Solar Powered Water Filtration System

Cecile MD. Bui, Jose Alejandro Gonzalez Nunez, Jose Gabriel Gonzalez Nuneze, Henok Brhane

Department of Electrical and Computer Engineering, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* — The purpose of this project is to make a difference in people's lives by providing a portable, easy to use solar powered water filtration system. The system is powered by a set of four 7.6 x 9.6 x 0.8 inch detachable solar panels that charge an 88Wh/2400mAH rechargeable battery. This battery in turn powers a water pump, UV filter and a PCB with multiple sensors that monitor the quality of the water and the operation of the system. Unfiltered water will be pumped and sent through a set of four filters that ensure the system complies with FDA and the EPA standards. The sensors allow the user to further monitor the quality of the water through the LCD screen and a smartphone application.**

***Index Terms* — PCB, pH sensor, solar panels, turbidity sensor, water filters, water flow sensor.**

I. Introduction

According to the World Health Organization (WHO), every year, millions of people die from water-related diseases[1]. That means somewhere around the world, every ten seconds, somebody dies. It is a global catastrophe because it not only affects adults, but it also affects children and newborn babies. Most of the families living in these conditions can barely afford to buy food and having access to safe water is very difficult and sometimes non-existent. Conceived and developed thoroughly so adults and children can easily use it, our water filtration system is lightweight and portable, and the user has the option to either remove or fold the solar panels. By using multiple sensors that we have in our apparatus, we also incorporated an application that allows any users with a smartphone to have access to the following data: the pH, turbidity, and the water flow. Whether or not the user has the ability to access to a smartphone, we included an LCD display that shows the sensors readings or an error message if any of the sensors goes out of a safe range or an alert shows up if the filtered water is not safe to drink. By doing so, the application has the ability to display how well it has been operated, how much water has been used and filtered, the longevity of the filters being used, and if a problem encounters such as a high or low pH. Because the user may not use the water filtration system regularly or may overuse it, it was crucial for us to include a microSD card module in order to keep track and store the data for a long period of time. After months of research and testing, the ultimate goal is to save as many lives as we can and to reduce the number of deaths associated with water related diseases that affects millions of people around the world.

II. SYSTEMS COMPONENTS

Our water filtration system is best demonstrated in terms of system components and includes everything from physical modules — whether bought or created — that are interconnected to build the final product. This segment provides a brief explanation to each of these components.

The two first components of our system are foldable solar panels and a battery. The set of four detachable 7.6 X 9.6 X 0.8 solar panels charge an 88Wh/2400mAH rechargeable battery, which in turn powers the electrical components in our system. First the battery powers a water pump that circulates water across four water filters which include a that consist of a sediment filter, a pre-carbon filter an ultra-filtration membrane, and a UV filter. This ensures that 99.99% of all water born bacteria and pathogens are destroyed. The UV filter is also powered by the battery. The battery also provides power to the microcontroller unit in a PCB. This microcontroller manages multiple sensors in the system as well as a LCD screen and a Bluetooth transmitter. Two of the sensors, the water flow sensors, are located after the water pump and after the last filter to measure the flow in those two places. The other two sensors, the pH and turbidity sensors, are used by the user to determine the quality of the filtered water. Lastly the microcontroller displays the data from all the sensors in the LCD display and transmits it simultaneously to a smartphone application. All these components and its connections are illustrated in Fig. 1.

A. Solar Panels

With all the different types of solar panels in the market, it is crucial to choose the right solar panels in terms of durability, size, efficiency and weight for the entire water filtration system. Different solar panels mean different materials and multiple uses. One important factor in the decision was to pick a specific type of solar panels that combine and save enough heat, and then from generated amount of heat, convert it into power, electricity. After doing research on the three different solar panels, the monocrystalline, polycrystalline, and the thin film solar

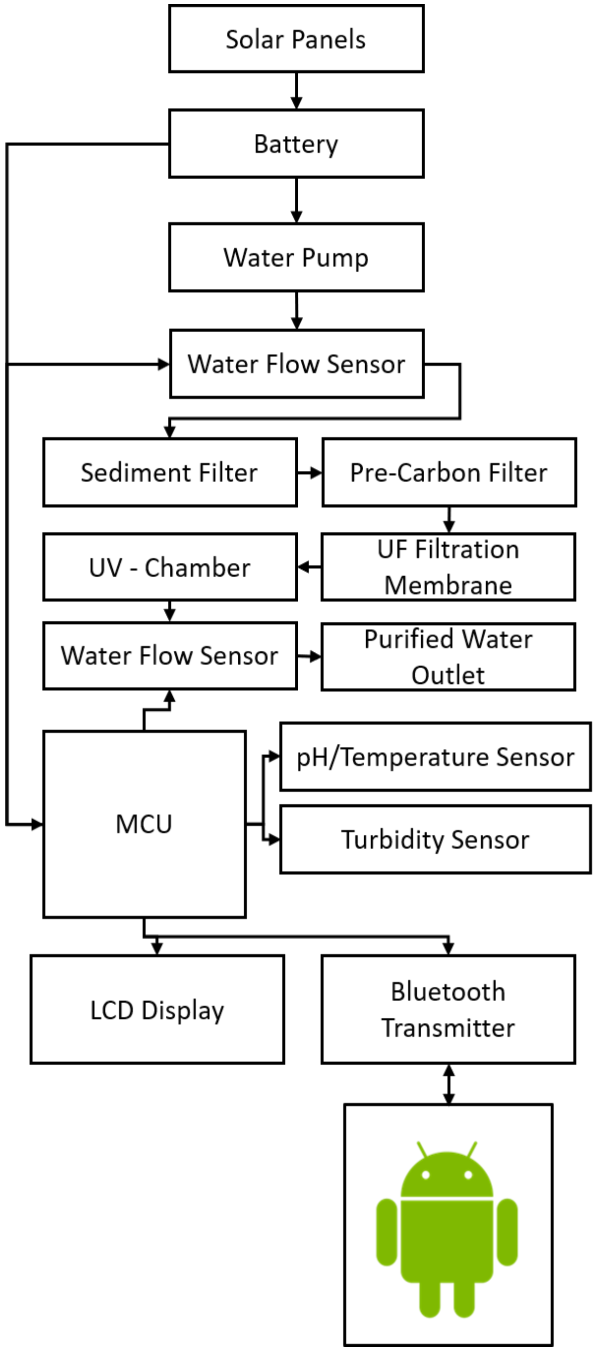


Fig. 1 Water Filtration System Block Diagram

panels, we decided to go with the monocrystalline solar panels, made from a single ingot of higher grade of silicon. They have the highest efficiency rate of 19% meaning that 19% of the sunlight absorbed by the solar panels is converted to electricity. They are also very portable with a weight of 1.7 lbs. for three foldable solar panels and are very durable with longevity of about twenty-five years. When taking into consideration multiple factors needed for the entire water filtration system to be a success, the other solar panels available in the market have a lower efficient rate (at most 16%) and have multiple factors from the size/weight to voltage/power requirements that did not work with our specific goals.

The monocrystalline solar panels we chose come with a USB port and are compatible with all USB powered devices including smartphones. It has an open circuit voltage of 20.0V, a peak voltage at 18V, peak current at 1.1A, a peak power at 19.8 Watts, and an output of 5V, 2A.

B. Battery

This project is powered by a solar rechargeable battery. since our portable water filtration system must be lightweight, easy to use, and maintain as well. Due to these constraints selecting a good rechargeable battery was one of the most important steps in our project. Our system was comprised of AC and DC utilizing components. After comparing multiple batteries and narrowing down to three, we decided to go with Omars 14.5V 88Wh/2400mAH 80W AC power bank with an AC output plug. The battery must provide enough power to our two water pumps, the PCB with all its components and the sensors as well as the UV filter part of the filtration chamber, which utilizes 110V AC power supply. Some of the reasons to why we decided to go with this battery include:

* High efficiency with minimal power loss during charge.
* Built in software to control over/under voltage.
* Short circuit, over current and overheat protection.
* Fast charging capabilities.

In addition to the above-mentioned qualities of the battery, throughout the design we adhered to the standards shown on Table I.

TABLE I
BATTERY STANDARDS

Standards	Description	Details
IEC 60950-1	Safety of Information Technology Equipment.	Intended to prevent injury and damage such as electric shock, fire, dangerous temperature.
IEC 61010-1	Safety of measurement, Control and Laboratory equipment	Requirements for measurement, control and laboratory equipment. It protects the electrical shock, fire and burns injury
IEC 60065	Safety of video, Audio, and similar electronic apparatus	Intended to protect against fire, electric shock and injury, electronic equipment and communication
UL 1310	Safety, Standards requirements for 2 class power units	Covers indoors, outdoors that use 2 power supplies and batteries. Uses for residential and industrial

The Battery comes with two 5V 2.1A USB output ports. One port will be used to power the microcontroller, and the other port will be used to power the water pump. Since the water pump requires 7-12V DV, a 5V to 9V step-up USB voltage converter was used.

C. PCB

The whole system except for the Ultra-Violet filter which takes 110V AC and the water pump which consumes 7-12V DC is implemented on a two-layered prototyping board. The rest of the components obtain their power through the PCB. The PCB itself is powered from the Omars 14.5V rechargeable power bank, which in turn is charged from the solar panels. The Arduino atmega328P microcontroller is used for this project. This microcontroller is rated for 5V and the LM317ADJ regulator is used to step down the 14.5V input voltage to 5V.

The desired 5V was obtained by selecting R_1 and R_2 values of 240 and 720 ohms respectively. The required 5V VCC is obtained by Eq. 1.

$$V_{OUT} = 1.25\,V\left(1+\frac{R2}{R1}\right)+I_{ADJ}(R_2) \tag{1}$$

The 5V VCC is also used to power the Turbidity, PH, temperature and two water flow sensors. The LM317ADJ comes with a heat sink to dissipate excess heat produced. Since our water filtration has over voltage protection, it will serve as additional safety and protection for the electronic components.

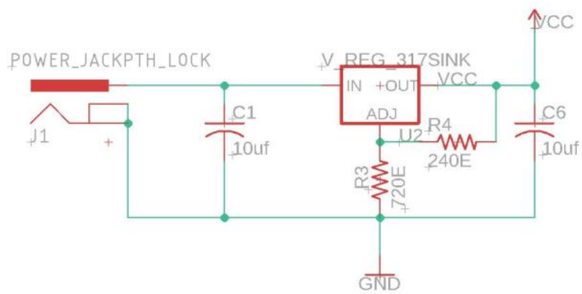


Fig 2. Input power and Regulator

C. Microcontroller

The microcontroller we chose for this project was the Atmega328. This is a very popular microcontroller chip produced by Atmel. It is an 8-bit microcontroller that has 32K of flash memory, 1K of EEPROM, and 2K of internal SRAM. It has a 23-pin size and uses I2C. UART, and SPI as its communication protocols. This microcontroller is programmable in C, has an extensive list of hardware libraries, and is compatible with the different sensors used in this project. Its large support community and simple layout allowed us to easily program and also test all the different peripherals.

D. Water Pump

The Amarine made water pump is a transfer water pump of 6-12 volts and has a current draw of 1.7 Amp. It generates 4.7 Liters per minute and has a size of 17cm (L) x10 cm (W) x 6.7cm (H). This water pump has a compact size and low voltage requirement that generates a considerable amount of water per minute without affecting the portability and performance of the device.

E. Filters

The water filters used for our device are probably the most important part of this project if low quality filters are used, it would affect both the outcome of the device and potentially the health of the users. For this reason, our group decided to use four different types of filters to ensure the safety of those who use the product and to get the best possible result.

The four types of filters used in our project are a sediment filter, a pre-carbon filter, an ultrafiltration membrane (UF), and an ultraviolet water purifier. These four filters will ensure that the filtered water is drinkable and safe for the user.

The GXRTDR general electric filter is the sediment filter used in our project and the first component in our filtration system to come in contact with the unfiltered water. This filter removes any suspended solid like mud, dirt, and debris from water.

The Purenex T-33 is our pre-carbon filter and the second component of the system. The purpose of this type of filter is to eliminate chlorine, organic chemicals, and odor active matters in the water. It also targets the removal of toxic components like lead, copper, chloroform, chemical residuals, herbicides, pesticides, and other volatile organic compounds.

For the third filter of the system. we chose LifeTech RO Ultrafiltration cartridge which removes cysts, spores, fungi, algae, and bacteria. This type of device ensures great quality water by removing more than 90% of pathogens found in contaminated water sources.

The Boeray Ultraviolet Light Water Purifier is the last part of the filtration system. Ultraviolet water filters are probably the most effective way of removing disease causing bacteria and viruses from any type of water resource. This type of device has been proven to remove and destroy 99.99% of harmful microorganisms without adding chemicals or changing water's taste or odor.

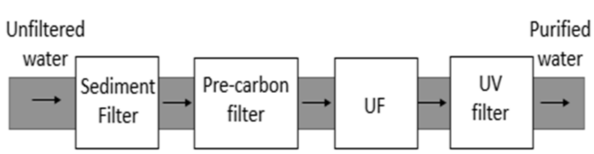


Fig. 3. Filtration system design.

F. Sensor

In our project we use multiple sensors that track the pH, turbidity and water flow in the system. For each of these sensors there were multiple aspects taken into consideration in the selection process of each sensor. Size is an important aspect that was taken into account for the parts used in the system, since one of the objectives of the project was to make it as small, lightweight, and portable as possible for easy use. Another important aspect considered when choosing the sensors is long term durability. This system is intended for use in developing nations and thus is required to operate under the assumption that it will have little maintenance over long periods of time. Since the system in this project is powered by a battery that is charged with solar panel, low power consumption was another key aspect in the selection of each sensor. Lastly, considering that the intended use for the filtration system is in developing countries with little access to drinking water, an important factor in the selection process was cost.

G.pH Sensor

The design for our project includes a sensor that monitors the pH of the filtered water. Measuring the pH of the water after being filtered is extremely important since this is one of the decisive factors on whether the water is safe for consumption or not. According to the Environmental Protection Agency (EPA), consuming water that is extremely acidic or alkaline is harmful. In order to be within EPA standards water for human consumption must have a pH value in the range of 6.5 to 8.5.

We decided to use in our device the most commonly available pH sensor that work by using a combination of electrodes that have both glass H+ ion sensitive electrodes and additional reference electrodes conveniently placed in one housing.

There are multiple models of pH sensors available for microcontrollers. The prices for these sensors vary greatly from around $29.50 on the lower end to approximately $72.6 on upper end models. However, there is little difference on their overall performance. The main difference between the models, apart from the price, is the necessary supply voltage and the lifespan of the probe. After comparing different models and brands, we decided to go with the GAOHOU Probe and value detector sensor module BNC which is completely waterproof and has one of the fastest response times. It is also sold at relatively low price compared to the other probes.

H. Turbidity Sensor

Monitoring the water quality is one of the most important features of our project. Being able to determine if the filtering system is working correctly and producing clean water for consumption is essential. Along with the pH sensor, our design incorporates a turbidity sensor to determine the quality of the water. This sensor detects the turbidity or opaqueness of the water by measuring the number of solid particles in the water.

The different models of turbidity sensor available for purchase offer similar characteristics and prices. The prices vary from $7.50 to $9.90. Their main difference lies on their operating and storing temperature ranges. After comparing different models and manufacturers, we selected the DFRobot Gravity Analog 0189 Turbidity Sensor which has a 5V operating voltage, 40mA maximum operating current and operating temperatures of 5°C – 90°C which all work perfectly for our system and its intended use.

I. Water Flow Sensors

The filtering system in this project consists of a water pump that drives water through different types of filters. Each of these filters has a lifespan that depends on the amount of water that is filtered through them. By including two water flow sensors in the system, we can use the information collected from them to detect any leaks and obstructions in the system by determining where the water flow has been reduced.

For this project, we compared seven different models of water flows sensor. After evaluating the different models of water flow sensors, we decided to use the YF-B3 model. This model has the correct size for our system and works in the appropriate water flow and pressure ranges. Its material also makes it extremely durable thus requiring less maintenance. The prices for this model are also on the lower end compared to the other models.

J. Wireless Technology

Having a connection between the water filtration system and the user's phone is an essential part of this project. In order to exchange data between both of these devices, remote connectivity technology is needed.

For our wireless technology, we decided to go with a Bluetooth module that will allow the users to connect their mobile devices without the need of an internet connection.

The HC-06 Bluetooth modules was the best option for our project this is the most popular module used for Bluetooth connection, once it is paired to a master Bluetooth device such as PC, smart phones and tablet, its operation becomes transparent to the user. It has an input voltage of 3.6V – 6V and its unpaired current is about 30mA. Its range is around 10 meters, with a band frequency of 24GHz, and includes a LED light that indicates the connection status.

IV. SOFTWARE DETAIL

A. Application Software

Even though our project can be used without any additional devices, and with all the information collected by the different sensor available is displayed in the LCD screen, we decided to create an app that gives additional information, tips, and safety measures when using the filtration device.

The application that we created relies on the Bluetooth module previously described in part II. The Bluetooth module will send all the information obtained by the sensors and the mobile app will display them immediately as shown on Fig. 4.

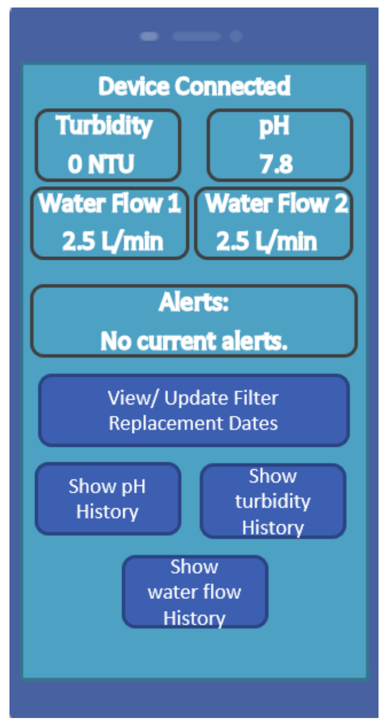


Fig. 4 Mobile App Screenshot 1

Additional information can also be obtained by selecting any of the displayed values, and different notifications will be received if any of the values obtained by the sensors are out of their acceptable levels as shown on Fig. 5.

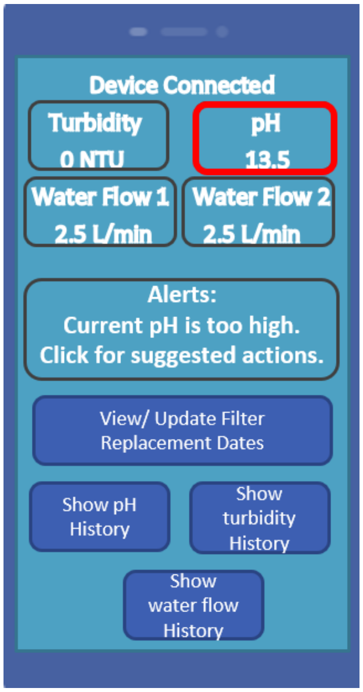


Fig. 5 Mobile App Screenshot 2

By selecting the alert in red displayed on Fig. 5 the app will give the user step by step instructions in order to resolve the issue as shown in Fig. 6.

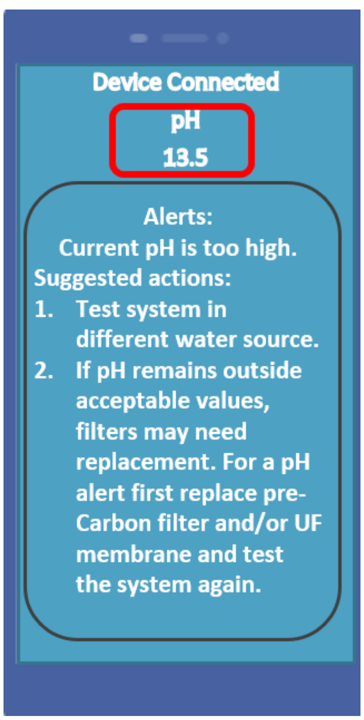


Fig. 6 Mobile App Screenshot 3

Another additional featured of the app will be the option to display a graph of the changes on the values of a specific measure. The options of displaying graphs for the history of pH, turbidity, and water flow will be available for the user and will indicate if any drastic change has occurred on the water values as seen on Fig. 7.

Fig. 7 Mobile App Screenshot 4

The last feature of the app will be the option to see when a certain filter needs to be replaced and to also update the calendar when this has already been done.

The application will ensure that the user is aware of the acceptable level of the values received by the sensor before drinking the filtered water. It will also help the user know when the filters need to be replaced promoting the safety of the user every time the devise is operated.

B. Microcontroller Software

The software that runs in the microcontroller has multiple functions to help the user during the utilization of our system.

The first function of the software is to read and analyze the data gathered by each of the sensors employed in the system. The sensors used in our project are intended to detect the status of the filtered water as well as the status of the system itself. The data from the pH and turbidity sensor are analyzed by the software to determine if the filtered water is safe from consumption. The water flow sensors data are analyzed to determine if there is problem in the system. The water flow is also used to verify if the system is being operated in the safe range required for the filters correct functionality.

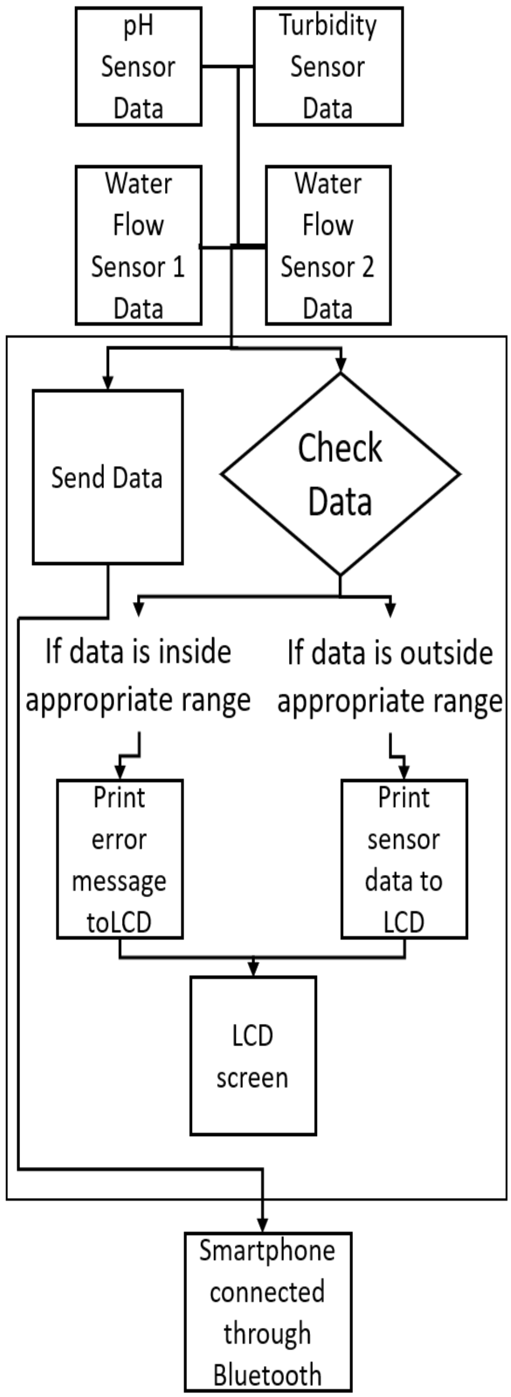


Fig. 8 Microcontroller Software Diagram

The data from some of the sensors are analog so the microcontroller software also converts this data from analog to digital so it can be properly analyzed. To make sure that the readings are accurate, the software collects multiple samples from each sensor. Each sample is collected after a small delay from the previous one. The average of these samples is what is used by the software for its calculations.

The software then has the function of sending the pH, turbidity and water flow data to the LCD display or to alert the user in case something is not working properly or if the data is outside a certain range. If everything in the system is working correctly and the filtered water is safe for consumption, the software will then show on the LCD display the current values for pH and turbidity of the filtered water, as well as the water flow data from the sensors. This allows users to know there are no potential issues and that they can safely drink the filtered water. However, if the pH or turbidity is outside a safe range, the software will show a message on LCD display to alert the user. In this case the users are informed that the filters may need to be replaced or that the system was unable to make the water safe for drinking. If the water flow goes down the software will the show a message informing the user that the unfiltered water in the container might be running out, or that the power from the power source to the water pump is decreasing. If the water flow goes above or below a determined range, the software displays a message alerting the user to turn the system off to avoid damage to the filters or water pump.

Finally, the microcontroller software has the function of storing the collected data and sending it through the Bluetooth transmitter whenever a device is connected.

V. PCB DESIGN

The PCB is the one in charge of collecting, processing, and managing all the data received from the sensors, as well as controlling the Bluetooth module and the water pump. The input voltage of the PCB will be controlled by a voltage regulator and the microcontroller will be on only when an external switch located in the battery is activated.

The final design for our PCB with all its components is shown on Fig. 9.

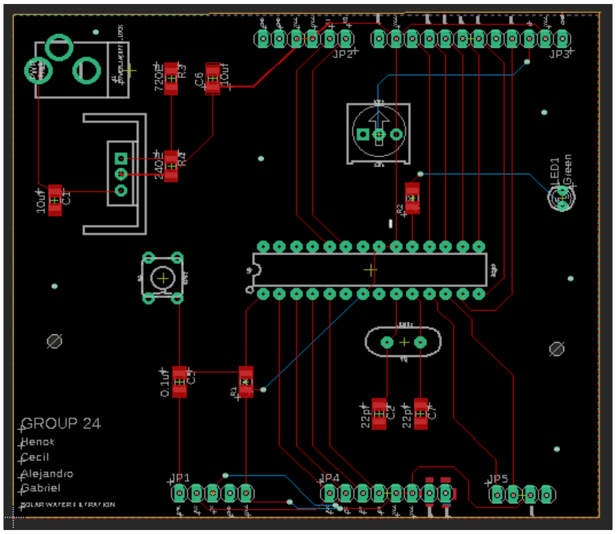


Fig. 9 PCB Board Design

VII. Conclusion

During these past two semesters, we had the opportunity to apply the knowledge we have gained in our engineering classes. It was rewarding for us to work together, setting weekly meetings, and assigning to everyone tasks to complete so we could meet the deadlines. We also had setbacks but that did not stop us from helping each other with the best of our abilities and also to learn from each other. It was an amazing experience being able to start with an idea, gather all the parts together to build a project that not only is the result of our hard work and dedication, but also to make a difference in somebody's life, and saving thousands if not millions of people around the world.

Acknowledgement

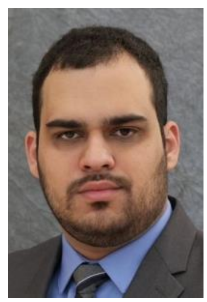
During these past few months, the entire group gratefully appreciates the time, assistance, and help of the following professors: Dr. Samuel Richie and Dr. Lei Wei. We sincerely would like to thank you for guiding us along and for giving us valuable information to succeed in the accomplishment of our Senior Design project.

References

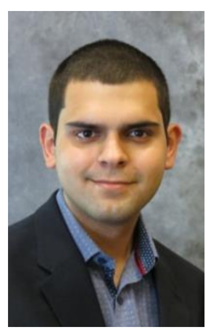
[1] World Health Organization (WHO)/ Water Supply and Sanitation Collaborative Council and Operation/Maintenance Network. "*Tools for assessing the operation and maintenance status of water supply and sanitation in developing countries.*" Geneva, WHO, 2000. (Document WHO/SDDE/WSH/00.3).

Cecile MD. Bui is a senior at the University of Central Florida. She will graduate in May 2020 with her degree in Computer Engineering. She is a member of Phi Theta Kappa Honor Society, as well as a member of the National Society of Leadership and Success and has an interest in AI and machine learning.

Henok Brhane is a senior at the University of Central Florida and will receive his Bachelor of Science in Electrical Engineering in May 2020. Currently he is interning with the Florida Municipal Power Agency (FMPA). He is interested in power delivery and sustainable Energy.



Jose Alejandro Gonzalez Nunez is a senior at the University of Central Florida and will receive his Bachelor of Science in Computer Engineering in May 2020. He hopes to work as a Software Developer for a big company such Microsoft, Sony, Amazon, etc.



Jose Gabriel Gonzalez Nunez is a senior at the University of Central Florida and will receive his Bachelor of Science in Computer Engineering in May 2020. He hopes to pursue a career in the area of Cyber Security working for a company such as Amazon or Google.