

# Automated Pearl Farming

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**Abstract**—Pearl farming plays a crucial position in aquaculture due to its high financial cost, but conventional techniques rely heavily on manual tracking and preservation, main to inefficiency and inconsistencies. The cause of this project is to increase an automated pearl farming machine that minimizes human intervention whilst making sure greatest growth situations for oysters. The proposed technique employs an ESP32 microcontroller included with numerous sensors to continuously display key water exceptional parameters including temperature, pH, and turbidity. Actuators which include an automatic feeder, water pump, and motor gadget are managed based totally on sensor statistics to maintain appropriate environmental situations. Real-time information acquisition and automated manage enhance precision and reliability in farm management. The results show advanced tracking accuracy, reduced exertions requirements, and steady oyster fitness. In end, this embedded automation machine notably enhances production performance and pearl satisfactory whilst imparting a sustainable and cost-powerful solution for cutting-edge pearl farming. Furthermore, the combination of IoT connectivity on this gadget allows faraway supervision and facts logging, which allows farmers music long-time period environmental styles and make informed decisions for destiny cultivation cycles. The computerized alerts and manipulate mechanisms ensure that sudden fluctuations in water best are addressed without delay, preventing ability damage to the oysters. This shrewd method no longer best will increase operational performance but additionally helps sustainable useful resource utilization by way of minimizing wastage of feed and immoderate water exchange. Overall, the gadget promotes a extra stable cultivation surroundings, improves pearl yield consistency, and offers a technologically advanced framework that may be scaled and adapted to numerous aquaculture settings.

## I. INTRODUCTION

Pearl farming, also called pearl culture, is a specialized form of aquaculture that has emerged as a key

component of the world money machine owing to the high commercial and aesthetic value of pearls. Natural pearls are quite scarce, and therefore, cultured pearl farming is a viable activity for supporting human livelihoods in coastal areas as well as meeting international demand for pearls. The key factor in the success of pearl farming is ensuring favorable aquatic conditions for oyster culture, as factors like water temperature, pH level, and levels of oxygen and turbidity in water contribute significantly to the interest of oyster metabolism, shell formation, and production of luster in pearls. Even minor variations in these factors have a negative impact on the quality of pearls. Traditionally, pearl farming has trusted guide practices for responsibilities consisting of monitoring water best, feeding, and cleansing oyster habitats. While those conventional strategies were used for many years, they present numerous drawbacks. Manual measurement of environmental parameters is frequently time-eating, exertions-intensive, and inconsistent, especially in massive-scale operations. Human blunders, rare tracking, and not on time corrective actions can result in suboptimal increase situations, expanded mortality fees, and in the long run, decreased productiveness. Furthermore, guide manipulate does now not allow for non-stop facts collection, making it hard to analyze long-time period environmental trends or implement predictive renovation techniques.

To overcome these disadvantages, automation through embedded systems can provide a modern, efficient, and intelligent solution. Embedded systems are dedicated electronic computing systems designed to perform a set of functions in a reliable and efficient manner with low power consumption. With the integration of sensors and actuators with a microcontroller, it can provide the facility of monitoring and regulating environmental factors critical for pearl farming in real time. This will ensure

that the water quality factors are maintained at optimum levels while reducing the need for human intervention. The project proposes an ESP32-based automation system for the intelligent monitoring and control of the environment in pearl farming. ESP32 is a low-cost, Wi-Fi and Bluetooth enabled, and highly advanced microcontroller platform that can be used as the main controller of the system. Several sensors, such as temperature sensors, pH sensors, and turbidity sensors, can be connected to the ESP32 to monitor critical water quality factors in the environment. The information can then be processed in real time and controlled by actuators such as feeders, pumps, and aeration systems to maintain optimum conditions for oyster growth

Furthermore, the system may be integrated with various technologies under the Internet of Things (IoT) concept. In this way, the system may be monitored online via mobile applications. This would enable the farm managers to take decisions by analyzing the trends of the data provided by the system. In the event of deviation of the parameters from the normal range, the system would send alerts. Such automation of the system would not only reduce the cost of operation but would also ensure the sustainability of the pearl farming techniques. It would be possible to increase the quality of pearl production by adopting the technology-driven approach.

## II. LITERATURE REVIEW-

[1] Swapnil Birunagi, Dr. Sushant Patil, Naveen Saini and Dhiraj K “Pearl farming: A review of farming in the future” May2024

Pearl farming is a type of aquaculture that is being developed as a modern form of pearl farming. In the past, pearl farming was carried out through the practice of pearl diving. In the past, pearl farming was carried out in India, China, and the Persian Gulf. In the past, the practice of pearl farming was advanced through the development of the nucleation technique of pearl farming in Japan. In India, the development of pearl farming was carried out through the efforts of the Central Institute of Freshwater Aquaculture (CIFA). In the past, the development of pearl farming in the world was carried out through the efforts of China, Japan, and Bangladesh. In the past, pearl farming was considered a type of agricultural practice that was

carried out through the practice of biodiversity conservation.

[2] Mohammad Ferdous Siddique<sup>1,2</sup>, Arun Chandra Barman<sup>2</sup>, Md. Ayenuddin Haque<sup>2</sup>, Mohosena Begum “Effects of pH on image pearl production in freshwater mussels (*Lamellidens marginalis*) under controlled temperature” October 2022

Pearls produced by the freshwater mussel, *Lamellidens marginalis*, have been reported to be greatly affected by environmental parameters, especially the pH. Previous studies have demonstrated the significance of environmental parameters, especially the pH, on the biomineralization process, which regulates the nacre secretion and development in mollusks. The study on the *Lamellidens marginalis* mussels maintained at a controlled temperature has demonstrated that the mussels maintained at a pH of 7.5 have shown better survival and pearl production than those maintained at higher pH. The study has demonstrated that the nacre thickness and weight have not been affected by the pH. The study has provided valuable insights into the environmental management strategies for the better production and quality of pearls.

[3] Kamin Alexander<sup>1</sup>, Durgesh Kumar Verma, Monika<sup>1</sup> “PEARL CULTIVATION IN INDIA” 2023

Pearl cultivation is one of the most valuable forms of aquaculture, producing pearls known as the “queen of gems.” While natural pearls are now rare due to overexploitation and pollution, cultured pearls dominate the market as they are produced through scientific implantation techniques in oysters and mussels. Studies highlight different types of pearls—natural, cultured, and imitation—with cultured pearls being larger, uniform, and commercially viable. In India, freshwater pearl farming has gained attention for its economic potential, especially in rural areas. Research stresses the importance of grafting methods, pre- and post-operative care, and water quality management to improve success rates. However, challenges such as limited broodstock, lack of standardized technology, and weak industry organization hinder its growth. Government subsidies, training programs, and institutional support aim to address these issues. Overall, literature suggests that with improved technology dissemination and farmer

training, pearl cultivation in India can become a profitable and sustainable aquaculture practice.

[4] Neelambika\*, Shwetha G1 and Punitha B C1  
“MASTERING PEARL CULTIVATION: AN EXPLORATION OF FRESHWATER PEARL FARMING AND HARVESTING” September 2024

Freshwater pearl farming is becoming increasingly important as a sustainable and profitable form of aquaculture. Unlike saltwater pearl farming, mussels can form more than one pearl at a time, as well as serve as a biofilter to improve water quality. Freshwater pearl farming can provide a profitable livelihood for farmers. Freshwater pearl farming requires ponds to be well designed, with factors such as pond size, depth, pH, oxygen, and temperature being considered. The grafting technique, which involves inserting a piece of mantle tissue into a mussel, is important for pearl farming. Freshwater pearl harvesting is a critical process, and the quality of pearls is graded according to their shape, size, lustre, and color, with round pearls being considered the most valuable. Freshwater pearls can significantly contribute to the global pearl market, considering the increasing demand for eco-friendly and affordable luxury products.

[5] Deependra Singh<sup>1</sup>, K. B Rajanna<sup>2</sup>, Shiwam Dubey<sup>1</sup>, Narendra Maurya<sup>1</sup>, Aitwar Vajjnath<sup>1</sup>  
“Overview of Pearl Farming and its Benefits” September 2023 Pearl farming is now a prominent aquaculture practice with a history that dates back to ancient times in India, China, and Japan. Today, modern culture techniques, first used in Japan, have made it possible to cultivate cultured pearls on a large scale, which now dominate the market (Singh et al., 2023). Pearls are formed as a protective mechanism in bivalves. Pearls are made of calcium carbonate and proteins like conchiolin (Kinoshita et al., 2011). Techniques used in pearl farming include surgical implantation, pond culture, and water quality management. Success rates of pearl farming have been reported to be around 60-70% (Wallace et al., 2008). Grading of pearls is done according to their luster, symmetry, and surface quality (Ruiz-Rubio et al., 2006). Even though it provides good socio-economic benefits, there is still a need to improve the mortality rates of the oysters.

[6] Kalyani Akash Kumar Student of IES University, Bhopal, M.P “Pearl Farming” May 2023

Pearl farming was first commercially cultured by Kokichi Mikimoto in Japan. However, pearl farming is a popular form of aquaculture due to the low maintenance costs and high profitability of the business. “Pearls are formed when a nucleus is inserted into the oyster shell, which then starts to secrete nacre around the nucleus. This process takes 6 to 12 months to produce marketable pearls.” (Kumar, 2023). The requirements of pearl farming are ponds or marine systems, oysters, nylon bags, and ropes. However, the success of pearl farming depends on the water conditions and the health of the oysters. Moreover, the pearls can be sold at higher prices if they are of Category A compared to the normal ones. According to the literature, pearl farming is considered to be eco-friendly, organic, and profitable with good socio-economic potential.

### III. METHODOLOGY

The development of the automated pearl farming system is performed by employing a specific methodology, which is based on a series of steps or phases necessary to achieve the overall goal of developing the proposed solution. The development of the proposed solution involves five specific phases: system design, hardware implementation, software development, testing/calibration, and performance evaluation.

#### 1. System Design

In the system design phase of the development of the proposed solution, the overall architecture of the proposed solution is conceptualized, focusing on the integration of both hardware and software aspects of the proposed solution. The ESP32 microcontroller is chosen as the CPU of the proposed solution because it is equipped with Wi-Fi and Bluetooth capabilities, low power consumption, and adequate I/O pins.

Environmental parameters, including temperature, pH, and turbidity, are identified as the most critical parameters in relation to the health of the oysters as well as the formation of pearls. Sensors are chosen based on the sensitivity, precision, response time, and compatibility of the sensors with the ESP32 microcontroller. Actuating devices, including pumps,

motors, and feeders, are added to automate various processes, including circulation, aeration, and feeding. A block diagram as well as a circuit diagram is created to show the interaction between the various devices and the microcontroller.

## 2. Hardware Implementation

After the design is complete, the system then moves to the hardware implementation stage. Here, sensors and actuators are connected to the ESP32 with the appropriate signal conditioning circuits and relay or transistor driver circuits to ensure the appropriate voltage or current ratings.

In the hardware implementation stage, the ESP32 picks real-time data from the sensors and processes the data as per the control logic implemented. The system then operates the appropriate actuators as per the input data received from the sensors, such as operating the pump when the turbidity is high or operating the feeding system when the appropriate time intervals are attained.

In the hardware implementation stage, the wiring arrangement is given considerable emphasis to ensure the system is stable with no electrical faults or system interference. The hardware is built on a prototype or a PCB designed specifically for the system.

## 3. Software Development

In the software development process, the control and automation logic are created by writing the embedded C code for the Arduino IDE and ESP IDF (Express if IoT Development Framework). The software processes three different operations: data acquisition, decision-making, and control.

- **Data Acquisition:**

The ESP32 continuously samples the data from the temperature, pH, and turbidity sensors. The data is then filtered and stored in temporary variables for further processing.

- **Control Algorithm:**

The control algorithm compares the data from the sensors and the threshold values. If there is a deviation in the parameters, the control actions for the respective parameters take place. For example, the control action for turbidity involves the activation of the water pump.

- **User Interface and Communication:**

The data is displayed on the serial monitor, LCD, and web page for further analysis and visualization. The integration of Wi-Fi into the project is an optional feature.

Conditional statements, interrupt statements, and time control statements are used to create the automation process without lag and conflicts.

## 4. Testing and Calibration

Once the hardware and software integration are finished, the system is subjected to a rigorous process of testing and calibration. For this purpose, each of the sensors is calibrated using standard solutions or equipment to ensure precise measurement of temperature, pH, and turbidity.

The entire system is also subjected to rigorous tests in a simulated environment to check the accuracy, timing, and reliability of the automation process. For this purpose, the following test scenarios are implemented:

- Response of the sensors to environmental changes
- Timing and synchronization of the feeding and water control cycles
- Accuracy of the data being displayed or transmitted
- Reliability of the system with continuous usage

## 5. Performance Evaluation

The final step includes a thorough performance evaluation of the developed prototype. The evaluation parameters considered for this process are:

- **Monitoring Accuracy:** The accuracy of the sensors, as compared to manual measurement.
- **System Responsiveness:** The time taken by the system to correct the fluctuations in environmental conditions.
- **Energy Efficiency:** The power consumption by the microcontroller and other devices.
- **Reduction in Manual Intervention:** The extent to which the system can reduce labor dependency.
- **Improvement in Farming Operations:** The consistency and stability provided to farming, along with the potential effects on pearl quality.

Detailed Design

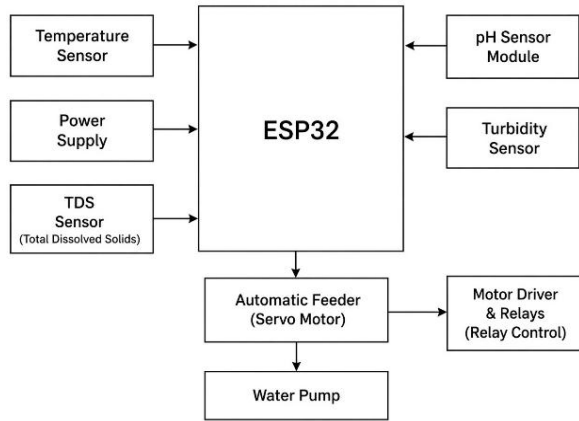


Fig .1 Block Diagram of Proposed System

IV. SYSTEM DESIGN AND ARCHITECTURE

The automated pearl farming system is designed to intelligently monitor and control important water quality parameters necessary for oysters and pearl farming. The system uses a number of sensors and actuators that communicate with an ESP32 microcontroller, which acts as the brain of the system. The block diagram demonstrates the communication between the sensors, microcontroller, and actuators. The automated pearl farming system consists of three important processes: sensing, processing, and actuating, which work together as a loop.

System Operation Overview

1. The temperature, pH, and turbidity sensors will be used to monitor the environmental conditions of the pearl farming tank or aquatic system.
2. These real-time readings will be monitored by the ESP32 microcontroller, which will compare the readings with the standard threshold value for each sensor.
3. When there is any form of deviation, the ESP32 microcontroller will trigger the motor driver and relay module, which will switch the water pump on for circulation or exchange of water.
4. The automatic feeder will be used to feed the oysters at regular intervals using a servo motor.
5. The power supply unit will be used to supply a stable and regulated voltage supply to the components of the system.
6. Detailed Explanation of the Circuit Diagram

The circuit diagram provided above shows a fully developed automated water quality monitoring and

control system, which is centered around the ESP32 microcontroller. This system is intended for the measurement and monitoring of various water quality parameters like the pH level, turbidity, and total dissolved solids (TDS), and it is also possible for the system to control external devices like the water pump or mist generator for the maintenance of the water quality. Additionally, the circuit includes a TFT display module for the visualization of the sensor readings. The circuit works on a 12V DC supply voltage, which is then reduced to lower voltage levels for the functioning of the circuit components. All the components of the circuit have a common ground plane for the stable reference of the signals.

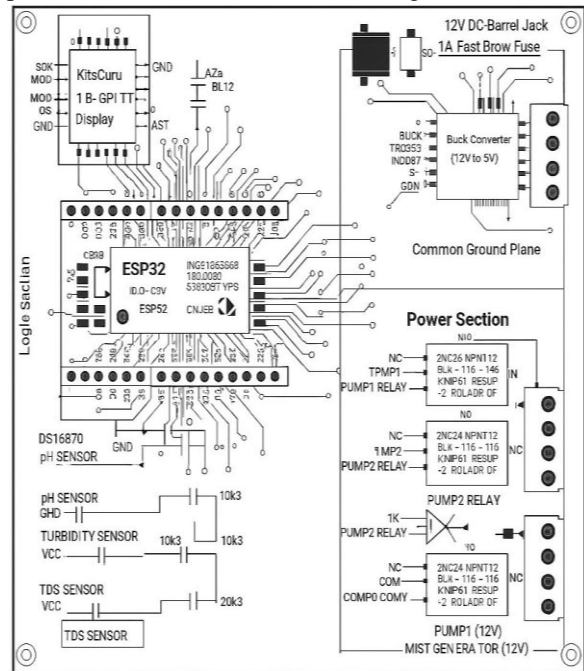


Fig 2 IoT-based Water Quality Monitoring and Automation System

Main Controller: ESP32

The brain of this circuit is a microcontroller known as ESP32. This acts as a central processing unit that reads data from all sensors, processes this data, and displays information on the TFT screen and controls relays to run external devices. This microcontroller was selected for this purpose because it can connect to Wi-Fi and Bluetooth networks and also provide multiple Analogy to Digital Converter pins and GPIO pins to carry out digital communication. The Analogy pins of this microcontroller are connected to all sensors, where the voltage levels sent by all sensors are

converted to digital form. Several GPIO pins are also connected to relay modules to run pumps. This microcontroller can be powered either through a 5V supply rail or a voltage regulator on this board, depending on the version of this module. All these components are also connected to a common ground line to function properly and reduce electrical noise and interference.

#### Display Module Section

A 1.8-inch TFT display module is used in the circuit. This module is used for the display of real-time information. This display module is used for the display of the current pH value, the level of TDS, the turbidity level, the status of the pumps, and the warning messages. This display module is connected with the ESP32 microcontroller through SPI communication lines. SPI communication lines include data transfer lines, clocking lines, and command control lines. By using the display module, the system becomes easier to handle without the need for connecting it with a computer or a mobile device. The display module works on a voltage of 3.3V or 5V. The ground line of the display module is connected with the ground line of the ESP32 microcontroller.

#### Sensor Interface Section

The circuit integrates three important water quality sensors: a pH sensor, a turbidity sensor, and a TDS (Total Dissolved Solids) sensor. Each of these sensors provides an analogy voltage output corresponding to the physical parameter it measures. The pH sensor measures the acidity or alkalinity of the water. Its signal typically requires conditioning to stabilize noise, and a resistor is used for this purpose. The turbidity sensor determines how clear or cloudy the water is based on the amount of light scattered by particles suspended in it. It also uses a small resistor network to scale the output voltage to a safe level suitable for the ESP32's ADC input. The TDS sensor measures the concentration of dissolved minerals and salts in the water, which is important for determining water purity. All sensors share a common ground connection with the ESP32, which ensures accurate readings by preventing variations in reference voltage. The use of resistors in the sensor lines helps prevent signal spikes and ensures that the input voltages remain within the safe operating range of the ESP32.

#### Power Supply Section

The power supply section utilizes a DC supply of 12V, which is commonly obtained from a DC adapter or a battery pack. A fast blow fuse is connected in series at the input terminal of the circuit to protect the circuit from any surge currents or short circuits. From the DC supply of 12V, a buck converter module reduces the supply voltage to 5V. The buck converter module is necessary as many of the devices, including the ESP32 module and the display, require a supply voltage of 5V or 3.3V instead of 12V. The buck converter module helps in efficient supply voltage regulation without any heat generation problems. The reduced 5V supply is distributed across the circuit, while the ESP32 module utilizes its internal voltage regulator to generate a supply of 3.3V for its core circuitry. A common ground plane is provided across the entire circuit to maintain the supply voltage at a constant reference value, which is necessary for the accurate working of analog sensors as well as the reliability of the relay circuit.

#### Relay and Pump Control Section

The system includes relay driver modules, which enable the ESP32 to control other devices, such as a water pump and a mist generator. The ESP32 uses 3.3V logic, which is not enough to power other devices, as they use 12V and require a lot of current. The relay acts as a switch that can be activated electrically using the GPIO pins. The relay includes a normally closed and a normally open terminal. The pumps or the mist generator can be connected through the normally open terminal, which ensures that they are switched off by default. The pumps or the mist generator can be switched on by the ESP32. A transistor and a resistor are included in the relay driver circuit, which enables the relay to be activated without damaging the microcontroller. The system can be used to automate corrective measures. For instance, the pH level can be too high or too low. The ESP32 can be used to control a pump that circulates chemicals or fresh water. The system can be used to control the humidity level through a mist generator, which can be activated to maintain humidity levels, as required, for a greenhouse or an aquaponics system.

#### Working Principle of the System

In the working principle of the system, the sensors continuously transmit the values of the parameters

being monitored to the ESP32 microcontroller. The microcontroller processes the information, displaying it on the screen while making decisions based on the threshold values set. If the values are within the limits of the parameters, the microcontroller remains in its state of monitoring the parameters. If any of the values are outside the limits of the parameters, the microcontroller activates the corresponding relay, thereby adjusting the parameters accordingly. This helps in the maintenance of the parameters without any human intervention. The values are constantly being displayed, allowing the user to see changes in the parameters in real time. The microcontroller is programmable, allowing it to be modified as required.

#### Component-Level Design Details

##### 1. ESP32 Microcontroller

The ESP32 microcontroller is a dual-core microcontroller that is low-cost, comes with Wi-Fi and Bluetooth connectivity, and is the brain of the system. It is used for:

- Reading analog and digital data from all the connected sensors.
- Processing and analyzing the data from the sensors through programmed logic.
- Controlling the actuators like the servo motor for the feeding mechanism and the water pump through the relay module.
- Managing the time functions for the scheduled feeding and water circulation.
- Transmitting the data from the sensors wirelessly, if required.

The ESP32 microcontroller works on a 3.3V logic level.

##### 2. Temperature Sensor

The temperature sensor, like a DS18B20 or LM35 sensor, will be used to read the water temperature in real time.

- Function: This will ensure that the water temperature is within the optimum range of 20°C to 28°C to maintain oyster health and pearl production.
- Interface: This will provide an analogue or digital output that will be read by the ESP32 via an analogue input pin.
- Control Role: This will be useful in future versions to log data if temperature changes are detected beyond an acceptable level.

##### 3. pH Sensor Module

The pH sensor measures the level of acidity or alkalinity.

- Functional Role: The pH level needs to be maintained between 7.5 and 8.2, which is the ideal pH level for oysters.
- Control Role: The ESP32 can take necessary measures, replacing the water, if the pH level is not within the ideal range.

##### 4. Turbidity Sensor: The turbidity sensor measures the level of clarity or dirtiness.

- Functional Role: The water needs to be clean and clear to provide enough oxygen for the oysters.
- Interface Role: The level of dirtiness is indicated as an analogue voltage.
- Control Role: The ESP32 can replace the water using the pump if the level of dirtiness is too high.

##### 5. Power Supply

The power supply unit ensures a stable and regulated voltage supply to all components.

- Design: The design includes a 12V DC voltage supply for the actuators and a voltage regulator, which can be an LM2596 or an AMS1117, for stepping down the voltage to 5V or 3.3V for the sensors and ESP32.
- Function: The power supply ensures a safe and reliable voltage supply, protecting the components from voltage fluctuations and short circuit conditions.

##### 6. Servo Motor (Automatic Feeder)

The servo motor controls the automatic feeder.

- Function: The automatic feeder ensures a predetermined amount of food is dispensed at regular intervals to provide a consistent level of nutrition to the oysters.
- Control: The ESP32 sends a PWM signal to control the movement of the motor, which determines the amount of food being dispensed.
- Operation: The time interval for feeding can be predetermined, for example, to provide food two or three times a day.

##### 7. Motor Driver and Relay Module

The motor driver and relay module act as an intermediary between the low-power consumption

microcontroller and other equipment, such as the water pump.

- **Function:** The relay module functions as an intermediary between the ESP32 and other equipment. The motor driver module ensures the flow of electric current.
- **Control:** The relay module receives a digital signal from the ESP32 when it detects abnormal pH and turbidity levels. This signal activates the water pump.

8. **Water Pump:** The water pump ensures the continuous flow of water or partially replaces it to ensure the optimal levels of oxygen and waste.

- **Function:** Lowers the turbidity and maintains the optimal pH levels through the continuous flow of water into the habitat of the oysters.
- **Control:** Activated through the relay module by the ESP32.
- **Type:** A low-power consumption submersible DC pump is used for small-scale operations, while larger pumps can be used for larger operations.

**Circuit Schematic**

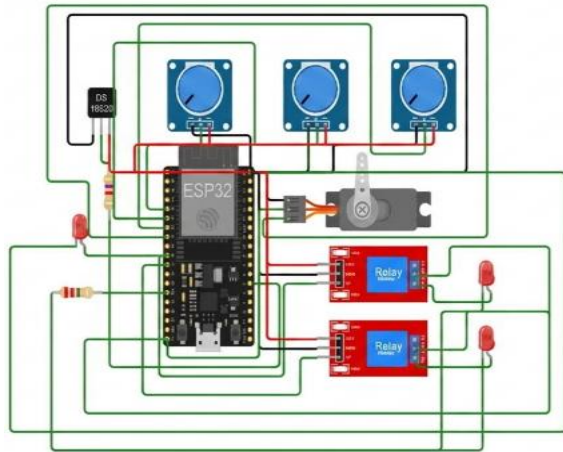


Fig 3. Circuit Schematic

The simulation above depicts the virtual simulation of the testing environment of the automated water quality monitoring and control system using the ESP32 microcontroller. The simulation is used to test the functionality of the circuit, the sensor input signals, and the control of the device connected through the relay module. At the center of the circuit is the ESP32 microcontroller. It is the brain of the circuit. It receives the sensor signals, processes the information, and then

makes the decisions regarding the connection of the external device connected through the relay module. This simulation is used to ensure the functionality of the circuit without damaging the components during the early stage of development.

In the simulation, there are three potentiometers used to represent the water quality sensors. The potentiometers used in the simulation are variable analogy input devices used to represent the changing values of the pH, turbidity, and TDS levels in the water. The rotation of the potentiometers is used to adjust the values being sent to the ESP32. This is a useful method because, in the real scenario, the water sensors need to be calibrated. In addition, the sensors need real fluid conditions, which may not be easy to simulate. The potentiometers act as a safe way to test the logic used in the microcontroller program. The output values from the simulated sensors are then read by the ESP32 using the analogy-to-digital converter pins.

In addition to that, the DS18B20 temperature sensor has been included in the simulation. This temperature sensor will be used to measure the temperature of the water. This type of sensor works on the principle of digital communication. The DS18B20 requires only one wire for communication. This reduces the complexity of wiring. The temperature of the water is very crucial for the monitoring and control of the quality of the water. The temperature affects the quality of the water in aquaponics, hydroponics, and fish farming.

The relay modules included in the simulation are used for controlling external devices. The ESP32 works on low voltage, and the voltage is not sufficient enough to control external devices. The relay acts like a switch. The microcontroller sends a digital signal to the relay if the sensor data is higher or lower than the desired value. This signal allows the flow of the current to the external device. In the simulation, LEDs have been included instead of pumps and motors. The LEDs glow when the relay is activated, indicating that the microcontroller has made the correct decision.

A servo motor is also included in the circuit to illustrate the capability to integrate mechanical control devices. This can be applied to control a valve or any mechanical part of the system depending on the sensor readings. The servo motor is supplied with a pulse-width modulated signal from the ESP32 to control the rotation of the servo. In the simulation, the servo motor

is made to respond to changes in the input value to illustrate how automatic mechanical control can be integrated into the system.

LED indicators have been included in the circuit to indicate the state of the relay-controlled devices. These LED indicators can be applied to monitor the working state of the system, particularly when validating the code logic. In the event that the sensor readings indicate values outside the normal range, the ESP32 switches the relay on, causing the LED to illuminate, which indicates that the system has responded to the problem.

## V. CONCLUSION

The proposed IoT-based automated pearl farming system has the potential to overcome the disadvantages associated with traditional pearl farming by incorporating IoT technologies. The proposed system automates the process of feeding and water circulation, and the monitoring of critical parameters such as pH, temperature, and turbidity in the water. The proposed system utilizes the ESP32 microcontroller to process the data and perform wireless communication, thus improving the efficiency and consistency in the quality of pearls. The proposed IoT-based automated pearl farming system has the potential to improve the efficiency and consistency in the quality of pearls, thus paving the path for the development of smart aquaculture.

Further developments in the system will continue to improve the efficiency, reliability, and scalability of the system.

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