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Thème

Automatisation et optimisation d'un système aquaponique

Présenté par

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Dedication

To my beloved sister Maroua

This work is dedicated to her, she stood by me in every step offering strength when I felt weak and joy when I felt lost ,she supported me emotionally ,she watched me grew ,achieved ,failed and finally graduated.

Her pride in my success meant the world to me, she gave with an open heart and never held back anything I needed whether care , comfort or something material.

Though she is no longer here,she remains a part of me , a memory that walks beside me for the rest of my life.

رحمها الله واسكنها فسيح جناته

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I would like to express my deepest gratitude to all the family who helped me during this work.

A special gratitude and respect to my supervisor Mr. Abdelkader Abderahman for helping me through the completion of this work. Special and warm thanks go to my beloved parents and my siblings, for their love and encouragement.

Thank you

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List of abbreviations:

- UMAB: Abdelhamid Ibn Badis University – Mostaganem
- FST: Faculty of Sciences et and Technology.
- PVC: Polyvinyl chloride

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GENERAL INTRODUCTION

Hydroponics is a method of growing plants without using any soil. Plants are grown with a nutrient solution that provides the mineral nutrients needed for growth, Plants get all their nutrition from this nutrient solution that is provided to their roots. However, challenges such as economic instability, food insecurity, and the inability to achieve global self–sufficiency have heightened the need for sustainable agricultural solutions.

To address these issues, scientists have developed a groundbreaking technology called aquaponics, which combines hydroponics and aquaculture into a single integrated system. This technology combines aquaculture and fish farming at the same time using the same water cycle.

Aquaponics leverages the natural symbiosis between fish and plants. In this system, fish produce waste rich in ammonia, which is converted by beneficial bacteria into nitrates—a vital nutrient for plants. The plants, in turn, purify the water, creating a sustainable cycle that benefits both organisms. This closed–loop system uses water efficiently and minimizes waste, making it environmentally friendly and highly productive.

The aquaponic system operates with minimal manual intervention, making it easy to manage and suitable for various scales of farming, from small home setups to large commercial operations. As a farming method, aquaponics offers a promising solution to address pressing food and environmental challenges, particularly in regions facing resource scarcity or adverse climatic conditions.

Aquaculture, the fastest–growing food production sector globally, employs diverse systems to meet rising demands. Among these, aquaponics stands out as one of the most efficient and sustainable methods of the 21st century. By integrating the cultivation of fish and plants within a recirculating water system, aquaponics not only enhances productivity but also reduces the environmental footprint of traditional farming practices.

This thesis explores the potential of aquaponics as a sustainable farming solution, examining its biological, environmental, and economic advantages in addressing global food security challenges.

CHAPTER I
GENERALITY

I.1. Introduction

This chapter introduces aquaponic systems, explaining how they work and their importance. It also discusses common challenges and the types of fish suitable for aquaponics, providing a foundation for improving and optimizing these systems.

I.2. How aquaponic system works

Aquaponics practice is a soil–less, controlled cultivation system. Aquaponics is the combination of the two agricultural practices, aquaculture, and hydroponics. It is a technique of mixing aquaculture with hydroponics in a symbiotic environment. In normal aquaculture, excretions from the raised animals accumulate within the water and increase toxicity.

In aquaponics, water from the aquaculture is supplied to the hydroponics system while the by–products are dilapidated by nitrifying bacteria, making the by–product to be utilized as nutrients by plants. The aquaculture system afterward receives the water by recirculation. If fishes are employed in an aquaponics system, the fishes are given their food, the fishes work to feed the plants, and the plants clean the water for the fishes. Note that the complexity in size, and kinds of foods grown in an aquaponic system varies.[1]

Aquaponic system importance

The main advantage of an aquaculture system is the water efficient the system uses to operate, using up to 10 times less water than conventional farming.The recirculation system reduces water waste and allows other items such as fish feed to be reused.

Aquaponics systems have a lesser environmental impact. Plants grow faster when they receive rich amounts of nutrients and natural fertilizers 24 hours a day, and a constantly regulated water source also promotes plant growth.

I.3.Challenges

Growing plants in a traditional way in the soil requires a lot of effort and time and wasting a large amount of water, including complete monitoring of the success of this method. A system has been invented that works automatically and provides all requirements without the need for monitoring.

I.4 Water quality parameters

I.4.1. Temperature

Temperature is a physical quantity that measures the level of hotness or coldness. It reflects the average kinetic energy of atoms in a substance and is commonly measured using a thermometer.

I.4.1.1. Temperature Scales

Four main temperature scales are used in science and industry: Fahrenheit, Celsius, Kelvin, and Rankine.

Fahrenheit Scale

- Defined with 32°F as the freezing point and 212°F as the boiling point of water, divided into 180 increments.
- Invented by Daniel Gabriel Fahrenheit in the 18th century.
- Conversion:
  - $C = \frac{5}{9} \times (F - 32)$
  - $K = \frac{5}{9} \times (F - 32) + 273.15$
  - $R = F + 259.67$

Celsius Scale:

- Defined with 0°C as the freezing point and 100°C as the boiling point of water.
- Introduced by Anders Celsius in 1742 and widely used in scientific contexts.
- Conversion:
  - $F = \left(C \times \frac{9}{5}\right) + 32$
  - $K = C + 273.15$
  - $R = (C + 273.15) \times \frac{9}{5}$

Kelvin Scale:

- The SI unit for thermodynamic temperature, where 0 K represents absolute zero (molecules have minimal energy).
- 1 Kelvin equals 1 degree Celsius in magnitude.

Rankine Scale:

- An absolute temperature scale with degrees equivalent to Fahrenheit.
- Zero Rankine ($0^{\circ}R$) corresponds to absolute zero.

I.4.1.2. Temperature requirements for aquaponic fish

The temperature of the water in aquaponic systems is critical for the health and growth of fish species. Each species has an optimal temperature range that must be maintained for proper metabolism, immune response, and growth.

Tilapia:

- Optimal temperature: 27–30°C (81–86°F).
- Tolerance range: Can briefly tolerate extremes of 14°C (57°F) and 36°C (97°F), but stops feeding below 17°C (63°F) and may die below 12°C (54°F).

Carp:

- Optimal temperature: 25–30°C (77–86°F).
- Tolerance range: Survives from 4°C (39°F) to 34°C (93°F), making it suitable for both temperate and tropical regions.

Catfish:

- Optimal temperature: 26–30°C (79–86°F) for African catfish.
- Tolerance range: Can survive in water as cool as 20°C (68°F), but growth halts below 20–22°C (68–72°F).

Trout:

- Optimal temperature: 10–18°C (50–64°F), with 15°C (59°F) being ideal.
- Tolerance range: Becomes stressed above 21°C (70°F), with growth rates declining significantly.

I.4.2. pH in aquaponics systems

I.4.2.1. Definition

The pH of a solution measures its acidity and is defined as the negative logarithm of the hydrogen ion concentration [H^+]. It inversely reflects hydrogen ion concentration: higher [H^+] results in a lower pH (acidic solution), while lower [H^+] results in a higher pH (alkaline solution). In aqueous solutions, the product of [H^+] and hydroxyl ion concentration [OH^-] remains constant at 1×10^{-14}. A neutral pH is 7, acidic pH is less than 7, and alkaline pH is greater than 7.

I.4.2.2. pH in aquaponics

Maintaining proper pH is essential in aquaponic systems because it directly influences the health of fish, plants, and the nitrifying bacteria critical for system stability.

Fish: Fish thrive within specific pH ranges. For example, tilapia prefer pH levels between 6.5 and 8.5, while trout require more neutral to slightly acidic conditions around 6.5 to 7.5. Deviations can stress fish, making them susceptible to diseases.

Plants: Plants absorb nutrients optimally in specific pH ranges, typically 5.5 to 7.0. Outside this range, nutrient availability is reduced, potentially causing deficiencies and reduced growth.

Bacteria: Nitrifying bacteria, which convert toxic ammonia into nitrate, function best in a pH range of 6.8 to 7.5. If the pH falls too low or rises too high, their activity declines, compromising the nitrogen cycle and water quality.

I.4.2.3. Concept of pH

The concept of pH was introduced by Søren Sørensen to simplify expressing the wide range of [H^+] concentrations encountered in chemical systems. It is mathematically defined as:

$$pH = -log_{10}([\mathrm{H}^+]) = log_{10}\left(\frac{1}{[\mathrm{H}^+]}\right)$$

This equation demonstrates the inverse relationship between [H^+] and pH.

I.4.2.4. Measurement of pH in aquaponics

pH meters:pH meters are crucial tools for monitoring aquaponic systems, ensuring conditions remain optimal for all living components.

- **Probe construction:** Modern pH meters utilize glass electrodes sensitive to $[H^+]$, connected to electronic meters that display readings. Calibration with buffer solutions is necessary to maintain accuracy.
- **Application in aquaponics:** pH meters are used to regularly check the pH of water, allowing for timely adjustments using buffers or natural agents like lime (to increase pH) or phosphoric acid (to decrease pH).

pH Indicators:

- **Use in aquaponics:** While less precise than pH meters, pH indicators like test strips can provide a quick and cost–effective way to monitor water pH. These tools are especially useful in smaller systems or as backups to electronic meters.

I.4.2.5. pH Dynamics in Aquaponic Systems

The interaction between fish waste, plant uptake, and bacterial activity constantly alters pH levels. For example:

- **Fish waste and feeding:** Fish release ammonia, which bacteria convert to nitrate. This process tends to lower pH over time.
- **Plant uptake:** Plants absorb nutrients, which can slightly alter pH depending on the nutrients taken up.
- **Water additions:** Adding new water can introduce pH fluctuations, especially if the source water differs significantly in pH.

I.4.2.6. Managing pH in Aquaponics

Maintain system balance is crucial, therefore, testing pH daily or weekly is needed, depending on system size and complexity.Using natural buffers to adjust pH gradually and avoid sudden changes that can harm fish and plants. In addition, monitor other parameters like ammonia, nitrate, and carbonate hardness (KH), as these also affect and are affected by pH levels.

I.4.2.7. pH in Nature and Aquaponics

In natural systems, pH governs aquatic life, soil health, and nutrient availability. Similarly, in aquaponics, pH is central to the health of the system:

- Fish, plants, and bacteria form a delicate, interconnected web that relies on balanced pH.
- Poorly managed pH can lead to fish stress, nutrient lockout for plants, and the failure of beneficial bacterial processes.

Finally, by understanding and managing pH effectively, aquaponic systems can achieve high productivity and sustainability while mimicking the natural balance found in ecosystems.

I.5. Types of fish species suitable in aquaponic systems

There are more fish species that have recorded excellent growth rates inaquaponics units. Such fish species, which are suitable for aquaponics farming.These species grow especially well in aquaponics units and they are discussed more detailed in the following sections.

I.5.1. Tilapia

Blue Tilapia (Oreochromis Aureus): Known for its bluish tint, this variety is cherished for its adaptability to cooler temperatures than other tilapia species. It’s a preferred choice for aquaponics enthusiasts in regions with colder climates.

Growth Rate: 3–4 pounds in 3 years.

- Feeding: 3 times a day.
- Diet: Omnivorous, feeds primarily on phytoplankton; adults are herbivores.
- Waste produced: heavy waste producer.
- pH requirement: 6–9.
- Temperature requirement: between 47° F to 90°.

Nile tilapia (Oreochromis niloticus): One of the most popular freshwater species which grow in aquaculture systems worldwide are the tilapias, they are native from East Africa. Resistant to many parasites and pathogens and handling well the stress, they do best in warmtemperatures and are able to tolerate a wide range of water quality conditions.

Figure I.1. Tilapia fish.

In spite of the fact that tilapias can briefly tolerate extreme temperatures of the water like 14°C and 36°C they do not feed or grow below 17°C, and they even die below 12°C. Because the ideal range for tilapias, in order to ensuregood rates of the growth is between 27–30°C. In temperate climates tilapias might be suitable for winter seasons only if the water is heated[7][8].

I.5.2. Carp

Carp are among the most widely cultured fish species globally, originating from Eastern Europe and Asia. Their adaptability to diverse environmental conditions, including poor water quality and low dissolved oxygen (DO) levels, makes them highly suitable for aquaponics systems. Carps are resilient and thrive in both temperate and tropical climates, tolerating a broad temperature range of 4°C to 34°C.

- Optimal temperature: 25°C to 30°C.
- Growth rates: Under proper conditions, carp can grow from fingerling to harvest size (500–600 g) within 10 months [8].
- Temperature sensitivity: Growth rates decrease significantly below 12°C.

In aquaponics, carp contribute to the system’s nutrient cycle by producing ammonia, which is converted by nitrifying bacteria into nitrate, a vital nutrient for plant growth. Their tolerance to varying water quality makes them ideal for beginner and advanced aquaponics setups.

Figure I.2 Carp fish.

Common Carp (Cyprinus carpio): The common carp is a hardy species that thrives in diverse water conditions. Known for its adaptability, it is one of the most farmed fish worldwide.

- Key feature: Highly tolerant of low DO levels and fluctuating water quality.
- Aquaponics use: Provides steady nutrient output for plant growth. Its robust nature allows it to coexist in systems with less stringent water quality controls.

Silver Carp (Hypophthalmichthys molitrix): The silver carp is a filter–feeding species that primarily consumes phytoplankton, zooplankton, and suspended organic particles.

- Key feature: Plays a natural role in controlling algae in aquaponic systems.
- Aquaponics use: Helps maintain water clarity by reducing algal blooms, complementing the system's filtration needs.

Grass Carp (Ctenopharyngodon idella): The grass carp is a herbivorous species that feeds on aquatic vegetation, making it unique among carp species.

- Key feature: Effective at consuming plant material, which can help manage plant overgrowth in aquaponics.
- Aquaponics use: Can be used in systems with edible plants that tolerate higher water temperatures. Its waste contributes to nutrient–rich water for other plant growth.

Carp in Aquaponics: Carps are particularly advantageous in aquaponic systems for the following reasons:

- Temperature resilience: Their broad temperature tolerance makes them suitable for year–round production in various climates.
- Nutrient contribution: Carps produce ample ammonia for nitrification, supporting plant growth in both leafy greens and fruiting crops.
- Low maintenance: Their hardiness and ability to thrive in low DO environments reduce system maintenance needs compared to more sensitive species.
- Sustainability: Grass carp and silver carp's unique feeding habits can reduce reliance on formulated feed, promoting system sustainability.

I.5.3. Catfish

Catfish are a group of hardy fish known for their ability to thrive in diverse water conditions. They tolerate wide fluctuations in dissolved oxygen (DO), temperature, and pH, making them an excellent choice for aquaponics systems. Catfish are also resistant to many parasites and diseases, further enhancing their suitability for aquaculture and aquaponics [8].

- Stocking density: Catfish can be stocked at high densities, up to 150 kg/m^3, but this requires robust mechanical filtration and solids removal to maintain water quality.
- Tank design: Overcrowding should be avoided, as catfish can injure each other with their sharp spines. Horizontal tank layouts are preferable, providing ample space for the fish to spread out.
- Ammonia tolerance: Unlike many fish, catfish can endure higher levels of ammonia, offering flexibility in system management during transitional phases like cycling.

In aquaponics, catfish produce nutrient–rich waste that serves as a valuable input for plant growth, particularly leafy greens and fruiting crops. Their resilience makes them ideal for beginners and commercial systems alike.

Figure I.3 Catfish.

Channel Catfish (Ictalurus punctatus): The channel catfish is a freshwater species native to North America and widely cultivated for its fast growth and robust nature.

- Key feature: Thrives in warm water and tolerates low DO conditions.
- Aquaponics use: Ideal for systems with slightly higher stocking densities. Channel catfish are omnivorous, consuming both feed and organic material in the system.

African Catfish (Clarias gariepinus): The African catfish, a member of the Clariidae family, is a fast–growing species renowned for its hardiness and adaptability.

- Key feature: Can survive in low oxygen environments by utilizing a specialized breathing organ.
- Aquaponics use: Suitable for high–intensity systems due to its tolerance of fluctuating water parameters. However, African catfish grow best at temperatures between 26°C and 30°C, with growth slowing below 20–22°C.

Catfish in Aquaponics: Catfish offer several advantages for aquaponic systems such as:

- Temperature tolerance: African catfish thrive in warm water systems (optimal: 26–30°C), while channel catfish are similarly adaptable.
- Nutrient contribution: Catfish produce high levels of ammonia, which bacteria convert into nitrates, essential for plant growth.
- Resilience: Their resistance to diseases and ability to handle wide swings in water quality make them ideal for systems with variable conditions.
- High stocking potential: Their high–density stocking capability allows for greater nutrient output in smaller system footprints.

- Sustainability: Catfish physiology supports efficient feed conversion, reducing overall system costs.

Management Considerations: Regular water quality monitoring is critical to maintain ammonia and DO levels within safe ranges, even for these hardy species. In addition, mechanical filtration and regular solids removal are essential for systems with high catfish densities to prevent waste buildup and maintain plant and fish health. Finally, horizontal tank layouts help reduce stress and physical injury, as catfish can spread out more naturally.

I.5.4. Trout

Trout are cold–water, carnivorous fish from the salmon family (Salmonidae). They require cooler water than other commonly used aquaponic species, making them ideal for systems in temperate or Nordic climates, especially during winter. Trout are valued for their fast growth, high–quality protein, and efficient feed conversion, but they demand precise water quality management to thrive [8].

- Preferred temperature: 10–18°C (50–64°F), with 15°C (59°F) being optimal.
- Temperature sensitivity: Growth rates decline significantly above 21°C (70°F), and trout may experience DO utilization issues even if oxygen levels are high.

In aquaponics, trout contribute to nitrogen cycling by excreting ammonia as a waste product. Their higher protein diet results in greater nitrogen input, enabling systems to support larger areas of leafy vegetables.

Figure I.4.Trout fish.

Rainbow Trout (Oncorhynchus mykiss): The rainbow trout is one of the most widely farmed trout species, known for its adaptability to various water conditions and rapid growth in cold water.

- Key feature: Tolerates a range of salinities, from freshwater to brackish environments.
- Aquaponics use: Suitable for colder regions where water temperatures naturally align with its preferred range. Rainbow trout's high protein waste supports plant growth, particularly leafy greens and nitrogen–demanding crops.

Trout in Aquaponics: Trout present unique opportunities and challenges in aquaponic systems:

- Temperature requirements:Trout are best suited for regions with naturally cool water sources, such as Nordic or temperate climates. They excel in winter systems where temperatures are typically within their optimal range.
- Nutrient output:Their high–protein diet increases nitrogen levels in the system, providing abundant nutrients for plants. However, this requires careful balancing to avoid ammonia spikes that could harm the fish.
- Water quality demands:Trout require high dissolved oxygen (DO) levels and low ammonia concentrations, necessitating constant monitoring and robust aeration systems. Backup systems for air and water pumps are essential to prevent stress or mortality during equipment failures.
- Salinity tolerance:While trout can tolerate higher salinity levels than tilapia or carp, aquaponic systems typically maintain freshwater conditions to accommodate plant requirements.
- Crop compatibility:The higher nitrogen levels from trout waste are particularly beneficial for leafy greens and herbs. These crops thrive on nitrogen, creating a balanced nutrient cycle in the system.

Management Considerations:

- Frequent monitoring: Ensure water quality parameters such as ammonia, nitrites, nitrates, and DO remain within safe ranges.
- Aeration: Maintain optimal oxygen levels with efficient aerators, especially in systems with higher stocking densities.

- Protein feed: Trout require a high–protein diet, which can increase operational costs but results in rapid growth and high nutrient output.
- Temperature control: Monitor and maintain water temperature within the ideal range. Use chilling systems, if necessary, in warmer climates.

I.5.5. Summary

Table below (Table I.1) represents a summary of the four fish species, their types, Arabic names, and farming conditions in aquaponic systems.

Table I.1. The four fish species, their types, Arabic names, and farming conditions in aquaponic systems.

Fish Type	Species	Arabic Name	Optimal Temperature (°C)	Key Farming Conditions
Tilapia	– Blue Tilapia (*Oreochromis aureus*) – Nile Tilapia (*Oreochromis niloticus*)	البلطي	27–30	– Thrives in warm water. – Tolerates a wide range of water quality. – Requires heating in colder climates.
Carp	– Common Carp (*Cyprinus carpio*) – Silver Carp (*Hypophthalmichthys molitrix*) – Grass Carp (*Ctenopharyngodon idella*)	سمك الشبوط	25–30	– Hardy, tolerates poor water quality. – Suitable for temperate and tropical climates. – Requires regular waste removal.
Catfish	– Channel Catfish (*Ictalurus punctatus*) – African Catfish (*Clarias gariepinus*)	سمك السلور (القرموط)	26–30	– Can handle low DO and high stocking densities. – Requires horizontal tanks to reduce stress. – Ammonia–tolerant.
Trout	– Rainbow Trout (*Oncorhynchus mykiss*)	سمك السلمون المرقط	10–18	– Requires cold, oxygen–rich water. – High protein diet results in high nitrogen output. – Demands robust aeration systems.

I.6. Aquaponics and nutrients

One of the principal benefits of aquaponics is that it allows for the recycling of nutrient resources. Nutrient input into the fish component derives from feed, the composition of which depends on the target species, but feed in aquaculture typically constitutes a significant portion of input costs and can be more than half the total annual cost of production [9].

Aquaponic systems take the dissolved nutrients from uneaten fish feed and faeces, and utilizing microbes that can break down organic matter, convert the nitrogen and phosphorus into bioavailable forms for use by plants in the hydroponics unit, in order to achieve economically acceptable plant production levels[9].

I.7 Aquaponics and land utilization

Aquaponic production systems are soilless and attempt to recycle essential nutrients for cultivation of both fish and plants, thereby using nutrients in organic matter from fish feed and wastes to minimize or eliminate the need for plant fertilizers. For instance, in such systems, using land to mine, process, stockpile and transport phosphate or potash–rich fertilizers become unnecessary, thus also eliminating the inherent cost, and cost of application, for these fertilizers. Aquaponics production contributes not only to water usage efficiency but also to agricultural input efficiency by reducing the land footprint needed for production. Facilities for instance, can be situated on non–arable land and in suburban or urban areas closer to markets, thus reducing the carbon footprint associated with rural farms and transportation of products to city markets[9].

I.8 Aquaponics and energy conservation

Technological advances in aquaponic system operations are moving towards being increasingly ‘energy smart’ and reducing the carbon debt from pumps, filters and heating/cooling devices by using electricity generated from renewable sources. Even in temperate latitudes, many new designs allow the energy involved in heating and cooling of fish tanks and greenhouses to be fully reintegrated[9].

CHAPTER II
MATERIALS

II.1 Introduction

This chapter covers the components and requirements used for collecting information, the type of microcontroller system to be used for data processing, and how the measurements are transferred to a remote computer.

II.2 Aquaponic System Components

II.2.1.Water Pump [10]

DC6–12V MINI Aquarium water Pump R385 is the perfect choice for any project that requires water to be moved from one place to another.

Figure II.1 R385 high lift water pump.

Features:

- Input voltage: DC12V
- Maximum height (Hmax):4–6m
- Maximum flowrate (Qmax):600–800L/h.

II.2.2.Boyu internal power submersible water pump and filter[11]

Figure II.2 Boyu internal power submersible water pump and filter.

Features:

- Power :6Watt.
- Voltage: 220 to 240V.
- Frequency: 50 Hz.
- Maximum height (Hmax):0.6m.
- Maximum flowrate (Qmax): 340L/h.
- Temperature:40°C

II.2.3 Polyvinyl chloride (PVC) pipes

In our aquaponic system we have chosen PVC pipes (Figure II .3) and transparent tubes(Figure II .4) for structural support and water distribution.

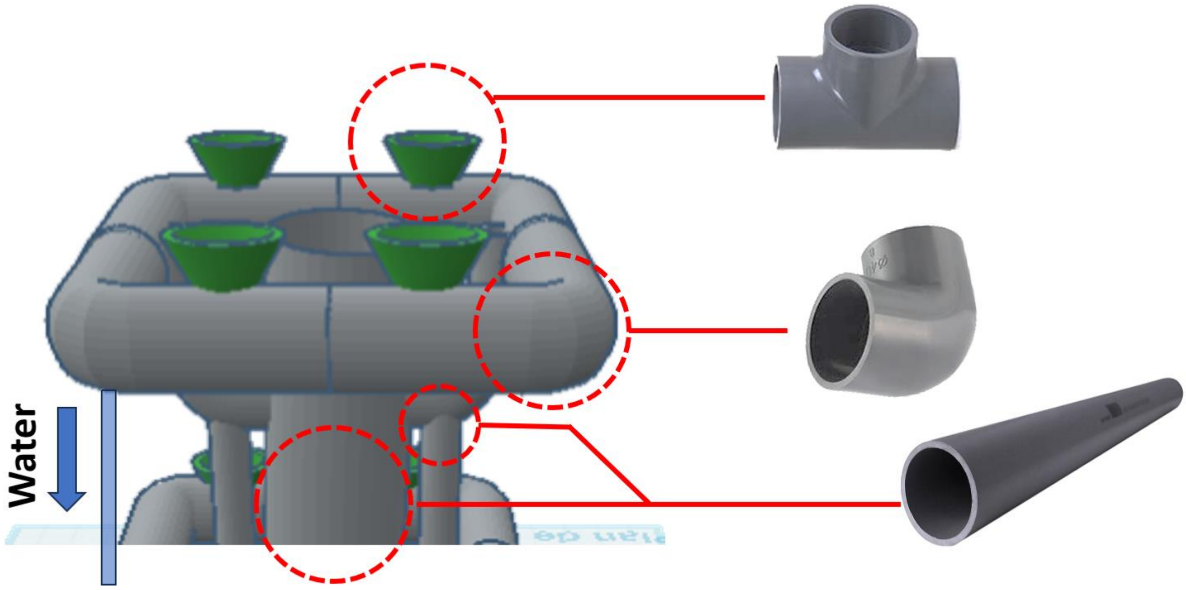

Figure II .3 Polyvinyl chloride (PVC) water pipes.

Figure II.4 Flexible transparent tubes.

II.2.4 Fish tank

In our first prototype, we chose transparent plastic fish tank in order to keep our system light.

II.3 Aquaponic system requirements

II.3.1 Sensors

A sensor is a system that detects and responds to multiple physical inputs and converting them into analogue or digital forms. The sensor transforms these variations into a form which can be utilized as a marker to monitor the device variable[12].

II.3.1.1 Ultrasonic sensor HC–SR04: It is an ultrasonic ranging module for embedded system projects. Ultrasonic ranging module HC– SR04 provides from 2 to 400 cm non–contact measurement function, the ranging accuracy can reach modules include ultrasonic transmitters, receiver and control circuit [13].Ultrasonic sensing/manipulate basics ultrasonic alerts are like audible sound waves, except the frequencies are plenty higher.

Our ultrasonic transducers have piezoelectric crystals which resonate to a desired frequency and convert electric power into acoustic power and vice versa [14].

- The trigger pin is given a supply of 5V i.e. high for about 10us to initiate the sensor module. A burst of 8 cycles of 40 kHz is transmitted and wait for the echo signal. [15].
- The ultrasonic sensor works using trigger and echo method.The transceiver module triggers and sends the signal to the water the water sends back an echo signal which is read by the echo i.e. the receiver module.
- The Ultrasonic sensor calculates the distance of the signal and returns the level of the water.
- The travel time value and the speed value allow the sensor to calculate the level of the water [16].

Figure II.5 HC–SRO4 SENSOR

II.3.1.2 pH Sensor:pH sensor is one of the most important tools for measuring pH and is commonly used in water quality monitoring. They use electrical potential to measure the pH of a solution. The sensor works by comparing the electric potential of a pH–sensitive system to the potential of a stable reference system.The sensing system uses a pH–sensitive glass bulb which changes voltage proportionally to the concentration of hydrogen ions. A sensing electrode measures the potential of the glass bulb. The sensor is filled with a potassium chloride (KCl) solution which conducts electricity between the pH–sensitive glass and the sensing electrode.

Figure II.6 pH electrode probe BNC with liquid pH between 0 and 14.

PH-4502CpH sensor [17]:

Features [18]:

- Power Supply: 5.00 V.
- Module Size: 43 × 32 mm (equivalent to 1.69 × 1.26 in).
- Measurement range: 0 – 14 pH.
- Temperature measurement range: 0 – 60 ℃.
- Accuracy: ± 0.1 pH (at 25 ℃).

- Response time: ≤ 1 min.
- Connectors:
  - BNC Connector for pH sensor – Industry–standard for pH probes.
  - pH2.0 interface (3–pin) – Often used to interface with microcontrollers like Arduino or ESP32.
- Additional Features:
  - Gain adjustment potentiometer – Common for calibration.
  - Power indicator LED – Indicates the module is powered.

pH Electrode Probe Features:

- Response time: 90% of the final reading in 1 second – This is typical for high–quality pH electrodes.
- Temperature range: 5 to 80 ℃ – This wider range is typical for standalone pH probes, ensuring functionality in diverse applications.
- Outer diameter: 12 mm – Standard size for many lab–grade pH electrodes.
- Range: pH 0–14 – Matches the universal pH scale.
- Iso-potential point: pH 7 – A standard feature for pH probes; this is the point where temperature variations have no effect on the sensor's output.

II.3.1.3 Temperature Sensor: Devices measuring the amount of thermal energy or coolness generated by an object or system. It makes it possible to detect any physical change in temperature producing an analog or digital signal.One of these sensors, is known as DS18B20 Sensor for getting temperature in liquids.

DS18B20 temperature sensor [19]

- Is a digital temperature sensor which follows 1–wire protocol and can measure temperature from -55°C to +125°C (-67°F to +257°F) with an accuracy of ±5%.
- Data received from single wire is in the ranges of 9bit to 12bit. DS18B20 follows One–wire protocol so we can control this sensor via a single pin of the Microcontroller. (We also have to provide GND). One–wire protocol is an advanced level protocol and each DS18B20 is equipped with a serial code of 64

bit which helps in controlling multiple sensors via a single pin of the microcontroller.

- In simple words, it assigns different addresses to all sensors attached and by calling the address, you can get that sensor’s value.

Figure II.7 DS18B20 temperature sensor.

Description: DS18B20 has 3 pins in total [19], which are:

- **Pin 1:** V_{cc} (connected to +5V).
- **Pin 2**: Data pin (it isone–wire from where we will get temperature value readings).
- **Pin 3:** GND (connected to the ground).
- SRAM and EEPROM memories
    - **SRAM:**it is volatile memory; it has data only in ON condition.
    - **EEPROM:**it isnon–volatile memory; it stores data in OFF condition.

DS18B20 temperature sensor works on the principle of direct conversion of temperature into digital value.Its main feature is changing its bit numbers according to change in temperature

II.3.2 Microcontrollers boards

II.3.2.1 ESP32: Definition, Architecture, and Applications

Definition:ESP32 is a series of low–cost, low–power system on a chip microcontroller with integrated Wi–Fi and dual–mode Bluetooth[20]. The ESP32 has become a catch–all term for a range of maker–friendly, Wi–Fi–capable development boards and chips. Simplifying connectivity with Wi–Fi networks and Bluetooth devices,it has become a staple of the maker community.It is a successor to the ESP8266 microcontroller[21].

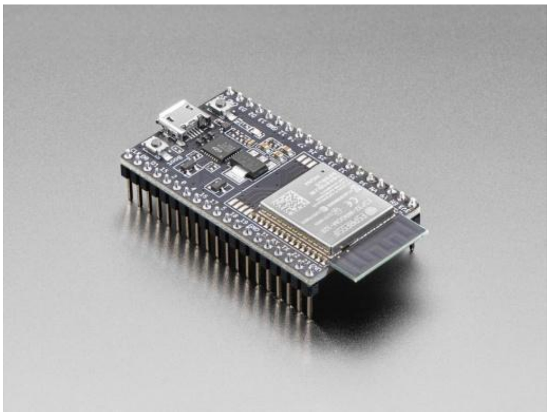

Figure II.8 ESP32 Microcontroller Board.

Features of the ESP32 Microcontroller Board [22]

- **Processors (CPU):** Xtensa dual–core, operating at 160 or 240 MHz and performing at up to 600 DMIPS Ultra-low power (ULP) co–processor.
- **Memory:**
  - 520 KB RAM.
  - 448 KB ROM.
- **Wireless connectivity:**
  - Wi–Fi: 802.11 b/g/n.
  - Bluetooth: v4.2 BR/EDR and BLE (shares the radio with Wi–Fi).
- **Peripheral interfaces:**
  - 34 × programmable GPIOs
  - 12–bit SAR ADC up to 18 channels
  - 2 × 8–bit DACs
  - 10 × touch sensors (capacitive sensing GPIOs)

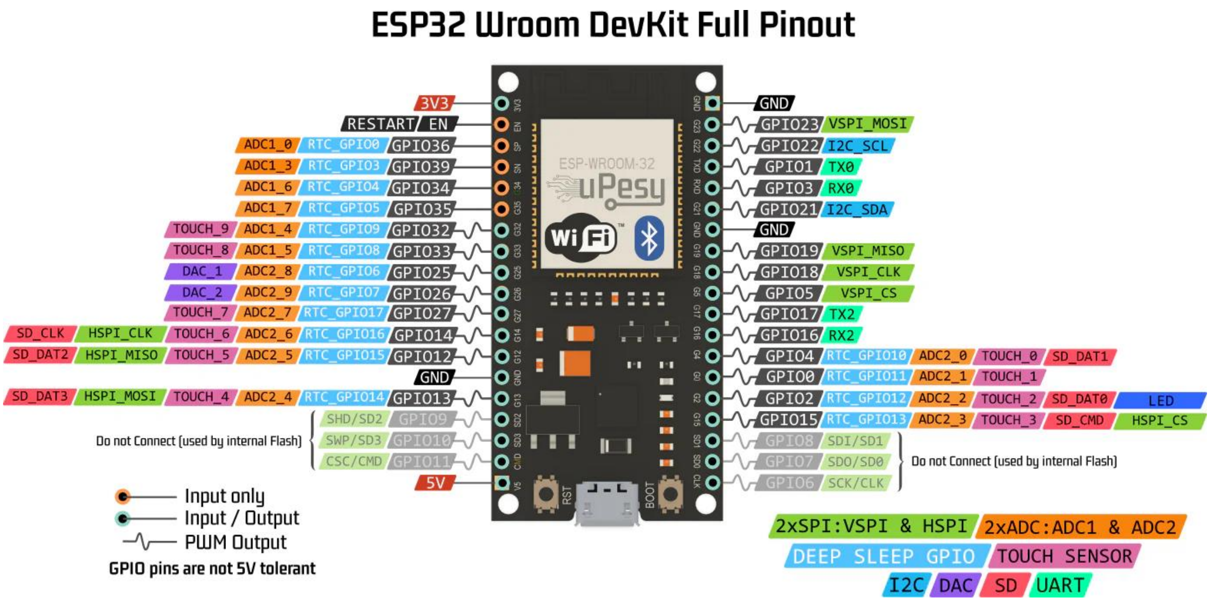

Figure II.9 Pinout diagram of the ESP32 –WROOM –32 Microcontroller.

II.3.2.2 ARDUINO UNO [23]

Definition of Arduino microcontrollers board: Arduino microcontroller is an open–source that can be easily programmed and can update at any time. First Arduino was introduced in 2005. It was originally designed for professionals and students to develop devices that can interact with the environment using sensors.Arduino microcontrollers have inputs and outputs that can be used to get information and based on received data Arduino can send output, as well, sending and receiving data via the internet using HTTP requests.

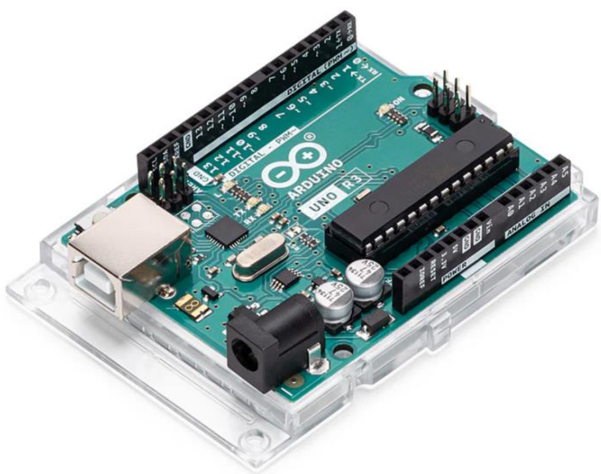

Figure II.10Arduino Uno R3 microcontroller.

Arduino microcontrollers board:it can be divided into two Hardware and Software.Arduino uses hardware known as the Arduino development board. Arduino software for developing the code is known as the Arduino IDE (Integrated Development Environment). Built–up with the 8–bit Atmel AVR microcontrollers that are manufactured by Atmel or a 32–bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE. The Arduino microcontroller is power up by an external power supply: of a DC voltage ranging from 9 – 12 volts.

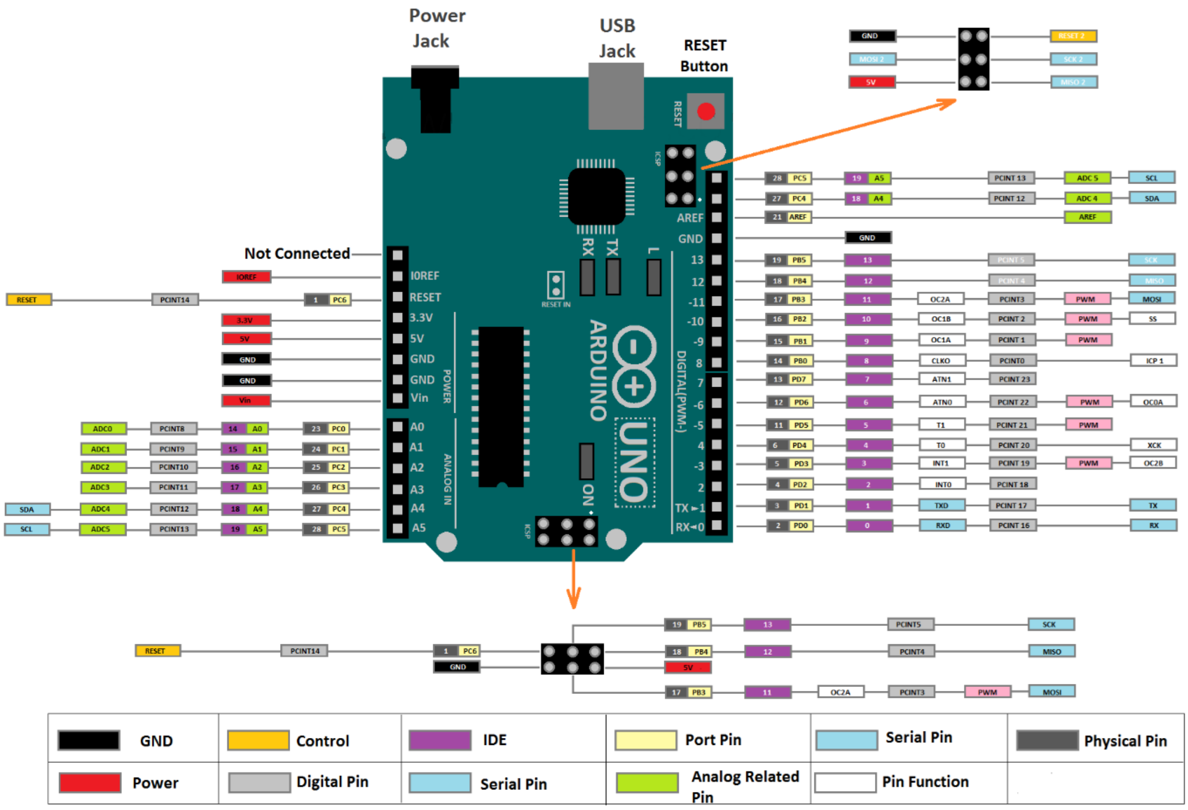

Figure II.11 Arduino UNO Pinout Diagram and Pin Configuration.

- **HARDWARE (Figure II.11):**
  - USB plug: This plug is a very important port in the Arduino board. It is used to upload a program to the microcontroller using a USB cable. The USB cable has a DC power of 5V that powers the Arduino board in cases when the external power supply is absent.
  - Internal programmer
  - Reset button

- Analog pins: These pins are used for the analog input/output. The number of analog pins also vary from board to board.
- Digital I/O Pins: These pins are used for the digital input/output. The number of these digital pins also varies from board to board.
- Power and GND Pins: There are pins on the development board that provides 3.3, 5 volts and ground through them.

- **SOFTWARE [24]:**
  - **Arduino IDE (**Integrated Development Environment).

II.3.2.3Arduino IDE (Integrated Development Environment)

Arduino IDE is an open-source software that is mainly used for writing and compiling the code into the Arduino Module. It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment. Figure II.12 represents an overview of the Arduino IDE interface.

Figure II.12 Arduino IDE interface overview.

Characteristics of Arduino IDE

- **Text editor:**This is where programming code can be written C/C++programming language.
- **Message area:** It displays an error and gives feedback on saving and exporting the code.
- **Text:**The console displays text output by the Arduino environment including complete error messages and other information
- **Console Toolbar:** This toolbar includes some buttons like Compile, Upload, New, Open, Save, and Serial Monitor.

II.3.3Programming basics

This section delves into the foundational programming techniques for creating Arduino sketches using the Arduino IDE.

II.3.3.1Programming basics*"void setup()"* and "*void loop()*" Functions

"setup()" **Function**

- Every Arduino sketch requires two primary functions: ***setup()*** and ***loop()***.
- The ***setup()*** function is the first process initiated when the Arduino board powers on.
- It is executed only once throughout the program's lifecycle and is responsible for setting up the initial state of the hardware.
- This function includes the configuration of pins as inputs or outputs and initializing peripherals.

Example Code: In this example, pin 2 is set as an input, while pin 3 is configured as an output. The Serial Monitor is initialized to facilitate data communication with peripheral devices.

```
void setup(){
  pinMode(2, INPUT);// Configure pin 2 as an input
  pinMode(3, OUTPUT);// Configure pin 3 as an output
  Serial.begin(9600);// Start serial communication at 9600
baud rate
}
```

***"loop()"* Function**

- The ***loop()*** function begins execution after the ***setup()*** function completes.
- As the name implies, ***loop()*** is designed to run indefinitely in a repetitive manner.
- This function contains the main logic that controls the behavior of the Arduino system and executes continuously to maintain the circuit's operation.

Example Code: In this example ***digitalRead(2)*** reads the state of the button connected to pin 2 (***HIGH*** if pressed, ***LOW*** if not). Then, if ***buttonState***is***HIGH***), which means checking if the button is pressed. Finally, turns the LED on if the button is pressed or turns the LED off if the button is not pressed using the function ***digitalWrite(3, state***).

```
void loop(){
int buttonState = digitalRead(2);// Read the state of the button connected to pin 2

if(buttonState == HIGH){// If the button is pressed
    digitalWrite(3, HIGH);// Turn the LED on
}else{// If the button is not pressed
    digitalWrite(3, LOW);// Turn the LED off
}
}
```

II.4Conclusion

In this chapter, we outlined the programming structures and essential components selected for our aquaponic system. These components not only ensure precise measurements but also facilitate seamless connectivity, enabling the system to function efficiently and reliably.

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CHAPTER III

CONCEPTION OF AQUAPONIC SYSTEM

Chapter III: Conception of aquaponic system

III.1 Introduction

Since we have covered all the important parameters in the previous chapters for the aquaponic system, we now move on to the creation, coding, and design of our own aquaponic system.

Tinkercad: An introduction to versatile CAD software

(Adapted from Journal of Engineering Education Transformations, Volume 34, January 2021, Special Issue, eISSN 2394–1707)

Tinkercad is a free, browser-based computer-aided design (CAD) software program that serves as a versatile tool for individuals and organizations across various industries. Its intuitive interface and feature-rich platform make it an invaluable resource for professionals in the manufacturing, healthcare, architecture, and promotional industries. Tinkercad not only simplifies the design process but also enables users to easily edit and modify files, whether recreating existing designs or developing entirely new ones.One of the most compelling aspects of Tinkercad is its user-friendly design, which supports both beginners and experienced users. This flexibility makes it a popular choice for educators, students, and professionals alike. As a free software, Tinkercad eliminates the financial barriers often associated with CAD tools, enabling users to access powerful design features without the need for costly licenses or subscriptions.

Features of Tinkercad

- 2D and 3D design capabilities: Tinkercad provides a robust platform for creating, modifying, and improving both 2D and 3D designs. Users can work with a library of modifiable shapes and objects to build intricate designs from scratch. The software allows the combination of shapes, the addition of gestures, and the stacking of blocks to produce highly detailed 3D models. This makes Tinkercad an excellent tool for prototyping in fields like engineering, architecture, and product design.
- Circuit design and simulation:In addition to its design features, Tinkercad enables users to create and simulate electronic circuits. By using adjustable traces and shapes, designers can model circuits with precision. This feature is particularly useful for students and educators, as it provides a practical and accessible way to understand circuit design principles.

- Code blocks for dynamic designs: Tinkercad includes a unique code blocks feature, which allows users to generate dynamic designs such as animations and GIFs. This capability is especially beneficial for advertising and marketing professionals looking to create visually engaging content for campaigns.
- Predefined interface presets:To ensure a smooth learning curve, Tinkercad offers interface presets that help new users quickly get started. These presets simplify the onboarding process and provide a solid foundation for exploring the software's extensive features.

Figure III.1 Open building area for design circuit.

III.2 3D design usingTinkercad

We used Tinkercad to create a 3D design for our project, the 3D design of our prototype is shown in Figure III.2.

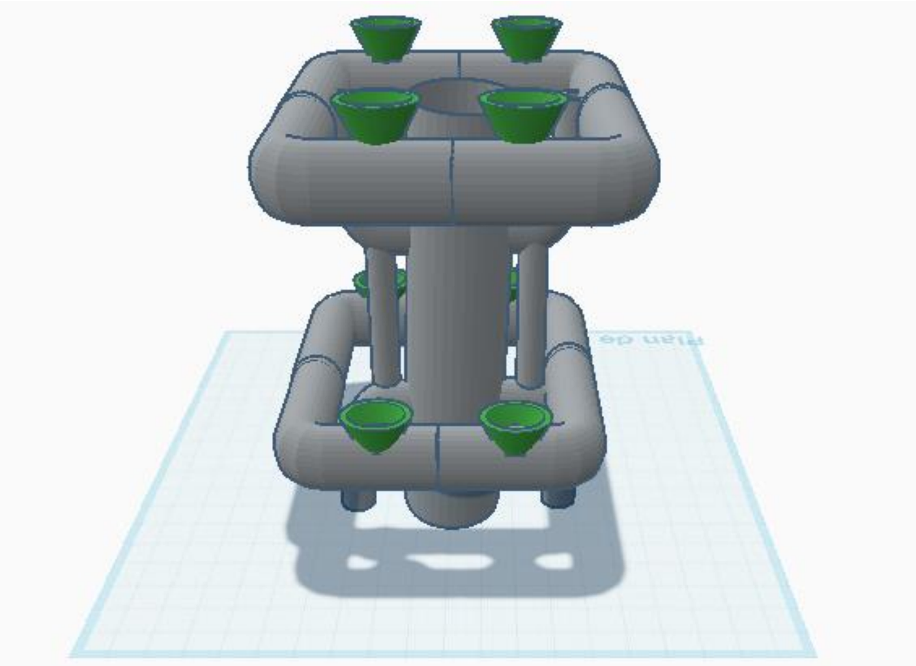


Figure III.2. 3D design of the aquaponic system.

The sensors have been strategically placed inside PVC pipes, positioned centrally to ensure accurate measurements and optimal functionality within the system (Figure III.3)

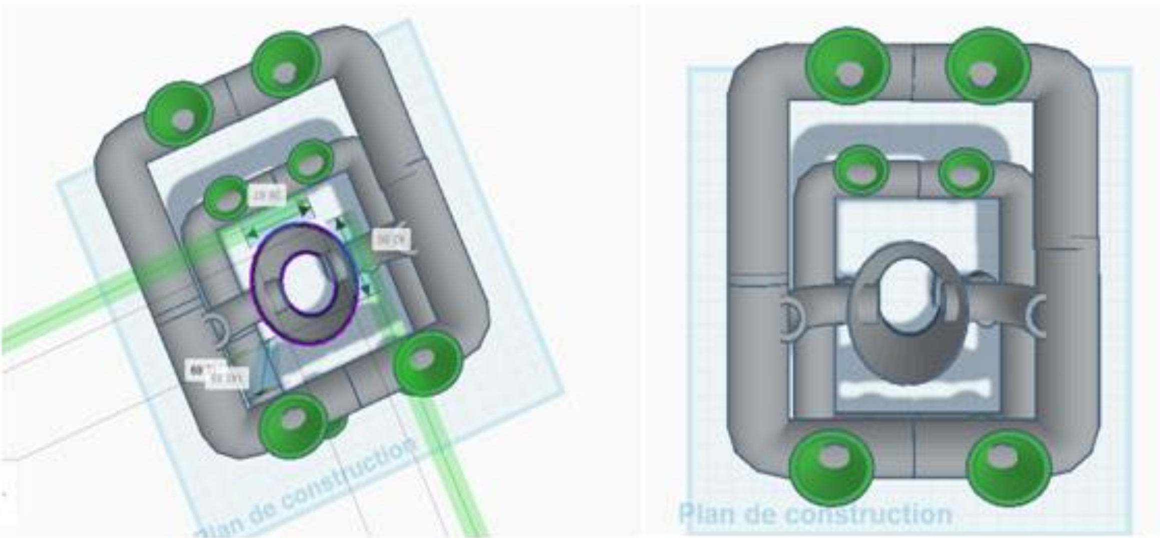


Figure III.3–Sensors and components position.

III.3 Coding for water level monitoring

For the implementation of coding techniques for monitoring water levels, we used the HC-SR04 ultrasonic sensor module. The focus is on utilizing the sensor to measure and maintain optimal water levels in tanks, ensuring the well-being of plants and aquatic life.

III.3.1 The HC-SR04 module in water level monitoring

III.3.1.1 Overview of the HC-SR04 module

The HC-SR04 ultrasonic sensor was chosen for its ability to accurately measure distances. While traditionally used for distance measurement, this project adapts it to monitor water levels in tanks. The sensor ensures that water levels are maintained within appropriate ranges, critical for sustaining the health of plants and fish in aquaponic systems.

III.3.1.2 System montage

Figure III.4 provides a detailed visual representation of the HC-SR04 sensor setup.

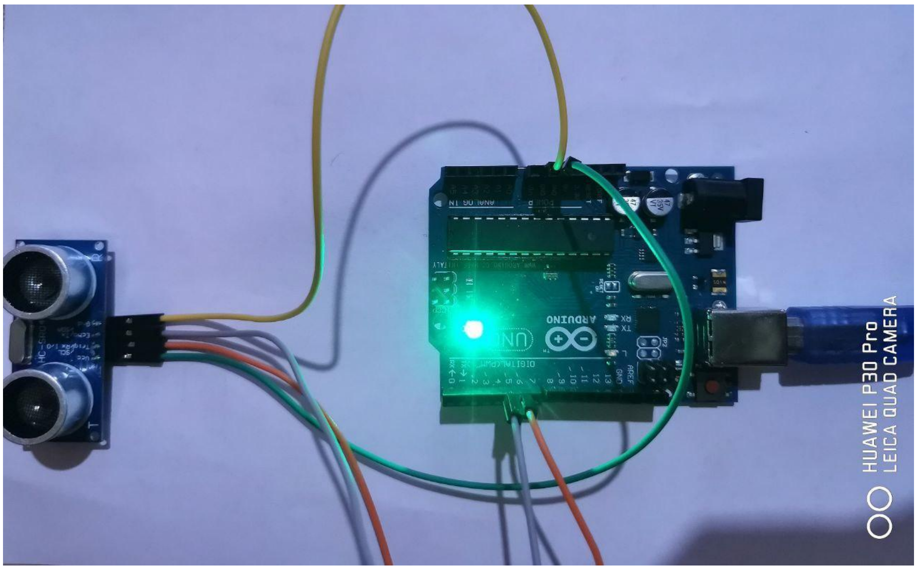


Figure III.4. The physical assembly of the HC-SR04 module.

III.3.1.3 Simulation and schematic view

Using Tinkercad, the HC-SR04 circuit is simulated and visualized to ensure functionality and accuracy in design (Figure III.5).

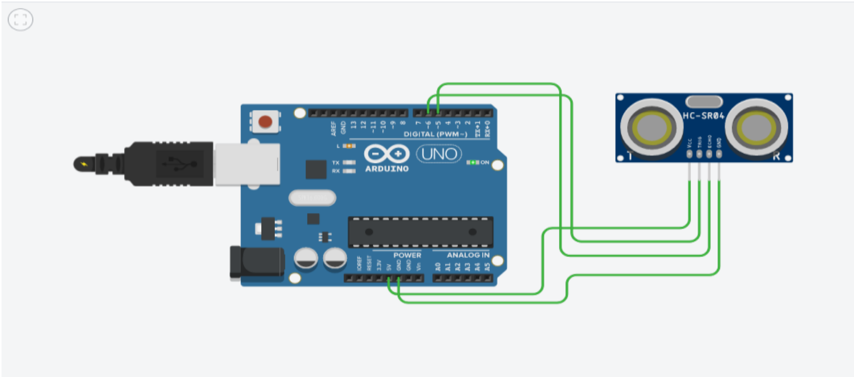


Figure III.5 Simulation of the HC-SR04 circuit, illustrating the connection of components.

The corresponding schematic view of the wiring and electrical connection of HC-SR04 circuit is illustrated in Figure III.6.

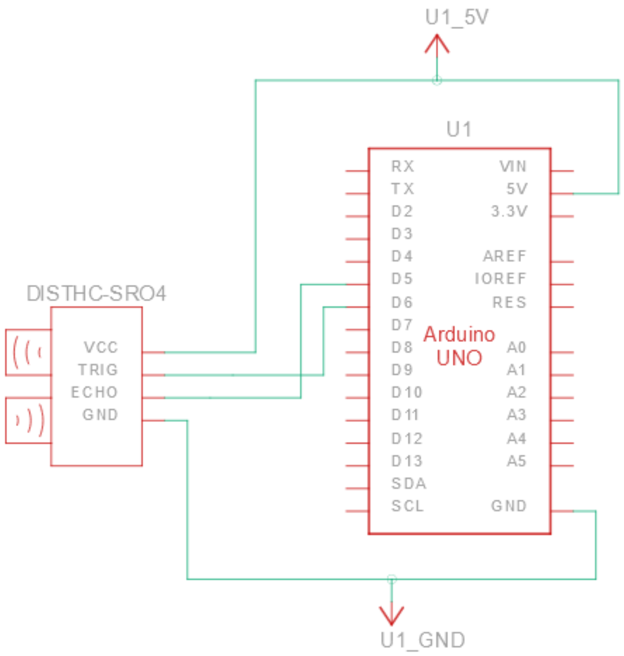


Figure III.6 Schematic view, showcasing the wiring and electrical connections for the module.

III.3.1.4 Coding and results for the HC-SR04 module

This section delves into the programming logic and outcomes of the HC-SR04 implementation.Key lines of code enable the sensor to operate effectively and gather distance measurements. The program Arduino for controlling HC-SR04 module is shown below:

```
// Programme de test HC-SR04

#define echoPin 5 // Broche Echo (réception)
#define trigPin 6 // Broche Trigger (émission)
long duree, distance;// Variables pour la durée et la distance mesurée

void setup(){
  Serial.begin(9600);// Initialiser la communication série à 9600 bauds
  pinMode(trigPin, OUTPUT);// Définir la broche Trigger comme sortie
  pinMode(echoPin, INPUT);// Définir la broche Echo comme entrée
}

void loop(){
// Nettoyer la broche Trigger en la mettant à LOW
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

// Envoyer une impulsion HIGH de 10 microsecondes sur la broche Trigger
digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

// Lire la durée de l'impulsion de retour sur la broche Echo
  duree = pulseIn(echoPin, HIGH);

// Calculer la distance en centimètres
  distance = duree /58.2;// La durée est divisée par 58.2 pour obtenir la
distance en cm

// Afficher la distance dans le Moniteur Série
  Serial.print("Distance : ");
  Serial.print(distance);
  Serial.println(" cm");

// Attendre 50 ms avant la prochaine mesure
delay(50);
}
```

Distance between the ultrasonic sensor and the water level was measured and showed in Figure III.7.Outputs from the HC-SR04 sensor verify the system's accuracy in measuring water levels.

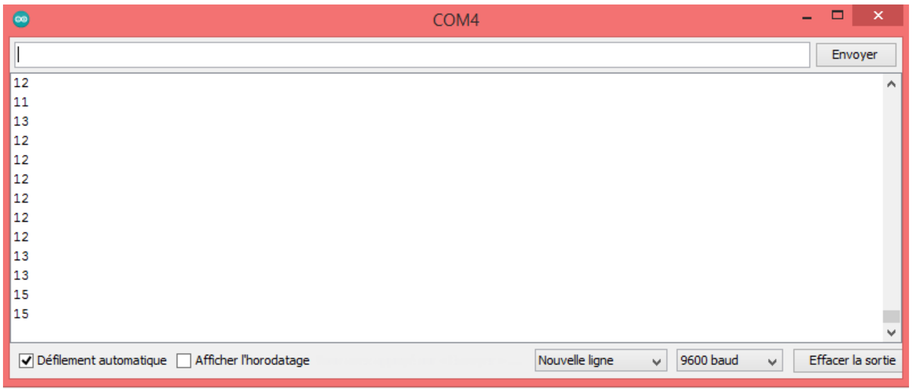


Figure III.7Distance between the ultrasonic sensor and the water level.

III.3.2 DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor widely used for accurate temperature measurements in various applications. Its simplicity, low cost, and capability to interface with microcontrollers make it an ideal choice for monitoring environmental conditions in projects such as aquaponics, greenhouses, and other controlled systems.

III.3.2.1 Physical Setup (Montage)

The physical assembly of the DS18B20 sensor involves connecting it to the microcontroller using the One-Wire protocol.

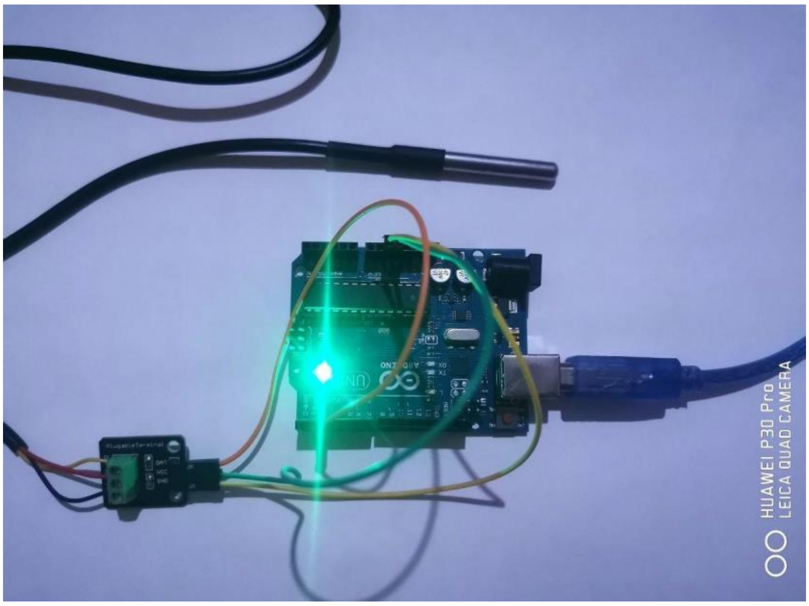


Figure III.8DS18B20 Montage – Displays the physical connections of the DS18B20 sensor to the system, including the data pin, power supply (V_{cc}), and ground (GND).

III.3.2.2 Simulation and Schematic View

Using Tinkercad, the circuit for the DS18B20 sensor is simulated and its schematic representation is provided (Figure III.9). This step ensures that the connections are correct before deploying the hardware.

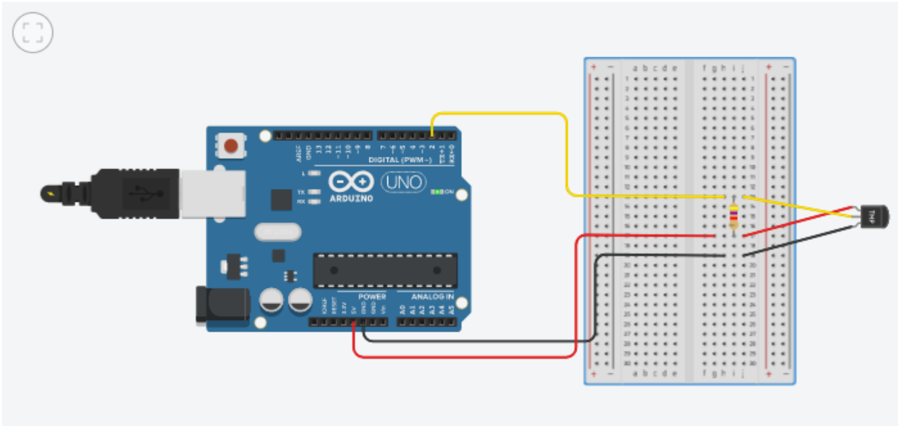


Figure III.9Simulation of the DS18B20 circuit.

Schematic view of the DS18B20 circuit, illustrating the wiring of the sensor to the microcontroller and pull-up resistor is shown in Figure III.10.

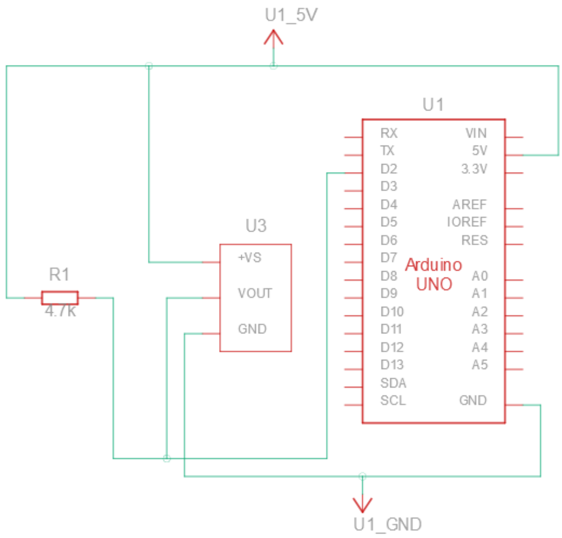


Figure III.10Schematic view of the DS18B20 circuit, illustrating the wiring of the sensor to the microcontroller and pull-up resistor.

III.3.2.3 DS18B20 Code and result

The following code is used to test the DS18B20 sensor, collect temperature data, and display the results. The program uses the OneWire and DallasTemperature libraries to simplify communication with the sensor.

```
#include <OneWire.h>// Bibliothèque pour communication One-Wire
#include <DallasTemperature.h>// Bibliothèque pour capteur DS18B20

#define ONE_WIRE_BUS 2            // Broche connectée au capteur DS18B20
OneWire oneWire(ONE_WIRE_BUS);// Initialiser One-Wire sur la broche définie
DallasTemperature    sensors(&oneWire);//    Initialiser    les    capteurs
DallasTemperature

void setup(){
Serial.begin(9600);// Démarrer la communication série
  sensors.begin();// Initialiser les capteurs
  Serial.println("Demarrage du capteur DS18B20...");
}

void loop(){
  sensors.requestTemperatures();// Demander une lecture de température
float temperatureC = sensors.getTempCByIndex(0);// Lire la température (en
°C)
float temperatureF =(temperatureC *9.0/5.0)+32.0;// Convertir en °F

// Afficher les résultats dans le Moniteur Série
Serial.print("Temperature mesuree : ");
  Serial.print(temperatureC);
  Serial.println(" °C");

  Serial.print("Temperature en Fahrenheit : ");
  Serial.print(temperatureF);
Serial.println(" °F");

  delay(1000);// Attendre 1 seconde avant la prochaine mesure
}
```

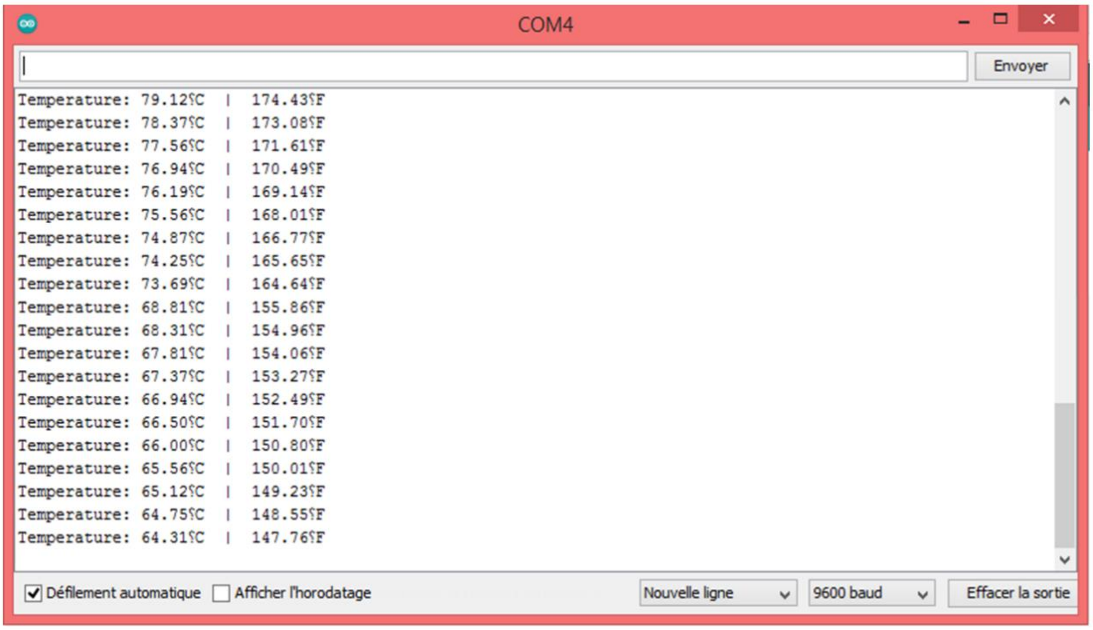


Figure III.11Measured Result by the Sensor – Displays the values measured by the sensor, as they appear in the Serial Monitor.

The measured result by the DS18B20 sensor are displayedin Figure III.11.

III.3.3 pH Sensor (pH meter)

The pH sensor plays a crucial role in maintaining the health of both the aquaculture and hydroponic components of the aquaponic system. By continuously measuring the pH levels of the water, the sensor helps in ensuring that the water quality remains within the optimal range for plant growth and fish health. A stable pH level is essential as it affects nutrient availability and fish metabolism.

III.3.3.1 Diagram of pH Circuit and Schematic View

The pH circuit consists of a sensor, signal conditioning, and processing elements. The sensor detects the pH level of the water, converting it into an analog signal that can be read by a microcontroller such as Arduino.Figure III.12 shows diagram that illustrates the components and connections of the pH sensor circuit.

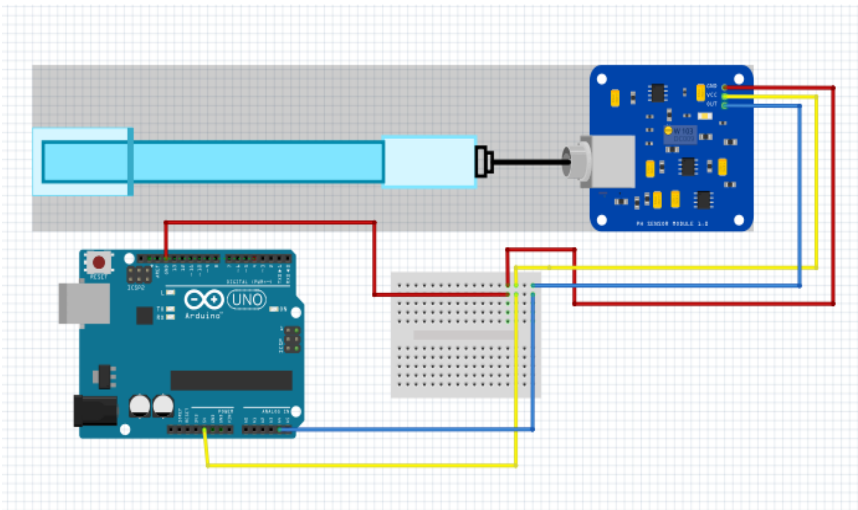


Figure III.12Diagram of the pH sensor circuit.

The schematic view (Figure III.13) shows the detailed layout of the pH sensor circuit, including the sensor’s interface with the Arduino for data acquisition and processing.

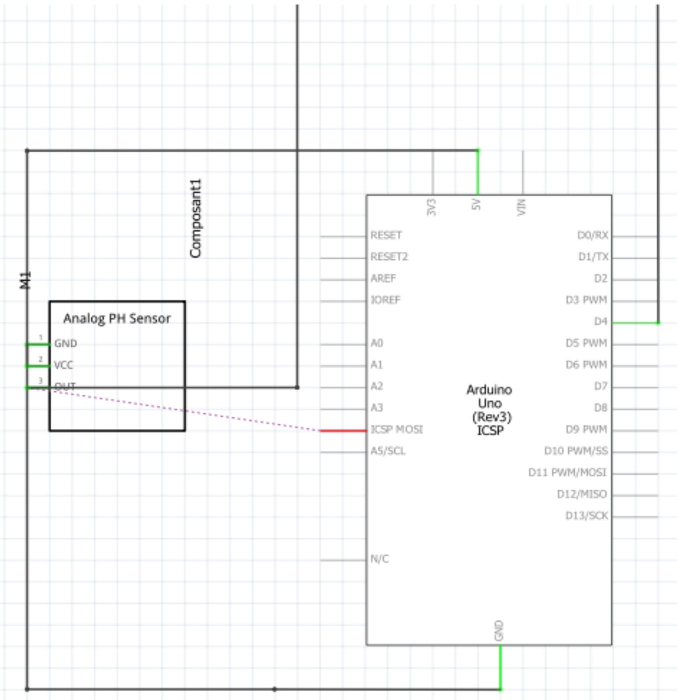


Figure III.13Schematic view of the pH electronic circuit.

III.3.3.3 Source code for Arduino

To interface the pH sensor with an Arduino, a simple code is used to read the analog signal and convert it to a corresponding pH value. The code includes functions for analog input and output, with calculations to convert the sensor's output to a readable pH value.

```
#include "DFRobot_pH.h"// Inclusion de la bibliothèque pour le capteur de pH
#define PH_PIN 32  // Définition du pin analogique où le capteur de pH est connecté

float voltage, phValue, temperature =25;// Déclaration des variables pour la tension, la valeur du pH et la température
DFRobot_pH  ph;// Création d'un objet de la classe DFRobot_pH pour le capteur de pH

void setup()
{
  Serial.begin(9600);// Initialisation de la communication série à 9600 bauds
  ph.begin();// Initialisation du capteur de pH
}

void loop()
{
staticunsignedlong timepoint = millis();// Déclaration d'une variable pour mesurer le temps écoulé
if(millis()- timepoint >10000){// Si 10 secondes se sont écoulées
```

```
    timepoint = millis();// Réinitialisation du compteur de temps

//  temperature  =  readTemperature();   //  Code  commenté  pour  lire  la
température si nécessaire

    voltage  =  analogRead(PH_PIN)/1024.0*5000;//  Lecture  de  la  valeur
analogique du capteur, conversion en tension (en mV)
    phValue = ph.readPH(voltage, temperature);// Lecture du pH à partir de
la tension et de la température

// Affichage des résultats dans le moniteur série
    Serial.print("temperature: ");// Affiche la température
    Serial.print(temperature,1);//  Affiche  la  température  avec  1  chiffre
après la virgule
    Serial.print("^C pH:");// Affiche l'indication "pH:"
}

// Affichage de la valeur du pH avec 2 décimales
  Serial.println(phValue,2);
  ph.calibration(voltage,  temperature);//  Effectue  la  calibration  du
capteur en fonction de la tension et de la température
}
```

This Arduino code reads the pH level of water using a pH sensor and displays the values on the serial monitor.It includes library for the pH sensor (DFRobot_pH.h). The variable voltage stores the voltage read from the pH sensor, phValue stores the calculated pH value and temperature was initialized to 25°C. The loop runs every 10 seconds, reads the sensor value, and converts it to voltage.The pH value is calculated using ph.readPH(voltage, temperature) and displayed along with the temperature. Finally, the sensor is calibrated with ph.calibration(voltage, temperature) to ensure accurate readings.

III.4 Blynk IoT

Blynk is a drag–and–drop programming system for the Internet ofThings (IoT) that makes it much easier to develop IoT applications. Not only does it enable building programs using a simple drag–and–drop interface, but it also standardizes the connection of devices such as sensors and motors, ensuring that the necessary drivers are in place. In this way, it simplifies both the programming and hardware setup.

To get started, you simply need to install the Blynk agent from the website. The Arduino must have an Internet connection which requires either an Ethernet or Wi–Fi shield. It is also needed to set up the Arduino IDE on a PC or Mac, and connect it to the Arduino via USB. This setup is quite standard, and all of the standard Arduino models are supported, including the more recent ones.The Blynk dashboard (Figure III.14) provides an intuitive interface for managing and monitoring IoT devices. It allows users to control and visualize data from connected sensors and devices in real-time through a simple drag-and-drop programming interface.

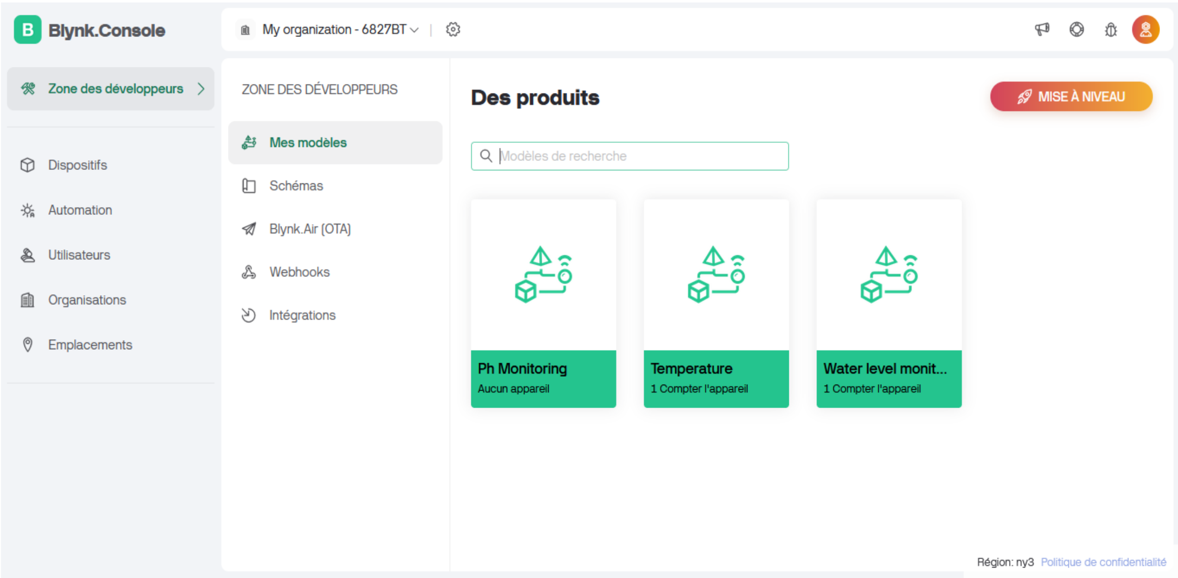
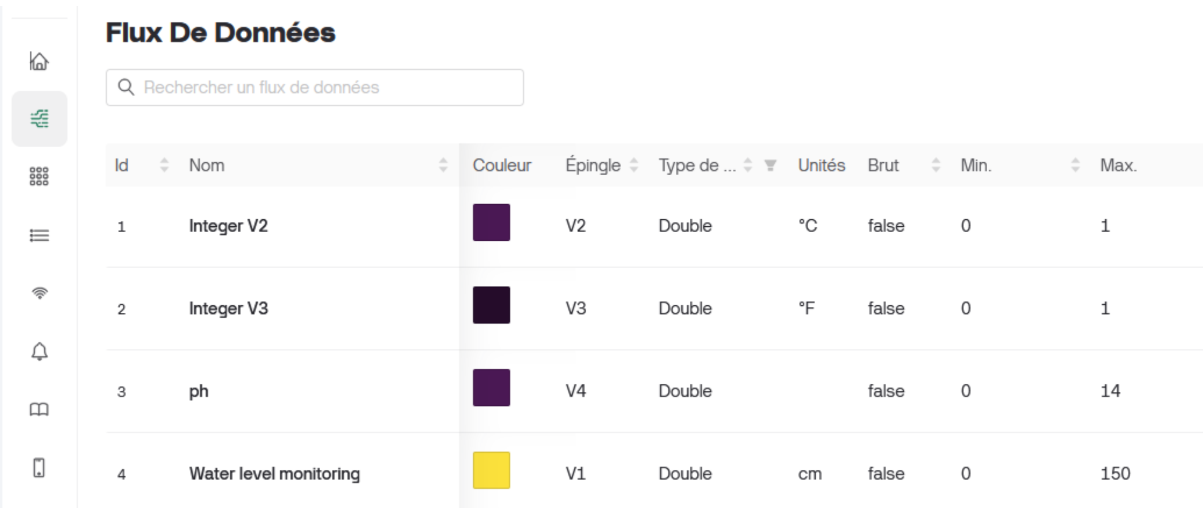


Figure III.14 Blynk dashboard.

The data stream of sensor readings in the aquaponic system displays real-time measurements from various sensors, such as pH and temperature, helping to monitor and optimize conditions for both plant and fish health in the system (Figure III.15).


Flux De Données

Rechercher un flux de données

Id	Nom	Couleur	Épingle	Type de ...	Unités	Brut	Min.	Max.
1	Integer V2		V2	Double	°C	false	0	1
2	Integer V3		V3	Double	°F	false	0	1
3	ph		V4	Double		false	0	14
4	Water level monitoring		V1	Double	cm	false	0	150

Figure III.15 Data stream of sensors readings in the aquaponic system.

III.5 Electrical circuit diagram created with Fritzing

The electrical circuit diagram for the aquaponic system is designed using Fritzing, a user-friendly tool for creating visual circuit schematics. This diagram provides a clear representation of how various components, such as sensors, pumps, and controllers, are interconnected within the system.

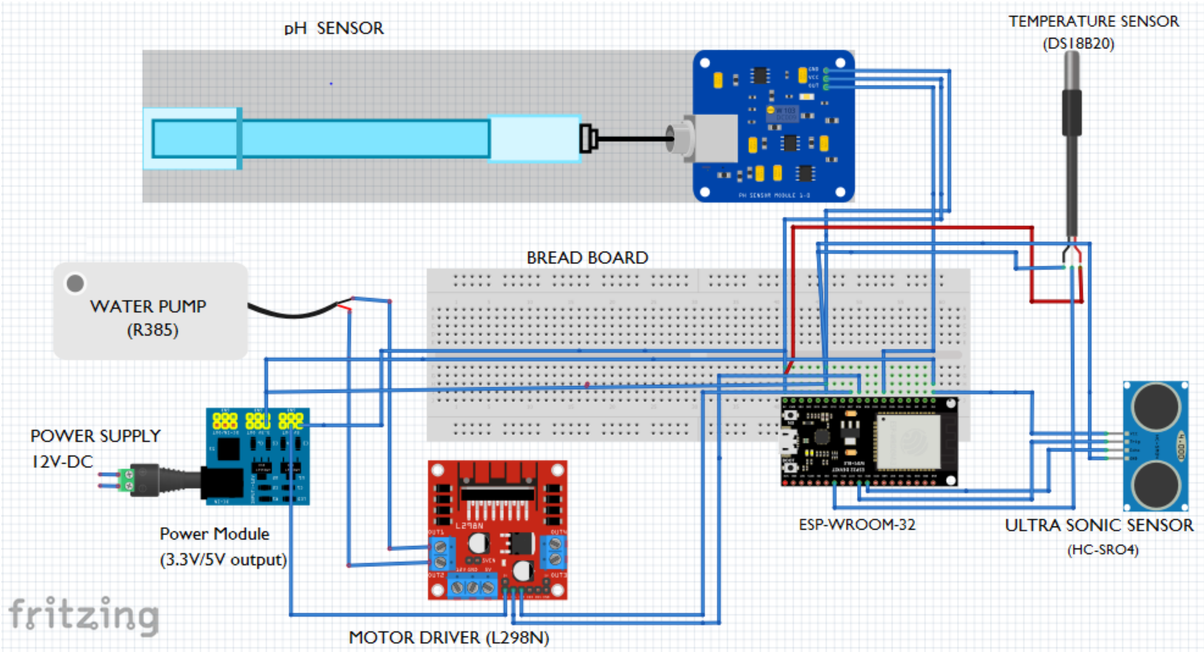


Figure III.16Electrical circuit diagram created with Fritzing.

III.5.1 Wire connections

The wire connections in the aquaponic system are carefully designed to integrate various components with the ESP32 and other power sources, ensuring smooth operation and reliable data transmission. The HC-SR04 Ultrasonic Sensor, responsible for measuring distance, is connected with its Vcc pin to a 5V power source and its Gnd pin to the ground. The Echo pin of the sensor is linked to pin G16 on the ESP32, while the Trig pin is connected to pin G4 to trigger distance measurement signals.For temperature measurement, the DS18B20 Temperature Sensor is used. It requires a Vcc connection to a 5V power source and a Gnd pin to ground. The Data pin of the sensor is connected to pin G13 on the ESP32, enabling real-time temperature monitoring in the system. This sensor plays a vital role in ensuring the optimal environment for both fish and plants in the aquaponic setup.

Table III.1. Wire Connections.

Component	Connection	Esp32 Pin/Power Source
HC–SR04 Ultrasonic Sensor	V_{cc}	5V
	Gnd	Gnd
	Echo	G16
	Trig	G4
DS18B20 Temperature Sensor	V_{cc}	5V
	Gnd	Gnd
	Data	G13
Water Pump (R385 Dc 12V)	Red Wire	Out1 (L298n)
	Black Wire	Out2(L298n)
L298n Motor Driver	In1	G12
	In2	G14
	Gnd	Gnd(Power Module)
	5V	5V (Power Module)
Power Module (3.3V /5V)	GND	Gnd
	5V	5V
pH Sensor	V_{cc}	5V
	Gnd	Gnd
	Analog Output	A0
Power Supply(12V DC)		Input To Power Module(3.3/5V)

The Water Pump (R385 DC 12V) is essential for circulating water in the system. Its Red Wire is connected to Out1 (L298n), while the Black Wire is connected to Out2 (L298n). This pump's operation is managed by the L298n Motor Driver, which controls the motor’s direction and speed based on inputs from the ESP32. The motor driver’s In1 is linked to pin G12, and In2 is linked to pin G14 on the ESP32. The Gnd pin of the motor driver is connected to the Gnd of the power module, while its 5V pin is connected to the 5V of the power module.The Power Module (3.3V/5V) is critical for providing the necessary voltage to power the system. Its Gnd pin is connected to the ground, and its 5V pin is connected to the 5V power input of the components like the motor driver and pH sensor.

Finally, the pH Sensor plays a critical role in measuring the water's pH level. It connects Vcc to the 5V power source, Gnd to ground, and its Analog Output to pin A0 on the ESP32, allowing the system to monitor and maintain ideal pH levels for both fish and plants. The Power Supply (12V DC) provides the required input to the power module to ensure the entire system operates effectively.

III.5.2 Implementation of the aquaponic system circuit with ESP32 and sensor connections

The implementation of the aquaponic system circuit involves connecting various sensors and the ESP32 microcontroller to enable efficient monitoring and control. The connections are made to ensure accurate data collection from the sensors, including the pH, temperature, and distance sensors, as well as control of the water pump through the motor driver. Figure III.20 illustrates the hardware implementation, showcasing how each component is connected to the ESP32.

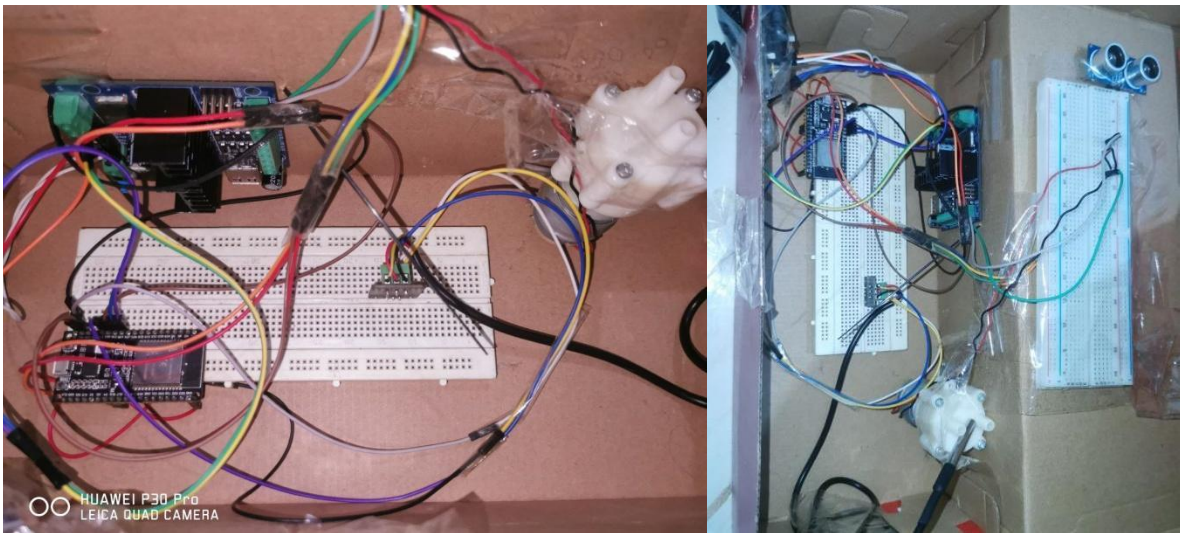


Figure III.17Implementation of the aquaponic system circuit with ESP32 and sensor connections

Conclusion

This chapter covered the design and placement of components in the aquaponic system, including 3D modeling and layout. It also detailed the sensor connections, and their integration with the Blynk IoT app for remote monitoring and control, demonstrating how the sensors and components are monitored and controlled remotely. The testing phase ensured the reliability and accuracy of the system.

CONCLUSION AND FUTURE PERSPECTIVES

Conclusion

This thesis highlights aquaponics as a forward-thinking, sustainable farming method that integrates the strengths of hydroponics and aquaculture into a unified system. By addressing global issues of food security and environmental sustainability, aquaponics offers an innovative and eco-friendly solution. Its efficient water use, waste reduction, and the symbiotic relationship between fish and plants make it particularly effective for areas facing resource shortages or harsh climatic conditions.

In conclusion, aquaponics has the potential to revolutionize traditional agricultural practices, providing a sustainable and globally impactful alternative for securing food resources amidst today's environmental and economic challenges.

Perspectives

The future of aquaponics is promising, with opportunities to enhance energy efficiency, develop new crop and aquaculture integration models, and reduce system setup costs. Incorporating advanced technologies like IoT and AI will facilitate more precise and automated system management. Moreover, adopting aquaponics in urban areas and developing regions can address water and space constraints. Ultimately, raising awareness and equipping local communities with knowledge and skills will be vital in advancing this sustainable farming method to tackle global food security challenges effectively.

ANNEXE

Annex A:

A.1. Business model for our aquaponic system

Key Partners	Key Activities	Key Resources	Value Propositions
- E-commerce platforms	- Manufacture and assembly of the system	- Technology and design for the aquaponic system	- Fresh and healthy food production (vegetables and fish) at home
- Garden and DIY stores	- Marketing and sales	- Materials (equipment, plants, fish, etc.)	- Portable and compact system suitable for small spaces
- Educational institutions (schools, universities)	- Customer support (online services, guides)	- Production facilities and workforce	- Eco-friendly food production through fish waste recycling
- Restaurants and fine groceries	- Development of tutorials and guides	- Expertise in aquaponics and gardening	- Easy-to-use and maintain system for beginners and experts alike
- Suppliers of fish feed and plants	- Customer community engagement (forums, loyalty programs)	- Online platforms for sales and communication	
Customer Segments	**Channels**	**Customer Relationships**	**Revenue Streams**
- Urban gardening enthusiasts (limited space)	- Online store and e-commerce platforms	- Online customer service (website, social media)	- Sales of the aquaponic system
- Health-conscious families	- Garden and DIY stores	- Tutorials and usage guides	- Sales of supplies (fish food, plants, etc.)
- Schools and universities	- Partnerships with schools and universities	- Community forum for shared experiences	- Subscription services (maintenance advice, technical support)
- Restaurants and fine groceries	- Partnerships with restaurants and fine groceries	- Loyalty programs for returning customers	- Licensing the technology to other businesses for manufacturing and sales

Cost Structure
- Material costs (for system production)
- Labor costs (for assembly, packaging)
- Marketing and sales costs
- Customer service and support costs

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

عبد الحميد إبن باديس

حاضنة الأعمال مستغانم

النموذج التجاري المفصل

المشكلة المراد حلها: يشكل نقص المياه العذبة تحديًا كبيرًا في العديد من مناطق العالم، مما يهدد استدامة الزراعة وتربية الأسماك. تعتبر أنظمة الزراعة المائية والأكوابونيك حلولًا واعدة لهذا التحدي. ومع ذلك، غالبًا ما تكون الأنظمة المتاحة كبيرة جدًا أو مكلفة للغاية للاستخدام في المشاريع الصغيرة أو المنزلية. المشروع المقترح يهدف إلى تطوير نظام أكوابونيك محمول وصغير الحجم، يعمل بتكلفة منخفضة، ويعتمد على التقنيات الحديثة لدمج الزراعة المائية مع تربية الأسماك في بيئة مغلقة، مما يعزز من إنتاج الغذاء بشكل مستدام ويقلل من استهلاك المياه.

/1القيمة المعروضة: Valeur proposée

- **إنتاج غذاء مستدام:**توفير حل موثوق ومستدام للإنتاج الغذائي باستخدام تقنيات أكوابونيك صغيرة الحجم لزراعة النباتات وتربية الأسماك في بيئة مغلقة.
- **الكفاءة المائية:**يقلل من استهلاك المياه بشكل كبير مقارنة بالزراعة التقليدية، مما يجعله مناسبًا للبيئات ذات الموارد المائية المحدودة.
- **التشغيل السهل:**تصميم بسيط وسهل الاستخدام للصيانة والتشغيل.
- **حلول مدمجة:**النظام يعزز من الإنتاج الغذائي في المنازل والمزارع الصغيرة مع الحد الأدنى من التكلفة.
- **قابلية التكيف:**يتكيف مع أنواع مختلفة من المحاصيل والأسماك بناءً على احتياجات المستخدم.

1/1القيمة التي نقدمها للعميل:

- **منتج مبتكر:**تصميم فريد يقدم للعميل طريقة مبتكرة ومستدامة للزراعة.
- **خفض التكاليف:**يوفر على العملاء تكاليف الري وتغذية الأسماك التقليدية.
- **سهولة في الاستخدام:**نظام سهل التشغيل مع الحاجة إلى الحد الأدنى من التدخل البشري.

1/2المشاريع الأخرى التي استهدفت نفس المشكلة والتي جرى تنفيذها: الأنظمة الحالية تقتصر في الغالب على حلول كبيرة جدًا أو باهظة الثمن وغير قابلة للتنفيذ على نطاق صغير. علاوة على ذلك، لا توفر أنظمة أكوابونيك صغيرة محمولة بأسعار معقولة تدير عمليات مدمجة بفعالية.

2/فئات الزبائن: Catégories de clients

- **الأسر والمنازل:** الأفراد الذين يسعون للحصول على حلول زراعية صغيرة للاستهلاك الذاتي.
- **المزارع الصغيرة:** المزارعون الذين يحتاجون إلى حلول فعّالة من حيث التكلفة لإنتاج محاصيل طازجة وأسماك.
- **المدارس والمؤسسات التعليمية:** المؤسسات التي ترغب في تعزيز برامج التعليم الزراعي والبيئي.
- **المجتمعات الريفية:** المناطق التي تعاني من مشاكل في الحصول على مصادر المياه التقليدية.

3/علاقات الزبائن: Relation client

- **دعم مخصص:** تقديم دعم فني مستمر من خلال الإرشادات والبرامج التعليمية للمساعدة في استخدام النظام بفعالية.
- **خدمة ما بعد البيع:** تقديم خدمات صيانة دورية وتحديثات لمنتجاتنا لضمان استمرار الأداء الأمثل.
- **استجابة فورية:** التواصل مع الزبائن لمعرفة ملاحظاتهم واحتياجاتهم والعمل على تحسين المنتج بناءً على هذه الآراء.
- **حلول مخصصة:** تصميم حلول تناسب الاحتياجات الخاصة للعميل، مثل تخصيص الأنظمة وفقًا لنوع المحاصيل أو الأسماك.

4/قنوات: Canaux

- **المعارض والمؤتمرات:** المشاركة في المعارض والفعاليات الزراعية لعرض النظام والتفاعل مع العملاء.
- **التسويق عبر الإنترنت:** بيع المنتجات عبر مواقع الإنترنت التي تستهدف المستخدمين المهتمين بالزراعة المستدامة.
- **المبيعات المباشرة:** التواصل مع العملاء مباشرة لتقديم استشارات مخصصة وعروض خاصة.
- **الترخيص مع المؤسسات التعليمية:** عقد شراكات مع المدارس والجامعات لتسويق النظام.

5/الشركاء الأساسيون: Principaux partenaires

- **الموردين المحليين:** شركات توفر مكونات النظام مثل أجهزة الاستشعار، الألواح الشمسية، وأنظمة التحكم.
- **المؤسسات البحثية:** التعاون مع الجامعات والمؤسسات البحثية لتطوير وتحسين الأنظمة.
- **المؤسسات التعليمية:** شراكات مع المدارس والجامعات للتسويق والنشر.
- **شركات تصنيع:** الشركات التي تساعد في إنتاج وتجميع المكونات الميكانيكية والإلكترونية.

6/الأنشطة الرئيسية: Principales activités

- **تصميم النظام:**تطوير الأنظمة الصغيرة المحمولة من خلال تصميم هندسي مرن وآمن.
- **تطوير البرمجيات:**تطوير واجهات وبرمجيات تحكم للتحكم في النظام بشكل فعال.
- **اختبار الأنظمة:**إجراء اختبارات ميدانية لضمان كفاءة الأداء في ظروف العمل المختلفة.
- **التوزيع:**توسيع شبكة التوزيع من خلال الشراكات مع الشركات المحلية والدولية.

7/الموارد الرئيسية: Ressources clés

- **الموارد المادية:**مكونات النظام مثل الأسطح المائية، وحدات الألواح الشمسية، الأجهزة الإلكترونية، وأجهزة الاستشعار.
- **الموارد البشرية:**فريق من المهندسين، المبرمجين، وفنيين لصيانة وتطوير الأنظمة.
- **الموارد المالية:**تأمين التمويل اللازم لتطوير النظام وتنفيذه.

8/هيكل التكاليف: Structure des coûts

- **التكاليف الثابتة:**تكاليف إنتاج النظام، تكلفة البحث والتطوير، الرواتب، وتكاليف التشغيل.
- **التكاليف المتغيرة:**التكاليف المرتبطة بالمواد والمكونات التي تعتمد على الطلب.
- **التكاليف الإضافية:**التكاليف المرتبطة بتوسيع السوق والتسويق للمنتجات الجديدة.

9/تدفق الإيرادات: Flux de revenus

- **مبيعات المنتجات:**الإيرادات الناتجة عن بيع الأنظمة المحمولة.
- **العقود والخدمات:**الدخل من عقود الصيانة والتحديثات الدورية.
- **رسوم الاشتراك:**رسوم للوصول إلى البيانات والتحليلات المتقدمة.
- **التوزيع عبر الإنترنت:**مبيعات المنتجات عبر منصات التجارة الإلكترونية.

الملخص :

يدمج النظام .ESP32 يعرض هذا البحث تصميم وتنفيذ نظام أكوابونيك ذكي باستخدام متحكم ، (DS18B20) مستشعرات أساسية مثل مستشعر عمق الماء (فوق صوتي)، ومستشعر درجة الحرارة لمراقبة الظروف البيئية الضرورية لصحة النباتات والأسماك. يتم التحكم في (pH) ومستشعر الحموضة لضمان دوران المياه بشكل مناسب. تُرسل البيانات إلى منصة L298N مضخة المياه عبر سائق المحرك لإنترنت الأشياء، مما يتيح المراقبة والتحكم الفوري عبر الهاتف الذكي. تم تصميم النظام ليكون Blynk منخفض التكلفة، فعال، وقابل للتوسعة، مما يوفر حلاً مستدامًا للزراعة الذكية.

الكلمات المفتاحية: الأكوابونيك، إنترنت الأشياء، مضخة مياه، مستشعرات، ESP32,Blynk, الزراعة الذكية

Résumé :

Ce mémoire présente la conception et la mise en œuvre d’un système aquaponique intelligent utilisant un microcontrôleur ESP32. Le système intègre des capteurs essentiels — profondeur de l’eau (ultrasonique), température (DS18B20) et pH — pour surveiller les conditions environnementales nécessaires à la santé des plantes et des poissons. Une pompe à eau, contrôlée par un pilote de moteur L298N, assure une circulation adéquate de l’eau. Les données sont transmises à la plateforme IoT Blynk, permettant un contrôle en temps réel via un smartphone. Le système est conçu pour être économique, efficace et évolutif, apportant une solution durable pour l’agriculture intelligente.

Mots-clés : Aquaponie, ESP32, Blynk, IoT, Pompe à eau, Capteurs, Agriculture intelligente

Abstract :

This thesis presents the design and implementation of a smart aquaponic system using an ESP32 microcontroller. The system integrates key sensors—including water depth (ultrasonic), temperature (DS18B20), and pH—to monitor environmental conditions crucial for plant and fish health. A water pump, managed through an L298N motor driver, ensures proper water circulation. Data is transmitted to the Blynk IoT platform, allowing real-time monitoring and control via a smartphone. The system is designed to be low-cost, efficient, and scalable, offering a sustainable solution for smart agriculture.

Keywords: Aquaponics, ESP32, Blynk, IoT, Water Pump, Sensors, Smart Agriculture

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