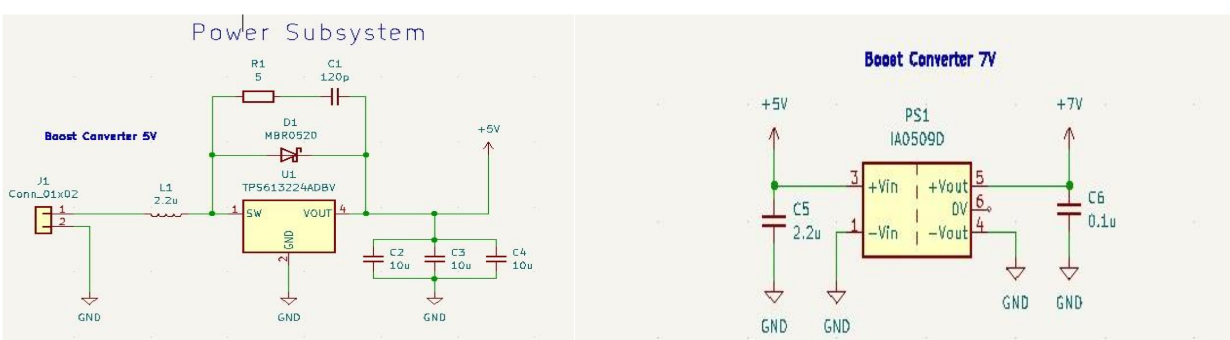

Figure 3 Power Subsystem Schematic

Firstly, we were choosing the solar panel to get the power supply of our whole system. We chose MPT15-150 as our initial design because it provides sufficient voltage and current suitable for powering our circuit. However, as the supplying voltage changes with the amount of solar energy received by the panel, we added a battery to make the supplying voltage for the circuit to be more stable. The new problem was that a normal battery cannot be charged and discharged at the same time. We finally found the solar charge controller bq24074 which can be used to connect the solar panel, battery, and the circuit, which can automatically stop the charging from the solar panel to the battery when the battery is working as a power source.

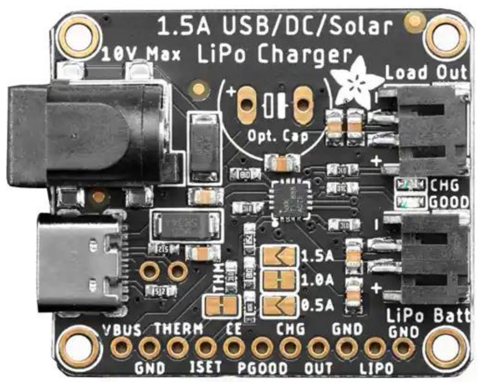

Figure 4 Solar Charge Controller

Based on the datasheet, a 3.7V/4.2V Lithium Ion or Lithium Polymer battery should be used and a 5-10V solar panel can be used aa s power source. The solar panel we used before was having a too large voltage supply. Therefore, we bought the recommended solar panel and battery corresponding to the solar charge controller. The solar panel is having 6V output voltage and the battery has an operating voltage of 3.7V, which are both perfect for the charge controller.

Then, the output of the solar charge controller is boosted to 5V using a boost converter because that is the voltage at which the two sensors and the microcontroller operate. We have also used the 5V output as the input for the boost converter to the 7V needed to power the ultraviolet lights.

The boost converter to 7V, we have placed it in series because we could not find any boost converter that would convert a voltage from 4.3V to 7V. In addition, in terms of efficiency, because the voltage difference is smaller, the efficiency improves.

2.2.2 Sensing Subsystem

The sensing subsystem is made up of two sensors chosen with delicate consideration to satisfy all of our requirements. Figure 5 shows the schematic used for the sensing subsystem.

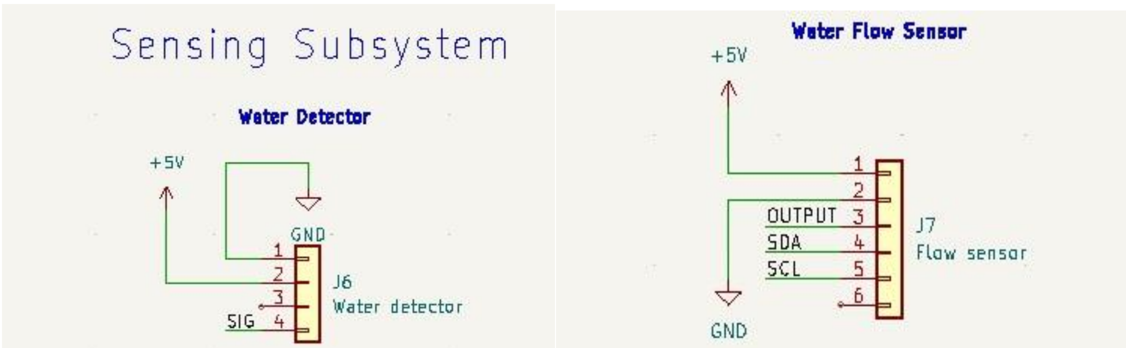

Figure 5 Sensing Subsystem Schematic

Water detector

We firstly chose a water leakage sensor that has two separated metal bars at the bottom. When the sensor is placed at the bottom of the upper tank, the two bars are about 1mm above the surface, so when the water exists in the upper tank, the two bars which were initially open are shorted, so it can send a signal about whether water exists or not.

Figure 6 Previous water detector

However, this type of sensor is comparatively expensive and large, so we decided to switch to another one. Our new water detector detects water through the metal traces it contains. When water is detected, the traces act as resistors and change the signal voltage to low. The more water it detects, the lower the output voltage the sensor will send.

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Figure 7 Cheaper and slimmer water detector

Challenges

This new sensor is supposed to be put vertically, so the metal bars on its surface are acting the same as the ones in the previous sensor. This sensor is priced at about 1/10 of the previous one, but there are also drawbacks. The first drawback is that because the metal bars are close to each other and connected by the green surface, when the water level drops below the sensor, sometimes a little amount of water drop would remain on the surface, which stops the sensor from working properly. This problem can be solved by covering the green surface with perfectly waterproof material. The second drawback is that unlike the previous sensor, which is completely waterproof, the connection ports on this cheaper sensor are not waterproof. This means that to avoid destroying it, the water level should not reach the connection ports. The amount of water being poured into the upper tank is restricted. This problem can be solved by adding a long plastic cover vertically outside of the port to make it waterproof.

Water Flow Sensor

The water flow sensor was supposed to be the core part of our design, which works for both the replacement of the microfilter and the carbon filter, but unfortunately, we broke it during the experiment. We firstly chose a cheap flow sensor which is 9.5$, as shown in the following figure.

Figure 8 Previous water flow sensor

The problem with this filter is that its minimum detecting flow rate is 1L/min, and through our physical design and experiment, the maximum water flow rate is 0.16L/min, which is much less than the 1L/min. We tried to figure out a way to avoid using the flow sensor, such as using a turbidity sensor to measure when to change the filters, but since the quality of the water coming out from the filters does not change whether the filters are clogged or not, we finally realized that we still need the flow rate sensor to achieve our goals. We tried our best to find a flow sensor that can test flow rates lower than 0.16L/min. Theoretically, based on the graph presented in figure 6, the new and much more expensive flow sensor can test flow rate starting from 0L/min

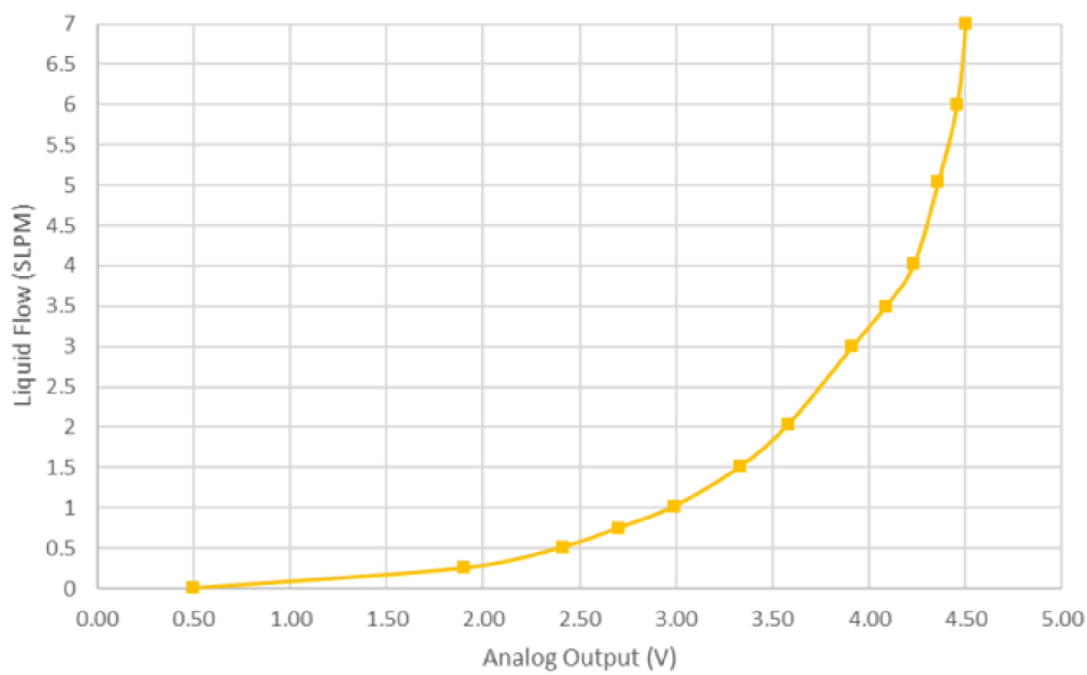

Figure 9 Flow rate vs analog output curve

At the beginning of the design, the water sensor is used for telling the system when the water has been all filtered and UV light can be turned on. The water flow sensor firstly measures the maximum flow rate in a long period to indicate the replacement of the microfilter (less than 0.08L/min) and record the consume of water being filtered to indicate the replacement of the carbon filter (over 40 gallons).

2.2.3 Control Subsystem

We used an ATMEGA48-20AU as our microcontroller. This microcontroller controls when different modules are turned on and off. It followed the finite state machine we designed and was able to properly use the stimuli from the sensors to transition between the different states.

Memory and timing

We chose this microcontroller as we can use its EEPROM to store flow rates. We can easily access the stored data in the microcontroller as well. This makes it easy for us to determine the change of filters and indicate that using LEDs. Also, our purification process depends a lot on the timing of our project as some parts of the finite state machine that controls our project depend heavily on the timing. For example, if our water filter takes too long to filter the water, we store that data in the microcontroller and use that data to determine if we need to change the filters. Also, the UV lights need to be switched on for 5 minutes for our purification to be the most efficient to kill germs. That is why this microcontroller works well for us as its internal clock can be recalibrated quite efficiently (mostly) with time in the real world.

Problems

Initially, we were using an ATMEGA 89LP828. This is because, as mentioned previously, our project needs a chip that can accurately sync its clock with the real world. This microcontroller has a stable internal clock that we could use for our project. It also had an EEPROM that we could use to store and access different data required by different parts of our project. However, this product cannot be coded into modern computers. It can only use Windows XP and Windows Vista. That is why we had to change our microcontroller to one that can fulfill similar functions but one that did not have a clock that was as stable as this one. We also had to change our PCB due to the same issue.

2.2.4 Disinfecting Subsystem

Because our entire system is powered by a small solar panel of not too much power, we had the impediment of choosing ultraviolet lights of type C that consumed a lot. So, we decided to use UVLeds as they consume less than 0.5W each. The other options were ultraviolet lamps which, although they provide more light and therefore have to be on for less time, consume about 20W.

Based on papers we have read we found that the minimum light power density we needed was 16,000 $\mu W*sec/cm^2$. Knowing that each LED provides a light output of 10mW and that the base of the second tank is $375cm^2$, we calculated the time it had to be on for a total of 10 minutes. To reduce the amount of time and because they do not consume much, we decided to place two LEDs evenly distributed under the second tank so that the new time was 5 minutes.

5 minutes is not a long period because with a single microfilter installed in the tank, the time needed for the filtering process is about 25 minutes, and when the carbon filter is added, the flow rate would even decrease, so 5 minutes is comparatively just a short extra waiting after the filter. With the current system, we can completely filter and disinfect one gallon of water in approximately 30 minutes.

2.2.5 User Interface Subsystem

We would have three 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 first LED will turn on indicating to the user that the UV light is on. Once it turns off, the water is ready to drink. The second LED should light up when the microfilter is worn out. Finally, the last 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.

For the design, we have used 3 panel LEDs connected in series to a 140 ohm resistor to limit the current flowing through them and prevent them from burning out or not working properly. Figure 10 below shows the circuit used.

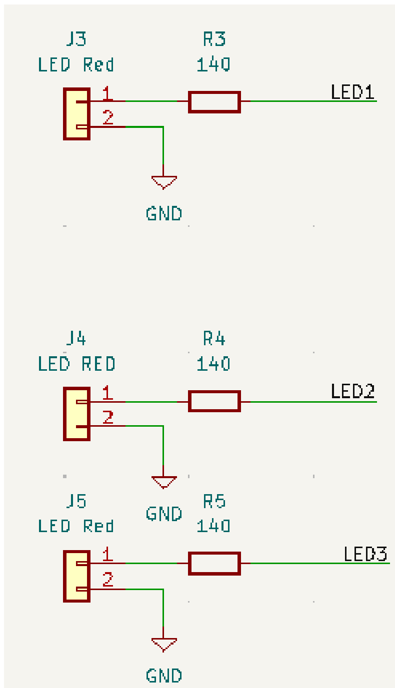

Figure 10 User Interface Schematic

3. Design Verification

3.1 Power Subsystem

Through the experiment, we found that the voltage output of the charge controller is 3.3V when the battery is low and 4.3V when the battery is fully charged. Typically, the value is 3.59V. The output voltage of the 5V boost converter is 4.83V, which works for both the two sensors and the microcontroller. Using the 4.83V as the input of the 7V boost converter, we get 7.2V as the output of it, and by supplying it to the UV lights connected in series with 20 ohms resistor, the voltage across the UV lights is 5.73V, which exactly matches our goal.

Figure 11 Typical output voltage of solar charge controller

Figure 12 Typical output voltage of 5V Boost Converter

Figure 13 Typical output voltage of 7V Boost Converter

3.2 Sensing Subsystem

The water detector works correctly since when the sensor traces do not detect water the output signal is around 4.56 (>3 = HIGH) and when it detects water the value, we get is between 1.1 V and 1.5 V (always <3 = LOW).

Figure 14 Output signal HIGH and LOW respectively

Theoretically, the new and much more expensive flow sensor can test flow rate starting from 0L/min. We have also proved it to be working by testing the voltage of the signal port, showing 0.534V for zero water flow and 1.395 V for 0.16L/min water flow.

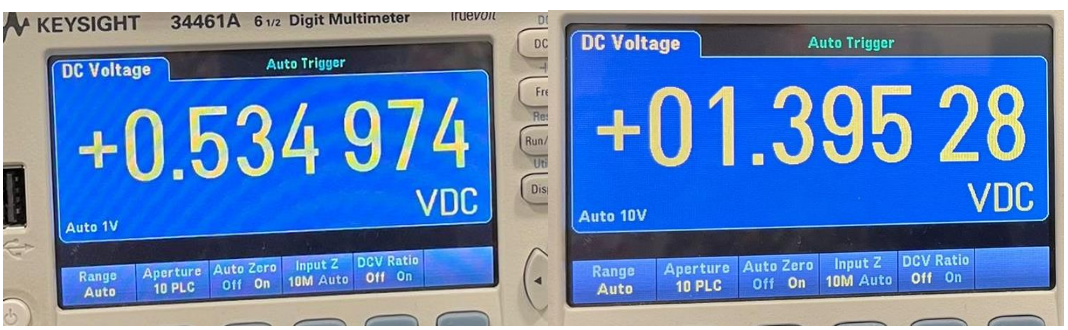

Figure 15 Analog Output without filtering and filtering respectively

Challenge

During one of the tests of the flow sensor, we forgot to limit the current supply by the power source, and we found the current going through the flow sensor was 220mA, which was 9 times its maximum rated current(25mA). After that, the flow sensor was no longer showing signal voltage change for any water flow, and we used a multimeter to find the short between its signal and ground ports.

Figure 16 Short between Signal and Ground

After it was broken, the resistance between the signal and ground ports of the water flow sensor is 1.5 ohms, which means that they are shorted.

However, even if the water flow sensor was broken, we tried to use whatever we had to keep the functionality of our design. We found that the water sensor could also be used to indirectly test the flow rate. For the original flow rate (0.16L/min), the time it took for the water level to drop from the top of the water sensor to the bottom of it was 25 minutes. Therefore, if the flow rate is equal to or less than half of the flow rate (0.08L/min), the time it takes for the water to maintain touching the sensor surface should be more than 50 minutes. We set the logic that as long as the water is maintained for 50 minutes during one filtering cycle, the indicator would light up to remind the user of replacing the filter. However, even the microfilter replacement problem could be solved in this way, the carbon filter replacement could not because the time for filtering cannot represent the volume of the water if the water flow is not constant. We would still try to make it functional after we receive a new flow sensor in the future.

3.3 Control Subsystem

To verify that our Control subsystem is working, we had to verify that our FSM was working properly to stimulus. For this we placed 5 additional LEDS that each lit up when the system was in that state. In this way it was easy to follow how the subsystem control was working properly. In addition, it was not necessary to turn on the ultraviolet lights to check the operation of the control, thus minimizing their exposure.

Our state machine presented in figure 17 has the following states:

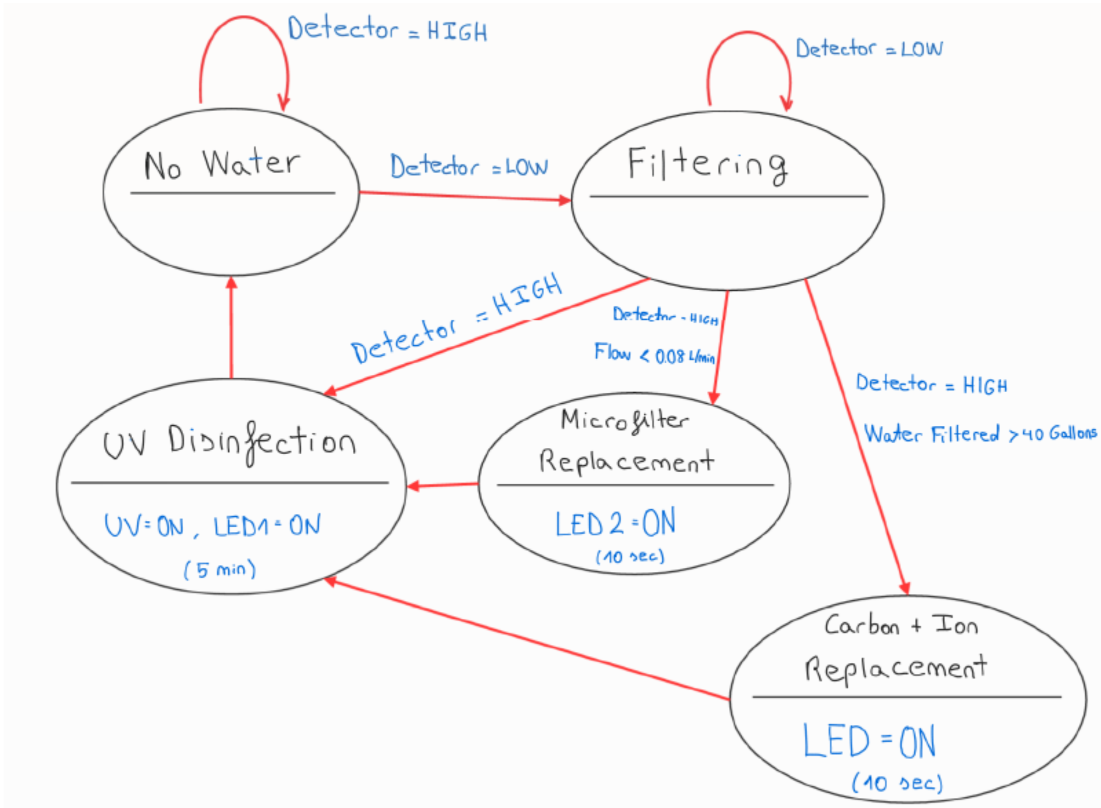

Figure 17 State Machine Diagram

0. <u>No Water:</u> This is the first state of our finite state machine. It is the base state. Whenever there is no water present in the tank, the system should go back to this state. However, when it detects the presence of water (low voltage from water sensor), it should transition to state 1 i.e., the filtering state.
1. <u>Filtering:</u> This is the state where the microcontroller stores the water flow data in its EEPROM. This is done so that it can determine when to change the Carbon + Ion filter. It also uses this data to determine when it needs to change the microfilter. If it detects that the filter is taking too long to filter water and that the flow rate is less than 50% of its average flow rate, then it transitions to the microfilter replacement state. If it detects that the filter has filtered more than 40 gallons of water, it transitions to the carbon + ion filter replacement state. Otherwise, after filtering is finished, it transitions to the UV disinfection state.
2. <u>Microfilter replacement:</u> This is the state that turns on the LED that shows that the microfilter needs to be replaced. After doing that, it transitions to the UV disinfection state.
3. <u>Carbon + Ion filter replacement:</u> This is the state that turns on the LED that shows that the carbon + ion filter needs to be replaced. After doing that, it transitions to the UV disinfection state.
4. <u>UV disinfection:</u> This is the state that turns on the LED that shows that the water is undergoing UV disinfection. After this disinfection has finished, it transitions to the filtering state.

3.3 Disinfecting Subsystem

To verify that our system is capable of eliminating 99.99% of the presence of microplastics, bacteria, heavy metals and vi,ruses in the water, it would be convenient to take contaminated samples and analyze them in a laboratory before and after they have been processed by our system. However, this system takes several weeks and is very expensive, so it is beyond the scope of the course. In addition, the handling of water containing viruses must be done with great care and being electrical and computer engineering, we do not have the necessary knowledge to do it safely.

As for the elimination of bacteria, heavy metals, and microplastics, we are using two conventional filters of the brand lifestraw in good condition. The manufacturer itself has carried out laboratory tests and guarantees that its filters can eliminate 99.99% of the presence of these contaminants.

For the elimination of viruses, knowing that the necessary power to eliminate the presence of viruses in the water is 16,000 µW*sec/cm2 and that we are turning on the LEDs for 5 minutes, it is demonstrated that we are applying sufficient power. However, for a check, we could use a safety factor of 2, and turn on the LEDs for 10 minutes to ensure that the viruses have been eliminated.

3.5 User Interface Subsystem

To check the correct functioning of the user interface we have verified that the LED1 always lights up at the same time as we turn on the ultraviolet light to warn the user that the water is being disinfected at that moment.

The microfilter has to be replaced when the flow decreases considerably. Our system takes approximately 25 minutes to filter one gallon of water so we have defined the replacement of the filter if the water detector detects water for a period longer than 50 minutes (twice as long as it should take). To verify the correct operation of the microfilter replacement because the time is so long, we have simulated the 50 minutes with 30 seconds.

The carbon + ion filter has to be replaced when the filter has filtered a total of 40 gallons of water cumulatively. For its simulation, we have also reduced the amount of water to the filtered water in a single-use (1 gallon) to be able to check the correct operation in a more efficient way.

4. Costs

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

4.1 Labor

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

$$Cost_{labor} = {}^{\$}/Hour * {}^{Hour}/Week * weeks * members * multiplier = \tag{1}$$

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

4.2 Parts

Table 1 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	R P400N501A	$1.48	1	$1.48
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	ATMEGA48P-20PU	$2.87	1	$2.87
Water Detector Sensor	Seed Studio 101020018	$3.2	1	$3.2

Continued on next page

Table 1 Continued from previous page

LED Panel Red	Dialight 5592101003F	$2.09	3	$6.27
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
Mosfets	SSM3K15AFU,LF	$0.25	2	$0.50
UV light	ELUC3535NUB-P7085Q15070100-S22Q	$7.08	2	$14.16
Coffe filter as a prefilter	10-12 permanent Coffe filter	$8.99	1	$8.99
			Total	$301.13

4.3 Machine Shop Cost

The 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 2 Other Costs for the Solar Portable Water Filter

PARTS	PRICE
Container	$100
Aluminum Film	$4
Labor	$400
Total	$504

4.4 Sum of Costs

The total sum of costs taking into account the cost of the parts, the labor cost, and other extra costs such as the machine shop gives a total of $45,822.28.

$$Cost_{\text{total}} = Cost_{labor} + Cost_{parts} + Cost_{others} = 45{,}000 + 301.13 + 504 = \\ = \$45{,}805.13 \quad (2)$$

5. Conclusion

5.1 Accomplishments

Of the three high-level requirements, we were able to meet two of our requirements fully and one of our requirements partially. We were able to demonstrate that our project could work on solar power entirely. We were also able to show that our filter purified the muddy water using the filter and the UV lights. However, our flow sensor got short, and we could not get a new one in time. That is why we could only show our microfilter sensor and not our carbon + ion filter sensor to be working.

5.2 Uncertainties

We were able to show most of our functionality on our project. However, we could not show our project with a PCB. Our circuit was on a breadboard. This is because we had to change our microcontroller midway through the project as we could not program it. That led to a lot of problems and the new PCB that we ordered got delayed so we did not have a working PCB for the presentation. We also could not show that our Carbon + Ion filter was working as shortly before the demo our flow sensor got short.

5.3 Ethical considerations

5.3.1 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 lab rules and regulations while using the lab and will make sure that we do not damage any equipment in the lab.

5.3.2 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 on 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].

5.4 Future work

We want to start working on our new PCB. It arrives shortly after this semester ends. We also want to buy another water flow sensor and replace our current water flow sensor. Once we get everything to work, we want to work on the following:

- Minimize the cost of manufacturing the physical product
- Create larger reservoirs, with larger solar panels to provide water for more people.

References

[1] World Health Organization. “Drinking-water.”, June 2019 [Online], available: https://www.who.int/news-room/fact-sheets/detail/drinking-water#:~:text=Contaminated%20water%20can%20transmit%20diseases,000%20diarrhoeal%20deaths%20each%20year

[2] IEEE Board of Directors. “IEEE Code of Ethics.” IEEE Code of Policies, Section 7 - Professional Activities (Part A - IEEE Policies), June 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed Sep. 16, 2021].

[3] Large 6V 3.5W Solar panel - 3.5 Watt Datasheet. [Online]. Available: Solar-Panel-Drawings/Voltaic Systems 3.5W 6V 113x210mm DRAWING CURRENT 2017 7 20.pdf at master · VoltaicEngineering/Solar-Panel-Drawings · GitHub

[4] USB, DC & Solar Lipoly Charger Datasheet [Online]. Available: usb-dc-and-solar-lipoly-charger.pdf (adafruit.com)

[5] Lithium Ion Polymer Battery - 3.7V 10050mAh (10 Ah) [Online]. Available: 规格书 (adafruit.com)

[6] DC DC CONVERTER 7V 2W Datasheet. [Online]. https://www.ti.com/general/docs/suppproductinfo.tsp?distId=10&gotoUrl=https%3A%2F%2Fwww.ti.com%2Flit%2Fgpn%2Fdcp020503+

[7] Switching Voltage Regulators Current Mode PWM/VFM Step-up DCDC Converter [Online]. Available: https://www.nisshinbo-microdevices.co.jp/en/pdf/datasheet/rp400x1-ea.pdf

[8] Liquid Flow Sensor Module Datasheet [Online]. Available: https://www.mouser.com/datasheet/2/698/REN_FS1025_DL_DST_20210701258148З.pdf

[9] Grove - Water Sensor [Online]. Available: https://www.mouser.com/datasheet/2/744/Seeed_101020018-1217524.pdf

[10] 8-bit Microcontrollers - MCU AVR 4K FLASH 256B EE 20MHZ TEMP GRN 1.8V Datasheet [Online]. Available: https://www.mouser.com/datasheet/2/268/ATmega48P_88P_168P_DS40002065A-2400474.pdf

[11] WATER FILTER DISPENSER [Online]. Available:
https://cdn.shopify.com/s/files/1/2631/0778/files/LS_Home_Dispenser_user_man ual_EN-FR-DE-ES.pdf?v=3444894861040912211

[1] EVERLIGHT UVC LED [Online]. Available:
https://www.digikey.com/en/products/detail/everlight-electronics-coltd/ELUC3535NUB-P7085Q15070100-S22Q/12177222

Appendix A Requirement and Verification Table

Table 2 Power Subsystem Requirements and Verifications

REQUIREMENTS	VERIFICATION	VERIFICATION STATUS (Yes/No)
1. Provide a voltage of 5.7 V +/- 0.5% from the battery to the UV lights. The UV lights should operate at 100 mA.	Measure the output voltage using a voltmeter to ensure it is within 5% of 5.7 V. Measure this subcircuit current using an ammeter to ensure it is 100 mA.	Yes
2. Provide a voltage of 5 V +/- 0.5% to all the parts of the device except the UV lights.	Measure the voltage of any subcircuit in operation using a voltmeter to ensure it is within 5% of 5 V.	Yes

Table 3 Control Subsystem Requirements and Verifications

REQUIREMENTS	VERIFICATION	VERIFICATION STATUS (Yes/No)
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.	Yes
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.	Yes
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.	Yes

Table 4 Sensing Subsystem Requirements and Verifications

REQUIREMENTS	VERIFICATION	VERIFICATION STATUS (Yes/No)
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 $I_s > 0$ to the microcontroller, then there is water present in the first tank. If there is no water present, $I_s = 0$. This can be verified using an ammeter in the circuit between the sensor and the microcontroller.	Yes
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 V_w 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.	Yes
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.	Yes
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.	No
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.	No
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 V_f is within 5% of 5 V, then it is working as planned.	Yes

Table 5 Disinfecting Subsystem Requirements and Verifications

REQUIREMENTS	VERIFICATION	VERIFICATION STATUS (Yes/No)
1. The UV lights should be turned on for about 5 minutes to kill the bacteria and viruses.	We can measure the time from when the UV lights LED switches on and closes to verify this.	Yes
2. The UV lights operate at 5.7V each. This is the best option for our design.	We measure the voltage provided to the subsystem. If V is within 5% of 5.7 V, then it is working as planned.	Yes
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.	No

Table 6 User Interface Subsystem Requirements and Verifications

REQUIREMENTS	VERIFICATION	VERIFICATION STATUS (YES / NO)
1. The LED1 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.	Yes
2. The LED2 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.	Yes
3. The LED3 should light up when the carbon + ion filter 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 carbon + ion 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.	Yes

Appendix B Schedule Followed

Table 7 Distribution of the tasks during the weeks

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.
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

Continued on next page

Table 7 Continued from previous page

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