ECE 445: Project Proposal
Automatic Pool Monitor and Regulator

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February 8, 2024

1. Introduction

1.1 Problem:

Every public or residential pool must be monitored for appropriate water quality to be safe for people to use it. To verify the pool water quality, chemical tests must be taken for several factors such as temperature, pH, and chlorine levels. These checks are very important to maintaining a healthy swimming environment for everyone who uses it. According to the CDC, maintaining the water quality of a pool by using chlorine concentration and pH "will help prevent the spread of germs that cause swimming-related illnesses" [4]. Therefore, having a system to do this efficiently will protect pool users.

Currently, a lot of these tests are done by lifeguards in public pools and they require lifeguard attention away from the pool and even sometimes require the pool to be shut down if the levels of the chemicals are too low or too high. Some products on the market help with this issue already, however, they are expensive or are used to test the water quality of the pool rather than automatically adjust the quality to the necessary standard. This new product will automatically adjust the pool to the appropriate levels for each chemical.

1.2 Solution:

Having consistent water quality throughout the day is very important, especially as people continue to use the pool throughout the day. Most products will alert users when the pool quality is not up to standard, but not dispense the product automatically. This product will automatically dispense the appropriate amount of chlorine to the pool and adjust the pH to maintain the water quality of the pool. The user will also be notified when the temperature is not in the correct temperature range, or the chemical dispensers are empty. The user will only be responsible for refilling the dispensers occasionally; the process of testing and mixing chemicals into the pool will be automated.

The product functions by collecting and analyzing the pool water to determine if it is at the appropriate levels, and then it will dispense the necessary chemicals into the pool to help it meet standards. There are three different sensors: temperature sensor, pH sensor, and chlorine sensor. The product will have a storage of chlorine powder, an acidic compound, and a basic compound that it can dispense into the pool water when necessary. When the pH levels are not up to standards, the product can dispense sodium bisulfate (acidic) or sodium bicarbonate (alkaline basic). When the chemical is notified to be dispensed into the pool, a stepper motor will turn for a specified amount of time to release the calculated amount of the chemical required for the pool; this is determined by the number of rotations x weight in each rotation. There would also be a sensor that notifies the user when each compartment is empty.

1.3 Visual Aid:

There are two separate entities: the dispenser and the sensors. The sensors (waterproof) will make direct contact with the top of the water and the wires connected to the PCB will be protected by a waterproof case. The case will be located slightly outside the pool. On the other side, the dispensers will be located on the ledge of the pool to add the necessary chemicals to the water, and the same case will be slightly further out for the dispenser's wiring and PCB.

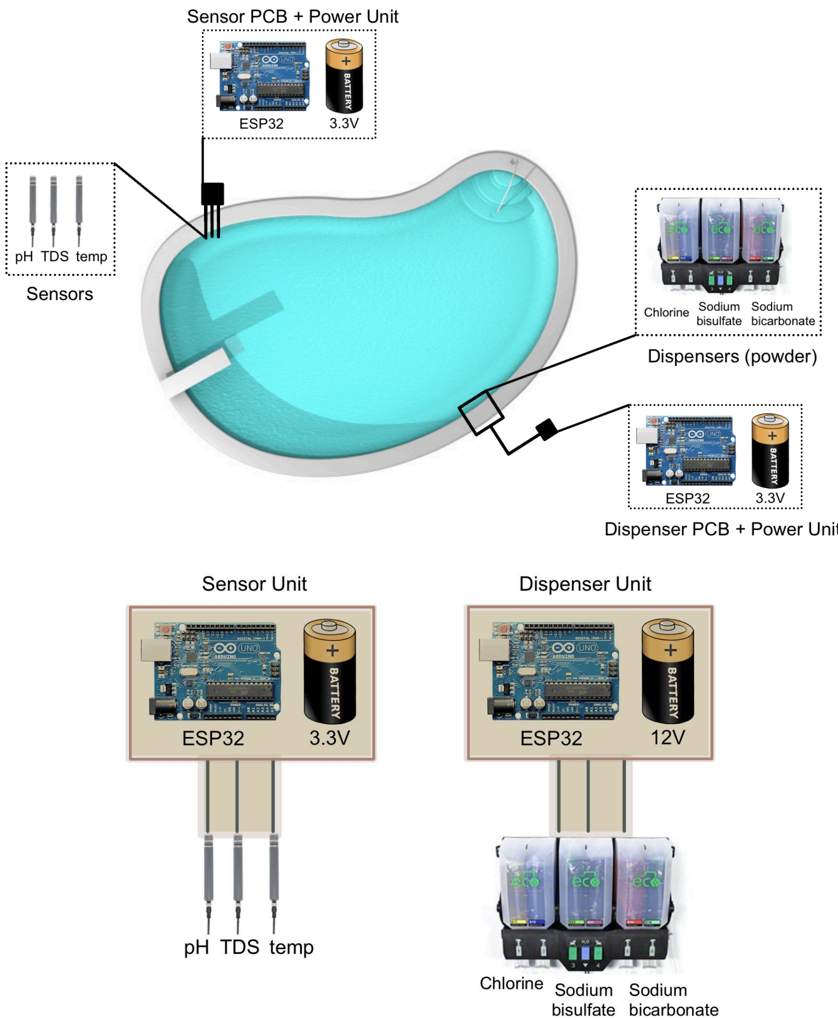

Figure 1: Visual Aid

1.4 High-level Requirements List:

For successful operations, our project must accomplish the following:

1. The pool sensors must be able to accurately measure water quality and quantify values for microcontroller calculations and user readability. Must be able to output analog readings for temperature, pH, and total dissolved solids level (TDS). The pool sensors

must accurately measure the water quality, with temperature between 78-82 degrees, pH between 7.2 and 7.8, and TDS levels between 0-1000 ppm. The standard deviation for temperature should be within 2 degrees, pH should be within 0.1, and TDS levels should be within 200 ppm.

2. The microcontroller must be able to calculate if readings are in acceptable range. If they are out of range, the microcontroller must be able to correctly perform the action to notify or rectify pool elements. The controller should display pool temperature, pH, and TDS levels on the LED displays. For pH-controlling compounds, the microcontroller should send signals to the dispenser unit to release a quantifiable amount of necessary chemicals into the pool. For TDS levels, the microcontroller should send a signal to the dispenser unit to release chlorine similar to pH chemicals. Still, if TDS levels do not change from prior measurements, an external alert should be sent to the user.
3. The dispenser unit should be able to release specific amounts of chemicals using motors according to microcontroller instructions. The amount released should be quantifiable, with values listed in requirement 1.

2. Design

2.1 Block Diagram:

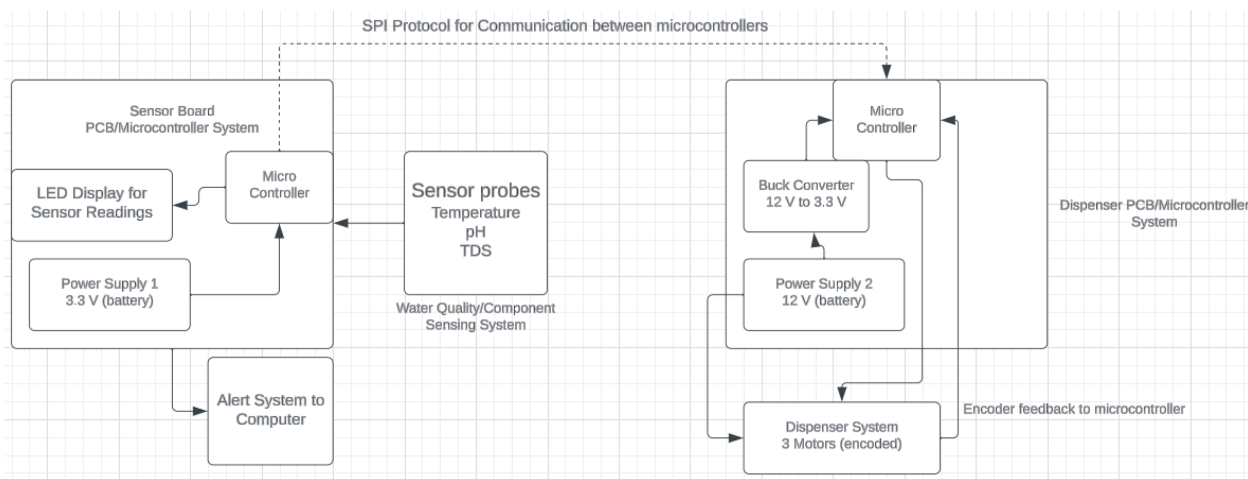

Figure 2: Project Block Diagram

The Sensor PCB system acquires signals from the sensor probes. It calculates if there need to be signals sent to the dispenser PCB system for chemical balancing, or to an external alert communication to alert the user of out-of-range measurements. It should also display sensor readings to the LED displays. The Dispenser PCB system should be able to receive signals from the sensor PCB, and control stepper motors to dispense a set amount of chemicals.

2.2 Subsystem Overview:

Water Quality/Component Sensing:

The first subsystem will involve using a pH sensor, a temperature sensor, and a TDS sensor to gather data about water quality. The sensor data will be sent to the microcontroller, which does the closed-loop control system.

- pH Sensor
- Temperature sensor
- TDS sensor

Sensor PCB:

The second subsystem contains a microcontroller, LED displays, and a power supply. It will determine what part of the pool needs to be changed and what part is in the acceptable values. If the temperature data is too high or too low, then the microcontroller on the sensor PCB will send out an alert to the user about the temperature differential. Suppose the pH or TDS level is outside acceptable zones. In that case, it will calculate the volume of chemicals needed to be added to a specified pool size to revert these factors into an acceptable range and send a wireless signal to the microcontroller on the dispenser PCB.

- Microcontroller: ESP32 (supports Bluetooth and WiFi for wireless alerts)

Dispenser PCB/Dispenser Unit:

This subsystem contains a microcontroller and power system and will connect with the dispenser subsystem. The microcontroller's main job is to receive wireless signals from the sensor PCB's microcontroller and interpret the data to control motors in the dispenser system. The dispenser will be stationed next to the water and will have three compartments for 3 different chemicals: an acidic compound such as sodium bisulfate, an alkaline basic compound such as sodium bicarbonate, and chlorine powder. These compartments will sit above a motor each, which will turn and let a set amount of compounds through with each rotation. The total amount will be the number of rotations x weight in each rotation.

- Motors: 3 stepper motors for each compartment to accurately dispense compounds

Power

The project will have two power subunits on each PCB board to power the microcontrollers and motors for the dispenser PCB. The power unit on the sensor PCB will be a 3.3 V battery, as it will only need to power the microcontroller. The power system on the dispenser board will be a 12 V battery, as it needs to power 12 V motors and the microcontroller as well. It will need a buck converter to step down the 12 V battery to 3.3 V for the microcontroller.

2.3 Subsystem Requirements:

Water Quality/Component Sensing

Requirements	Verification
The subsystem must be able to acquire sensor data from all sensors and transmit it to the microcontroller.	Verify that different values are being collected when the water environment changes. Accuracy will be determined by the sensor PCB system.

Sensor PCB

Requirements	Verification
Must be able to receive and convert analog data from the sensors into the right units for temperature (F), pH (unit), and TDS (ppm) based on the respective datasheets for the sensors.	We can print values to a screen or the display to verify if the data is correct or within range. Also, acquire multiple readings of the same environment to see if the standard deviation in requirements is within a valid range.
Must be able to determine if there are any readings out of bounds. Maintain temperature between 78-82 F, pH between 7.2-7.8, and TDS below 1000 ppm.	We can artificially change the environment of the sensors to produce values that are out of range. We can print if values are out of range, or light an LED if any values are out of range.
Must be able to send signals to the dispenser subsystem or computer according to calculations.	Validate with oscilloscope readings, and determine if MOSI data is the one intended.

Dispenser PCB/Dispenser Unit

Requirements	Verification
Must be able to receive signals from the microcontroller.	Validate if the data sent from microcontroller Tx is the same as the data received by the dispenser microcontroller. Use an oscilloscope to validate the MISO line
Must be able to move motors to dispense chemicals at the correct amount	Use a weight to determine if the correct grams of powdered chemical are released from the dispenser.

The motor must be able to spin 360 degrees ± 5 degrees to maintain consistent performance for repeated actions.	Spin the motor for multiple rotations and see if motor positioning is significantly off or not. Verify this with a real load from the dispenser with powder on top of the shaft/disk.

Power

Requirements	Verification
Must supply 12±0.5V of power to the dispenser unit	Use a multimeter across the ground and power supply to measure the voltage
Must supply 3.3±0.3V of power to the microcontrollers	Use a multimeter across the ground and a power supply to measure the voltage. Include test points on the board to validate trace voltages.

2.4 Tolerance Analysis:

One of the most challenging aspects is making sure that the microcontroller and motors are receiving the rated power and voltage. We could potentially separate the power supply for both aspects, but doing so would increase the external power system complexity. Instead, we opted to step down the 12V voltage for motors to 3.3V for the microcontroller. However, this also poses challenges, since if we use an unregulated or non-isolated power supply, changing the load from the motor might fluctuate power and voltage to the microcontroller which can shut off or overpower it. To combat this, we should use a voltage step-down regulator instead of just a buck converter so that the voltage to the microcontroller is steady. If this does not work, then adding a capacitor between voltage and ground by the microcontroller should be enough to balance voltage ripples.

3 Ethics and Safety

While our project provides several advantages to the maintenance of a pool it is important to address some of the ethical and safety questions. [2,3]The main safety concerns center around improper chemical handling, potential excess chemicals, accessibility of chemicals, and cybersecurity vulnerabilities. Leaks, spills, malfunctions, or calibration errors could expose users, pets, and the environment to harmful chemicals or create dangerous pH imbalances. Easy access to these chemicals poses additional risks. There can be a discussion about safety issues with dispensing chemicals into the pool where people are swimming. If there is a technical malfunction and too many chemicals are put into the pool, it could be harmful [2]. Usage of while people are in the pool may have some security risk. Usage of expired chemicals is also something that may need to be considered. Some safety measures to counteract this are to dispense chemicals evenly across multiple locations in the pool and have the dispenser directly inaccessible to other people.

Ethically, transparency about chemicals used, potential risks, and safety measures is crucial. The environmental impact of the chemicals and their potential discharge raises sustainability concerns. Additionally, the cost of such devices might create an access barrier, furthering existing inequalities. Data privacy becomes an issue if the device collects usage or chemical-level data.

There are also safety concerns about using electricity around water, especially around pools where water is dynamic and can splash around. To combat this concern, we should protect all circuitry with water-resistant casing and make sure there are no exposed wires or circuits to the environment. We can also practice IEEE's powering and grounding electronics [1]. Any moving parts associated with the motors should also be encased to prevent injury.

Beyond these concerns, the device's reliability, maintenance needs, and user training are vital. Fail-safe mechanisms and regular maintenance are essential for safe operation. Pool owners need proper training on chemical handling, potential risks, and emergency procedures. Finally, adherence to relevant safety and environmental regulations is critical.

4 References

[1] CDC. "Water Treatment and Testing." *Centers for Disease Control and Prevention*, U.S. Department of Health and Human Services, 2 Apr. 2022, www.cdc.gov/healthywater/swimming/residential/disinfection-testing.html#:~:text=As%20a%20residential%20pool%20or,friends%20from%20swimming%2Drelated%20illnesses.

[2] "Safety Data Sheet Sodium Bicarbonate," Drill Chem, https://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/IndustryResources/InformationalResources/HDD_Saftey_Data_Sheets/Sodium_Bicarbonate_SDS.pdf (accessed Feb. 20, 2024).

[3] "Sodium bisulfate," Safety Data Sheet, https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-s/S25535A.pdf (accessed Feb. 20, 2024).

[4] "IEEE code of Ethics," IEEE Code of Ethics, https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Feb. 20, 2024).