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MASTER THESIS

On

INNOVATIVE SYSTEM FOR THE COMBINED REALIZATION OF CROPS AND FISH FARMING. STUDY OF THE DESIGN AND AUTOMATION ASPECTS

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ABSTRACT

The thesis discusses the emerging need for an Integrated vertical farm by examining issues related to food security, urban population growth, farmland shortages, "food miles", and associated greenhouse gas (GHG) emissions. The proposed system designed and developed an integrated system and method of multiple cultivation enslaved to farms and crops of algae and plants. In this thesis the work proceeded with the study of the existing models and implementation of a new design model with parameters. A mathematical model also has been developed with multiple calculations and simulations. The work continued with designing and development of automated system with micro controller along with sensors and actuators which can monitor and control the Garden Photo Bioreactor Fish (GPBF) system. The model developed based on the work which can show a significant outcome in the yield in both crop and fish farming.

CHAPTER-1

INTRODUCTION

Background

Wild fish stocks are at an all-time low, with many species on the brink of an irreversible decline. Overfishing is on every list of coming or current environmental disasters but with an ever-expanding human population, the pressure on fish to play a significant role in food and nutrition security can be expected to grow.

The "Sea Around Us" database shows that wild fish catches peaked in 1996 and have been falling by 1.22 million tonnes (~1%) per year since. Further reductions are expected due to degraded ecosystems, continued coastal development, destructive fishing practices and climate change. Serious human health impacts are predicted to develop from fishery declines, because 1.39 billion people worldwide currently get more than 20% of their essential micronutrients from fish. Poor people, especially in the tropics, will be more at risk.

Aquaculture appears to be a viable alternative to wild fishing, with the potential to reduce the pressure on some capture fisheries, and in 2014, for the first time, world aquaculture produced more fish for human consumption than fishing did. However, there are many environmental concerns with conventional aquaculture too, particularly in the intensive form favoured by large companies [1].

An emerging paradigm (in aquaculture as well as in other fields of natural resource management) is for planning and management to have a focus on whole ecosystems, rather than solely on anthropogenic requirements. In the literature, this has been referred to as an 'ecosystem approach' to aquaculture. In practical terms, ecologically sensitive aquaculture projects ensure food production but reduce or eliminate the detrimental environmental impacts that have been observed in conventional aquaculture.

A workshop of experts convened by the FAO in Spain in 2007 agreed that: "An ecosystem approach for aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems" [2].

In addition, the publication resulting from the workshop states that: “Such strategy should be guided by three main principles that should ensure the contribution of aquaculture to sustainable development: i) aquaculture should be developed in the context of ecosystem functions and services with no degradation of these beyond their resilience capacity; ii) aquaculture should improve human wellbeing and equity for all relevant stakeholders; and iii) aquaculture should be developed in the context of (and integrated to) other relevant sectors” [3].

In other words, the three linked spheres of sustainable development - environmental, social, and economic, are upheld and reinforced by this type of aquaculture.

Based on this definition, the ultimate example of EAA could be aquaponics, and yet aquaponics has taken a long time to become established and is still underutilised considering its great potential for improving aquaculture in line with the three principles listed above [4].

Aquaponics is defined as the polyculture of fish and plants. The word derives from a combination of aquaculture and hydroponics, which is the practice of growing plants without soil. Typically, aquaponics is part of a recirculated aquaculture system (RAS) where fish waste is used as fertiliser for the plants, to the benefit of both the product streams. Usually, water is the growing medium for the plants, with fish living in that water, but there are many possible varieties of systems. Other designs use soil, gravel or biological material for the plant growth media, and the used fish water may be pumped over the plants, filtered first, and/or chemically adjusted before being used for irrigation.

The aquaponics is a cycle that is naturally present in all waterways, where plants grow using the waste from fish as nutrients, and fish benefit from the cleaner, oxygenated water. In a natural ecosystem, the fish could be eating plants, including microscopic algae, and they might be eating insects, which would in turn be eating down the food chain – subsisting on phytoplankton or zooplankton. Other elements of this natural food web replicated in an aquaponics facility could include crustaceans such as shrimp or crabs, or even higher animals such as ducks or geese, which, in the case of the Incas of Peru, were utilised to move nutrients from the water, where they ate aquatic plants and small fish, to the land, where they roosted and fertilised the soil.

The concept of aquaponics systems as self-contained ecosystems lends itself to the field of agroecology, and so it is through this lens that that the arguments in the discussion will be made.

1.1 Project Aims

The aims of this project were:

- To review the current aquaponics literature and describe the status of the scientific and technological knowledge in the aquaponics industry, as well as discussing examples of successful business models.
- To increase the scientific and practical knowledge base when applying ecosystem approaches in aquaculture and horticulture combined.
- To investigate suitable fish and crop species for Nordic aquaponics in terms of growth, quality, effluents, temperature, and nutrient balance.
- To Design and develop an integrated system for forming plants, fish and algae trial utilising the above literature analysis

1.2 Garden Photo Bio Reactor Fish (GPBF)

GPBF is a farming method that utilizes aquaponics hydroponics and phototrophic microorganisms which contains all necessary nutrients and carbon dioxide, is pumped around in a cycle for better crop yields. These organisms use photosynthesis to generate biomass from light and carbon dioxide and include plants, mosses, macroalgae, microalgae, cyanobacteria, and purple bacteria [5]. Within the artificial environment of a photobioreactor, specific conditions are carefully controlled for respective species. Thus, a photobioreactor allows much higher growth rates and purity levels than anywhere in nature or habitats like nature. Hypothetically, phototropic biomass could be derived from nutrient-rich wastewater and flue gas carbon dioxide in a photobioreactor. It might be more accurate by economic definitions to call it a cottage industry or a branch of another industry (such as farming or gardening) since there are relatively few aquaponics jobs, and aquaponics presumably has a very low economic impact everywhere that it is practiced. However, aquaponics does have businesses, associations, training courses, conferences, books, trade journals and extremely devoted advocates concerned solely with its activities and its development. In terms of the language and culture of aquaponics, it seems to fit somewhere between gardening, farming and sustainable living, and has borrowed terminology, techniques, and expertise from all these fields as well as hydroponics and aquaculture.

'Aquaponics' is loosely defined for the purposes of this paper, as everyone with an interest in aquaponics, whether they are a 'backyard' community-based aquaponic gardener, an 'industry leader' type, who may be running an aquaponics business and be a source of advice and mentoring, or one of the few academics involved in attempting to formalise aquaponic science. As in any community, there are conflicts, politics, and arguments. In the case of the aquaponics community, one of the arguments is about what can be called aquaponics and what should not.

Some purists have a strict definition of the term, which excludes systems that are not recirculating, not 'organic', involve soil or nutrient addition and/or do not use fresh water. For the purposes of this research, a much broader definition is used, so that techniques from sustainable aquaculture, biological water treatment, and IMTA (Integrated Multi-Tropical Agriculture) can be considered, depending on the site-specific requirements of the system. Aquaponics for this thesis, therefore, refers to any system growing plants (including algae) and fish (including shellfish and crustaceans) together.

1.3 Project Development

This project has been conducted in three parts. Firstly, extensive online research was undertaken to collect technical information on aquaponics. An important second element was a set of experiments which obtained quantitative data about the feasibility of adding a hydroponics arm to the production system. Finally, analysis of the data and other literature informs an analysis of aquaponics in a global context.

The system is focused on increasing economic efficiency and sustainability of alternative farming system. Agriculture sciences must be reconsidered to develop environment-friendly technologies. Combining aquaculture with hydroponics, farmers obtain an innovation with Garden Photo Bio Reactor Fish. It respects the principles of sustainable agriculture (wastewater bio filtration by plants) and gives the possibility to increase economic efficiency with an additional production (organic vegetables) to produce nutrient-rich foods.

With all the elucidated details that this study was conceptualized, the researchers were inspired to develop a digital render design of a vertical aquaponics system for urban areas. It will eliminate the stressful gardening chores and make an alternative to soil-based gardening that will best address the stated problems. The project aims to improve aquaponics to be more affordable to the masses particularly in urban areas, be able to produce a space-friendly design and provide an efficient food source through a more sustainable urban farming system.

1.4 Conceptual Framework

INPUT	PROCESS	
Advantages of using Integrated system made in cheaper or recyclable materials but can still provide efficiency for food production.	• Construct a vertical structure of system that is space-friendly for efficient food production and can be widely used in urban areas. • Utilization of cheaper or recyclable materials. • Testing the quality of the vertical structure of system.	A proposal for a vertical Integrated system which serves as an innovation towards a more sustainable urban farming system.

This study used the Input, Process and Output (IPO) model as it is a dominant approach in understanding and describing the structure and process of the information.

The first frame of paradigm in the conceptual framework contains the input of data to be used. This includes the advantages of having a vertical aquaponics made in cheaper or recyclable materials but can still provide efficiency for food production. The gathered data was essential for the continuation of conceptual framework.

The second frame indicates the process or the construction of the aquaponics. This includes all materials needed and measures the exact sizes of material. This process stage also stated the designing of the subject that is primarily space friendly.

The output of the research was a vertical aquaponics which serves as an innovation towards a more sustainable urban farming system.

CHAPTER-2

LITERATURE REVIEW

2.1 Integrated system and process of joint and systemic cultivation of flora-horticultural products, algae, and food fish fauna

Author: Luigi Randazzo.

There exist various aquaponic cultivation systems and are well known, also integrated with fish fauna farms. But it does not appear that contiguous crops of algae and plants have been set up, in a single systemic solution and with structures in pipes in vertical racks. This is an integrated system of multiple cultivation finalized to fish fauna farms. In general, in algal crops the CO2 requirements are not implemented with natural and contiguous processes, with symbiosis such as those proposed by the invention. However, there are no similar systemic processes for treatment / purification, combining Phyto depuration and algal growth upstream of the water for fish farms, downstream of the latter in a single virtuous, symbiotic, and circular economy process. But this does lack in monitoring and governing remotely or locally and the system that is mentioned is not automated.

2.1.1 Optimization and Control Of Hydroponics Agriculture Using IOT

Author: S.Charumathi , R.M.Kaviya , J.Kumariyarasi , R.Manisha and P.Dhivya

Agriculture is plagued by several problems like small and fragmented land holdings, manures, pesticides, chemicals used for agriculture etc. consumers also increasingly demand for the healthy diet that is rich in quality and free of agricultural chemicals and pesticides. This project fills in the above said difficulties and demands using hydroponics and it can go organic. Since it is done in the controlled environment, it can be done anywhere like room terrace, balcony etc. also large number of plants can be planted in a less place. This type of agriculture could be high yielding if monitored and controlled efficiently. In this project they implemented a system that controls the necessary conditions required for the plant to grow hydroponically and cultivators may control the agriculture remotely using IoT [6].

2.1.2 Automated Aquaponics Maintenance System

Author: Muhamad Farhan Mohd Pu'ad , Khairul Azami Sidek , Maizirwan Mel

In this paper an automated aquaponics maintenance system was developed as a prototype to reduce human involvement in the activity. The system covers water level and light-emitting diode (LED) power switch maintenance. Furthermore, the automation system can be controlled via Telegram for user convenient. Moreover, it also measures the pH level of the water as an additional feature. Numerous tests were conducted on aquaponics to observe the reliability of the system at the Malaysian Institute of Sustainable Agriculture (MISA), a non-profit organization focusing on urban farming. Positive results were obtained from the tests which suggested that the system is self-dependent. Therefore, the system is suitable to be used in aquaponics [7].

2.2 Key Concepts

Aquaponics is a technique made of two separate farming techniques, namely hydroponics and aquaculture. Aquaponics uses about 90% less water than traditional farming, provides more crop yield per unit area, and does not require the use of poisonous herbicides and pesticides. Hence the produce from aquaponics is organic.

Since the technique can be applied with different types of systems, it is possible to monitor and control it. Making automation a possible solution, which can provide with organic products grown with optimum conditions.

For the monitoring of the system, pH, Electrical Conductivity, and temperature are the main variables that need to be checked. Based on these it can be decided which crops can be grown.

2.2.1 Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods

Hydroponics is more efficient compared to traditional land based agricultural methods. In the case of lettuce, hydroponics offered 11 ± 1.7 times higher yields per area and saved up to 95% of water (20 ± 3.8 L/kg/y of hydroponics vs. 250 ± 25 L/kg/y of traditional land based)– mainly lost through evaporation, if not absorbed. The downside is that it required a tremendous amount of energy (90,000 ± 11,000 kJ/kg/y) compared to the 1100 ± 75 kJ/kg/y of traditional land based.

The energy consumption is mainly to keep the water circulating, and in the case of indoor hydroponics, to keep the growth LED lights on. This problem is countered by us by integrating solar energy in Cropotronics [8].

2.2.2 Design of a Smart Monitoring and Control System for Aquaponics Based on Open WRT

The paper deals with collecting data from the aquaponics system and transferring wirelessly through the server. The user can access this data through an application and from there decide which system to turn on or off. This signal is then transferred back to the server which then sends the signal to the actuators [9].

2.2.3 The Production of Catfish and Vegetables in an Aquaponic System

A total of fifteen aquaponic sets were installed in an aquaculture setting at Kuala Sungai Baru, Perlis, Malaysia. Over the period of 60 days, 2 batches of 3 different vegetables were grown. Catfish were not changed during the cycles. The research recommended the use of catfish for aquaponics mainly due to their tendency to survive in low oxygen environments [10].

2.2.4 Design of Aquaponics Water Monitoring System Using Arduino Microcontroller

Arduino was used to design a complete aquaponics system. pH, temperature, and water sensors were used, and the data collected. If the pH was found out of range, it was automatically brought to the desired value. If any value was found to be out of range of the desired value, a message was sent automatically through GSM.

2.2.5 How to Hydroponics, Fourth Edition[Keith Roberto]

The book explained different steps of designing a hydroponics system. It includes different models you can use. Different growing materials that can be used to grow seedlings, the type of growing environment plants require. It even includes data on multiple crops and the pH, temperature etc. they require for optimized growth [11].

Name	Technique	Country/ Region	Product Type	Price	Remarks
Grownup Urban Farms	Hydroponics	UK	Crops	-	Local produce
Tailor Made Fish Farms	Aquaculture , Hydroponics	Australia	Crops and Fish	-	Local produce
Kakovitch Industries	Aquaponics	USA	Designs and builds Custom Systems	-	Mostly for commercial farms
Aqua Sprouts	Aquaponics	USA May deliver in Pakistan.	Aqua Sprouts Garden.	$179.95 *Bundle (+LEDs etc): $260*	Small, decorative system. Can fit on a table.
Back to the Roots	Aquaponics	Only USA	Water Garden.	$ 99.99	Small, decorative system. Can fit on a table.
The Blue Green Box	Aquaponics	Only USA	System for plants and pumps.	$ 75, $ 120, $ 300	Aquarium and fish Not included.
Osmo Systems	Water monitoring sensor.	USA	Sensor system. (Includes 5 sensors)	$550+	DO sensors included for additional price.

Table 2.1 Notable Companies [12]

2.3 Current Industries

The following companies are working with hydroponics/aquaponics. However, they fail to provide the complete functionality of this project.

- The mentioned companies all have differences and or are lacking in something compared to our project.
- GrowUp Urban Farms, Tailor Made Fish Farms and Kakovitch Industries are all commercial scale farms. They do not provide systems for the end user.
- AquaSprouts, back to the Roots and the Blue Green Box, though are indoor aquaponics systems, they are more for indoor decoration than sustainable food growth. They provide no monitoring of the system. And so cannot be considered for home farming.
- Osmo Systems, although their product contains pH, electrical conductivity, and temperature, as well as an option for Dissolved Oxygen sensor; it does not have any variant with which humidity and light sensors can be integrated.

2.4 Future of Soilless Farming Trends

Soilless farming techniques are majorly used in developed countries, yet its share has continued to increase in the past few years. By the year 2020, hydroponics is predicted to account for about 6% of the Compound Annual Growth Rate (i.e., the total food production) of the entire world. While its Global market share is expected to increase to about 13 billion USD.

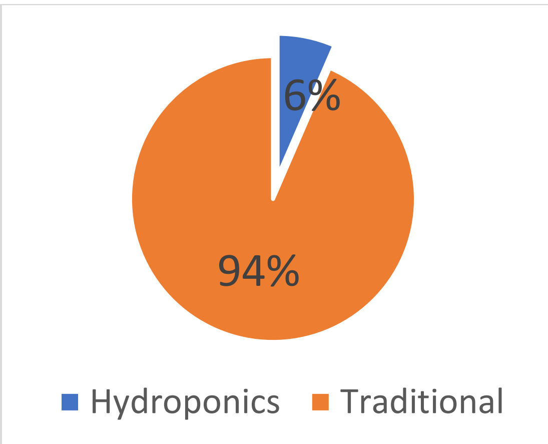


Fig 2.1 World Compound

Annual Growth Rate

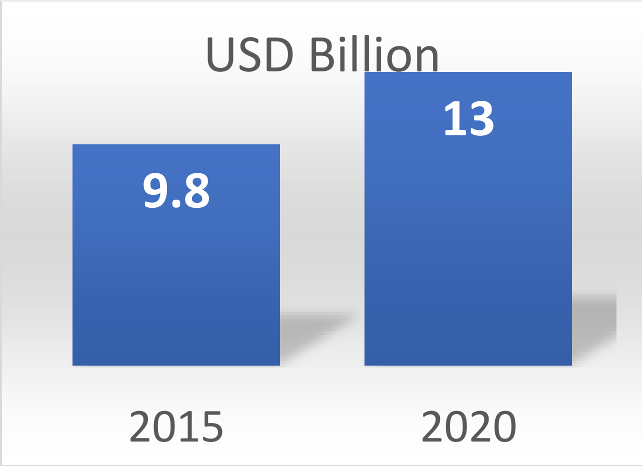


Fig 2.2 Global Market Share

Shrinking of agricultural land is already an increasing problem of the world -as shown below. This shortage is either due to de-fertilization of soil, because of heavy agricultural use in the past, or urbanization. This shortage means the word will need to find a suitable alternative for crop productions. The economical alternative in urbanized areas for agriculture, are hydroponics and aquaponics, whose share in CAGR, if increased, can easily account for the food shortage. No table of figures entries found.

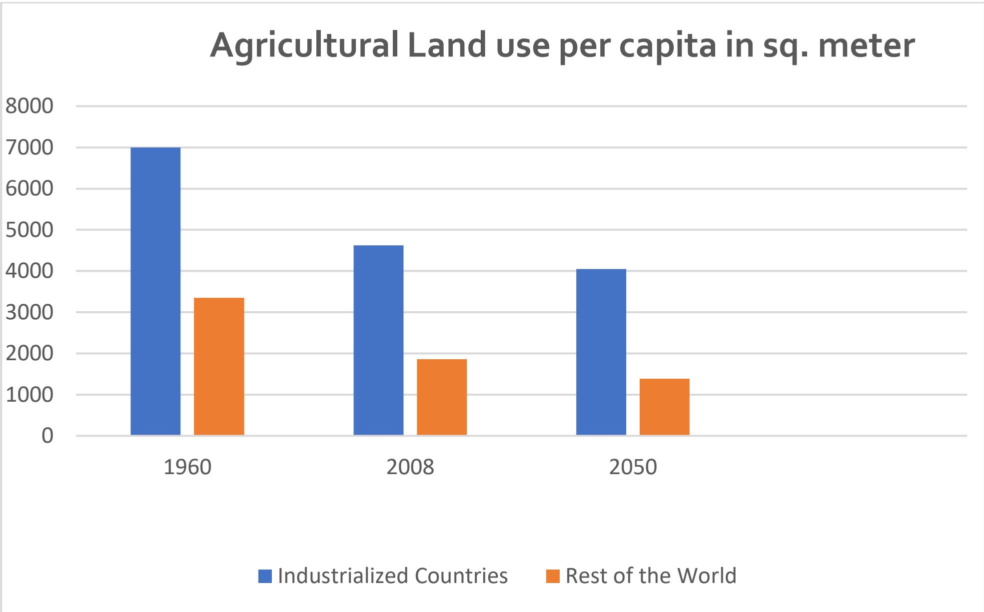


Fig 2.3 Agricultural Land Use

2.5 Problem with Aquaponics

Aquaponics requires continuous care and management, which is difficult for the people, because of lack of exposure with the technique. Hence the problem at hand is to make the monitoring automated, in an effort assist the novice farmers in growing produce efficiently, and with minimum loss of crops and fish.

Another problem is to make the running cost of system to be minimum to attract the masses. Hence the system designed is light-weight –made of PVCs–, scalable –multiple systems can work together or their size increased – and compensates its energy requirements using Solar Energy.

2.6 Synthesis

The literature and studies presented by local and foreign authors were considered substantial to the current study because the researchers understand better the most fundamental concepts studied in the research.

There are few studies which explains the importance of awareness against malnutrition or undernourishment and that a local food system shall be developed to solve this problem. While some other had given give initial information about how aquaponics started including its necessities to operate effectively. Moreover, few of them shared how aquaponics benefits in solving different problems in some countries in terms of environment, agriculture, and the economy. On the other hand, some organization shows the fundamental principles involved in aquaponics and its practical application nowadays. The potential of aquaponics to be a true alternative in farming system is further stated through the research.

Finally, the researchers find valuable insights from the related literature and studies mentioned which served as the basis of the present study since they also attempt to determine the benefits of Garden Photo Bio reactor fish system and much more when it will be innovated into a vertical structure to be space-friendly and widely used in urban areas.

CHAPTER-3

PROPOSED SYSTEM

This invention concerns a tool, and an integrated multiple cultivation system to farms and crops of algae and plants. Description of the known/background technique. As you know, agriculture is increasingly evolving towards forms of automation and digitalisation that allow efficient use of resources and reduction in the use of labour. This invention proposes an integrated system of multiple cultivation enslaved to farms and cultivation of algae and plants, in a single systemic solution and with arrangements in vertical rack tube. The found in question has a high degree of innovation as there do not seem to be any other found with similar characteristics and purposes.

In art, methods, and related systems for (both aeroponic and hydroponic cultivation of plants, in fruit and vegetables (e.g., tomatoes), but also ornamental plants, flowers and the like. These methods and systems are mostly used for "above ground" and/or “off-field" cultivation. where above-ground and/or off-field cultivation is defined as cultivation in environments other than the open field, for example in greenhouses and similar protected environments. As early as the seventeenth century it was believed that plants could be grown without soil. Since then, they have been repeated attempts to develop commercial systems for the cultivation of plants in water or on an inert carrier substrate, but so far it has not been possible to develop a satisfactory commercial method.

Early attempts at hydroponic culture were based on the immersion of the roots of growing plants in a stationary aqueous nutrient solution, having been provided means to keep the plants in place. However, this method has proved impractical, the other because the nutrient solutions did not contain from the beginning enough oxygen. In addition, after little time the little oxygen that had been presented.

The proposed solution to the problems mentioned above was to provide organic food to the masses living in through aquaponics, make the system urban compatible (small, smart, and sturdy) and provide smart monitoring of the system. The block diagram below describes the functionality of the system and interaction of different modules to get the task done.

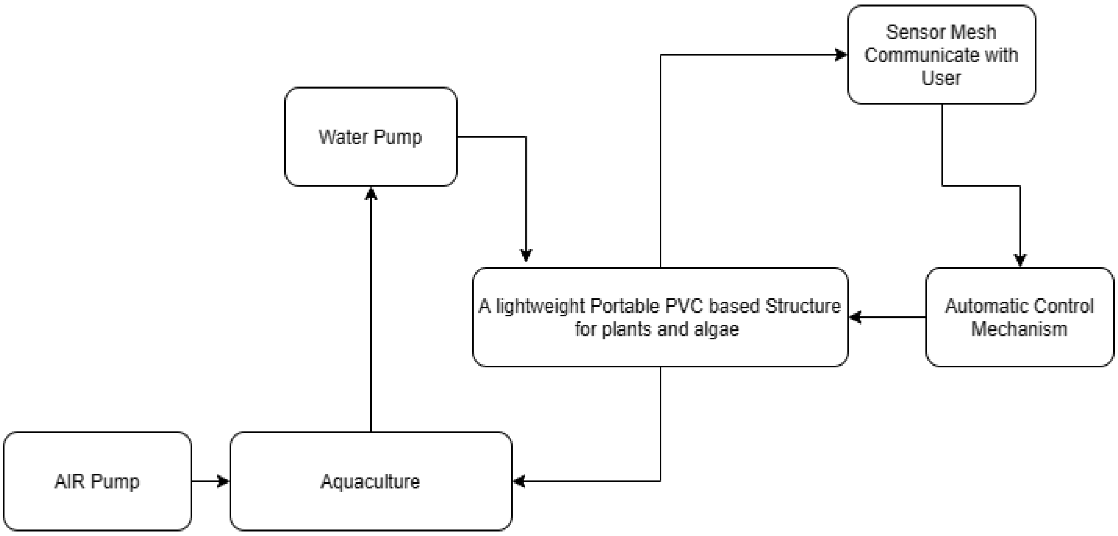


Fig 3.1 System Block Diagram

The block diagram depicts the proposed system. Starting from aquaculture, where fishes are fed, and their waste is deposited at bottom of the tank. The wastewater from the aquaculture is pumped out using a water pump. The water reaches plants and microalgae, is checked for its pH, Electrical Conductivity, Total Dissolved Solids, and temperature readings. This is done using the sensor mesh, which communicates with the user, and runs it through automatic mechanism. for monitoring purposes and provide valuable feedback to the user about the feasibility of the current crop in the given conditions.

The water travels through plants and algae, where plants and algae are grown inside a PVC structure. There ammonia in the water is reduced to nitrates, absorbed by the plants. The purified water along with fish feed produced by microalgae is fed back to the aquaculture, as it is now harmless to the fish.

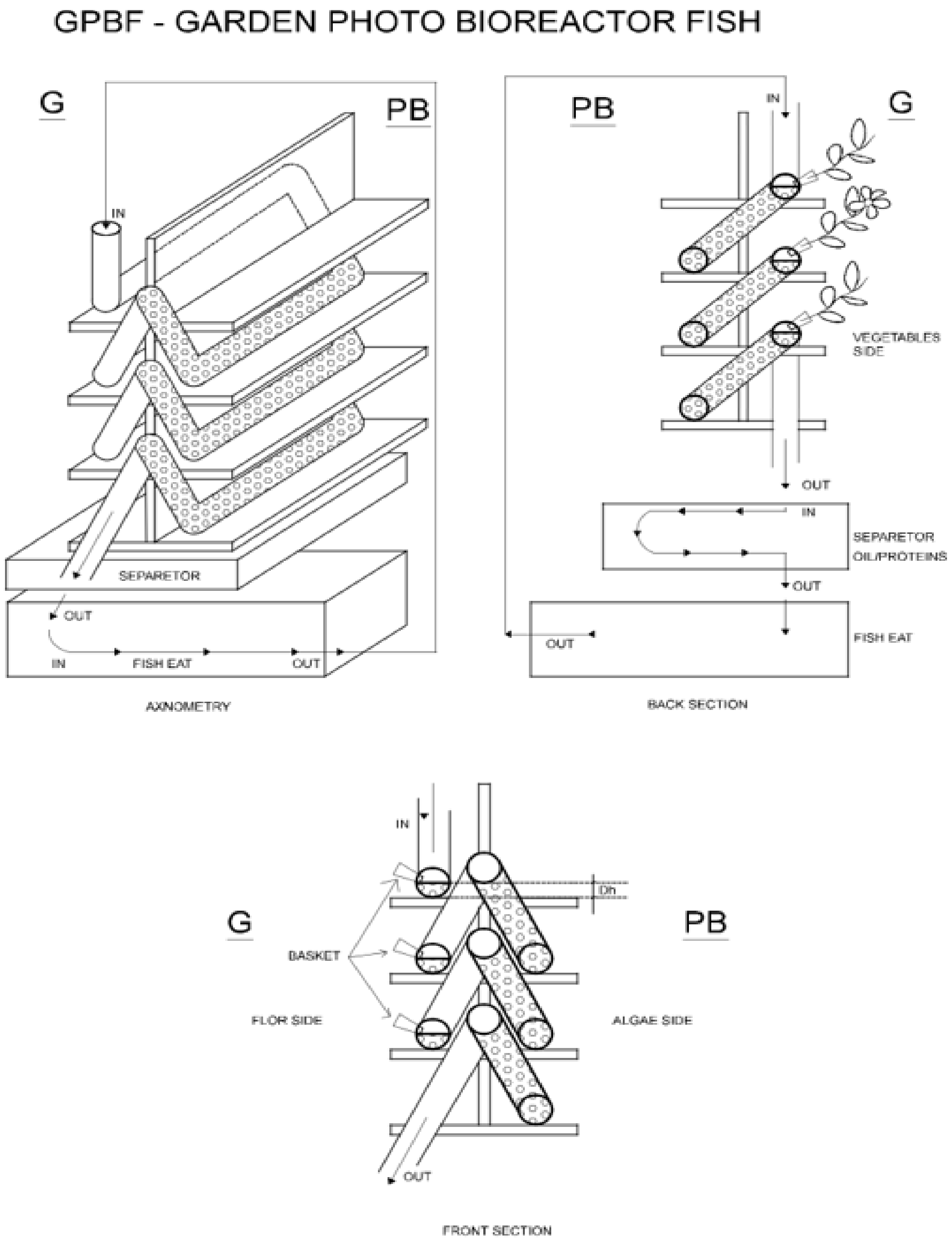


Fig 3.2 Structural View

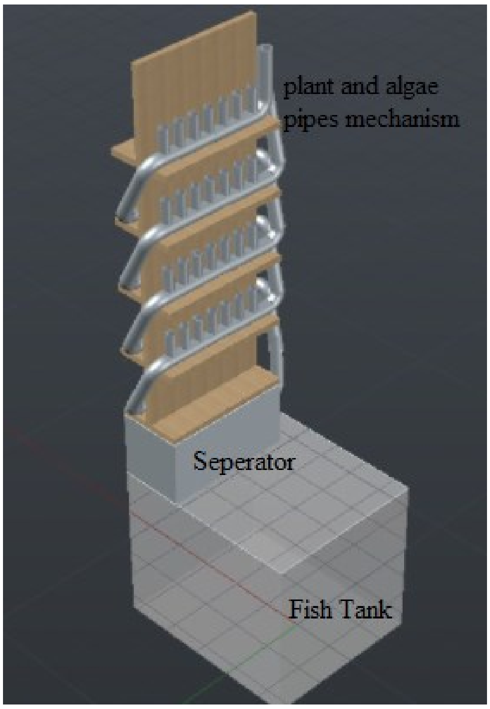


Fig 3.3 Structure of Proposed System

3.1 Sensors:

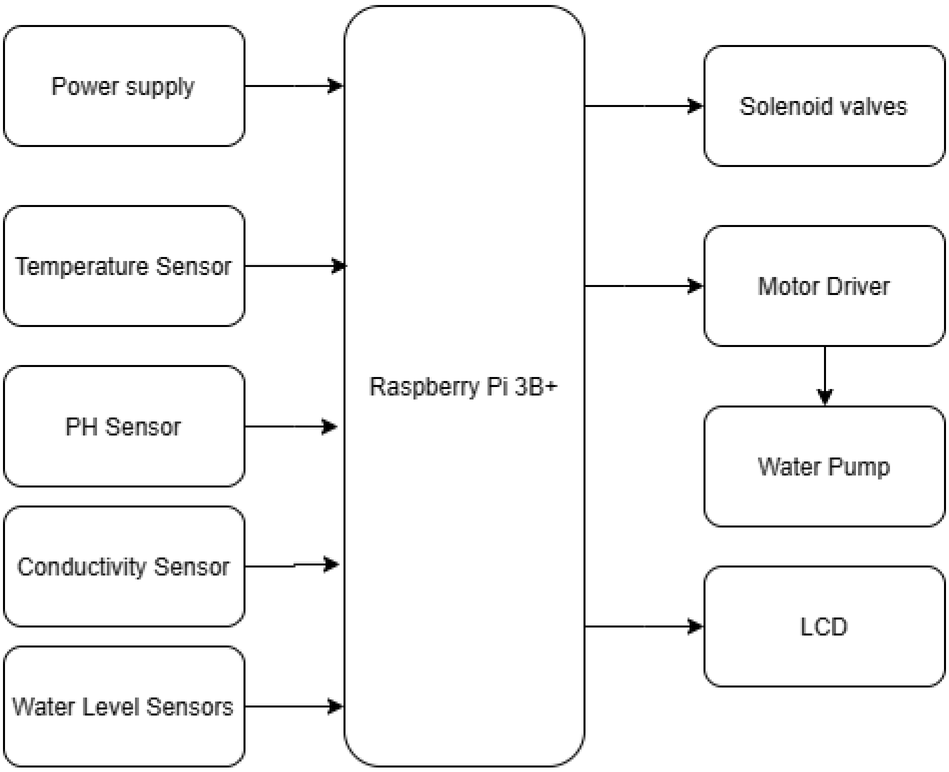


Fig 3.4 Sensors interfacing with raspberry pi

The sensors are interfaced with the Raspberry Pi which communicates with the read the sensor values and display for the user interface and sensor values (of the respective sensors shown below) which are stored on server. The table below shows the specific details of the sensors used, i.e., their accuracy, working conditions, limitations etc.

1.	pH Sensor SKU SEN0161		Response Time < 1min Accuracy 0.1 pH Temprature 1 to 60 Celsius
2.	Temprature Sensor		Accuracy within 0.5 Celcius Range -55 to 150 Celsius
3.	TDS Meter 3		Used for calibration of our self implemented EC Sensor
4.	**Turbidity Sensor**		**Used to measure turbidity of water** **Range 0 to 4000 NTU**

Fig 3.5 Sensors

3.2 Central Device:

The above-mentioned sensors are interfaced Raspberry Pi 3b+. which will read the sensor values and display on screen and stores in server.

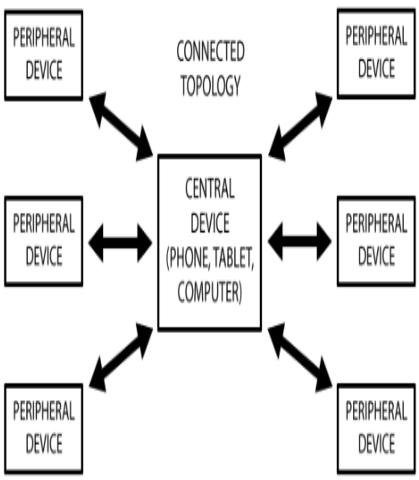


Fig 3.6 A&B Server Block Diagram & Raspberry Pi 3B+

From these sensor values raspberry pi will automatically control the watering system.

3.3 Justification of Method Used

The agricultural technique chosen for the system, aquaponics, was due to it having various advantages over other farming techniques. Aquaponics requires an estimate of 90% less water compared to the traditional land-based farming techniques. The water decrease is mostly by absorption by plants, or by evaporation. No water is lost to the ground as in traditional farming, where it seeps underground unchecked. The power requirement of aquaponics increases, a lot more than that of land-based farming. This is because land-based farming mainly uses power to pump water on different periods. While for different techniques for aquaponics, water needs to be circulated continuously, air pumps are needed to keep the fish from suffocating; and for indoor setups, lamps are used to compensate for the deficiency of sunlight. This increased power requirement is solved by using solar panels, and storing the excess electrical energy produced in batteries, for later use at night.

Hydroponics and aquaponics are essentially the same, except for the use of fish. Hydroponics is a comparatively easier farming technique, which uses fertilizer instead of fish waste. The two techniques already do not require the use of pesticides as in land-based farming; with the addition of fish waste, the need to add chemical fertilizers – as in hydroponics – is eliminated. Making aquaponics suited for the growing awareness and demand for organics crops. Another farming technique, aeroponics, was not considered suitable for the system, as it has an increased demand for electrical power. Verses, aquaponics, water is required to be circulated at increased pressures to create a water mist for use in aeroponics. Furthermore, water lost due to the mist is more than that in hydroponics and aquaponics but is still less than that of land-based farming.

The technique of aquaponics used above is known as NFT (Nutrient Film Technique). Nutrient Film Technique is a commonly used hydroponic method but is not as common in aquaponics systems. In NFT systems, nutrient rich water is pumped down small, enclosed gutters, the water flowing down the gutter is only a very thin film. Plants sit in small plastic cups allowing their roots to access the water and absorb the nutrients.

Fig 3.7 NFT example

In all other forms of production, there is a conflict between the supply of these requirements, since excessive or deficient amounts of one result in an imbalance of one or both others. NFT, because of its design, provides a system wherein all three requirements for healthy plant growth can be met at the same time, provided that the simple concept of NFT is always remembered and practiced. The result of these advantages is that higher yields of high-quality produce are obtained over an extended period of cropping. A downside of NFT is that it has very little buffering against interruptions in the flow, e.g., power outages, but, overall, it is one of the more productive techniques.

3.4 Justification of Design Tools

In the system described above, one may ask many questions regarding the choices made in selection of the design tools.

Let's start off with the structure, it is made up of PVC to keep it light and sturdy, thus making it compatible for forming of plants, algae, and fish. The users will be able to deploy the system on rooftops and terraces of apartments or their houses without the risk of extra weight. The small size of the chosen Micro-controller, makes it easy to be deployed in any system of any size and the nature of the sensors used, gives the user autonomy to use the sensor mesh system in aquaponics or hydroponics system.

CHAPTER-4

DESIGN ANALYSYS

The following section discusses several calculations that are performed in this entity of the model flow diagram. The calculations are divided into groups in accordance with their functions.

4.1 Calculations

The following section discusses several calculations that are performed in this entity of the model flow diagram. The calculations are divided into groups in accordance with their functions.

4.1.1 Pond Re-Stocking Calculations

This section explains the calculations regarding the re-stocking of fish into the tanks. The two ways of obtaining new fish with which to stock the ponds once the previous batch has been harvested are as follows. The first method is to have a separate bloodstock pond where several fully-grown female and male tilapia breed new stock for the system.

Alternatively, the new stock could be bought from a hatchery in the form of fingerlings every time restocking is required.

Breeding the fish within the system eliminates the cost of having to purchase the fingerlings every time but increases the labour and capital cost required for the system.

Buying new fish every time the ponds are restocked poses a threat that a disease could be introduced into the system which infects not only the new fish, but the other fish in the system too. The new fish could be placed in quarantine to monitor them for diseases, but this requires that they be separated from the existing fish in the system. This is a large constraint for small-scale farmers such as those considered in this thesis.

4.1.2 Calculating number of fishes needed

The number of fish in a particular growth stage is calculated backwards using the final stocking density, system volume and harvest mass, as well as the mortality rates during the various growth stages. It is calculated in this manner to arrive at the desired stocking density at the end of the final stage. The number of fish in each stage is calculated iteratively to determine the required number in the previous stage.

$$number\ of\ fish\ \left(stage(x)\right) = number\ of\ fish\ \left(stage(x+1)\right) \times \frac{1}{(1+\%mort(stage(x+1))}$$

The loss of fish occurs because of mortality and culling.

The final survival rate for the fish's life cycle is calculated as follows.

final survival (surv) rate = %surv(stage 1) × %surv(stage 2) × .. × %surv(stage x)

The number of fish required to re-stock the system is derived from the following:

- maximum stocking density (kg/m3).
- volume of water (m3).
- final mass of the fish (kg); and
- final survival rate of the stock (% of initial number of fish).

number

$$number\ of\ fish\ required\ initially = \frac{stocking\ density \times volume\ of\ water}{harvest\ mass \times final\ survival\ rate}$$

Using the following input data, the calculations below are computed:

cost per fingerling and number of ponds.

$$cost\ to\ stock\ system\ with\ fingerlings = cost\ per\ fingerling\ \times number\ of\ fish$$

$$number\ of\ fingerlings\ required\ per\ pond = \frac{number\ of\ fingerlings}{number\ of\ ponds}$$

$$cost\ to\ restock\ per\ pond = \frac{cost\ to\ restock\ per\ cycle}{number\ of\ ponds}$$

$$mass\ of\ fish\ harvested\ per\ cycle = stocking\ density\ \times volume\ of\ water$$

$$number\ of\ fish\ harvested\ per\ cycle = \frac{mass\ of\ fish\ harvested\ per\ cycle}{mass\ of\ harvest\ size\ fish}$$

$$number\ of\ fish\ harvested\ per\ batch = \frac{number\ of\ fish\ harvested\ per\ cycle}{number\ of\ ponds}.$$

$$mass\ of\ fish\ harvested\ per\ batch = \frac{number\ of\ fish\ harvested\ per\ i}{mass\ of\ harvest\ size\ fish}\ final\ weight\ per\ fish$$

The formula below can be used to determine the accuracy of the predicted mortality rate of the fish life cycle. The actual harvested mass can be compared to the calculated values.

$$mass\ of\ fish\ harvested\ per\ cycle = initial\ number\ of\ fish\ \times final\ survival\ rate\ \times$$

4.1.3 Broodstock calculations

If the system breeds its own fish for re-stocking, the following calculations are used to determine the requirements of the system, as well as the broodstock. A step-by-step process calculates the requirements as follows.

The number of fries required per batch is determined in the section above. This value is used to determine the number of eggs required, using the hatch rate.

$$number\ of\ eggs\ required = \frac{number\ of\ fry\ required}{hatch\ rate\ (\%)}.$$

Using the female fecundity as well as spawning cycle time, the weekly production of eggs per female can be calculated.

$$weekly\ production\ per\ female = \frac{fecundity\ (number\ of\ egg\ produced\ per\ cycle)}{spawning\ cycle\ (number\ of\ weeks)}$$

A method that can be used to calculate the number of eggs required per week to ensure that the batch of new fish is approximately of the same age is shown. The user should specify how many weeks the oldest and youngest of a batch are allowed to differ. Using this information, the required production per week is calculated.

$$number\ of\ eggs\ required\ per\ week = \frac{number\ of\ eggs\ required\ per\ batch}{weeks\ allowed\ between\ oldest\ \&\ youngest\ of\ batch}$$

The number of females required is calculated by dividing the required production by the production rate per female.

$$number\ of\ females\ required = \frac{number\ of\ eggs\ required\ per\ week}{number\ of\ eggs\ produced\ per\ female\ per\ week}$$

A breeding safety factor is used to ensure that the required production rate of new fish is attained.

$$number\ of\ females\ required = \frac{number\ of\ eggs\ required\ per\ week}{number\ of\ eggs\ produced\ per\ female\ per\ week} \times safety\ factor$$

A female to male ratio is used to specify the number of males required to fertilize the females.

$$number\ of\ males\ required = \frac{number\ of\ females}{female{:}male\ ratio}$$

Once the number of male and female broodstock fish has been determined, the feed costs can be calculated in the same manner as in the growth section, explained in the next section. The maximum feed rate is ordinarily in the region of 1.5 % body weight fed per day.

The water volume required can be determined once the maximum stocking density for the broodstock has been decided upon.

4.1.4 Growth

The model calculates the fish growth based on information gathered on the species.
The following aspects are calculated daily:

- length
- weight
- feed cost

The growth is calculated in the following manner. All fish increase in length at linear rate. Their weight, however, increases by a cubic function relative to length. Fig 4.1 shows the length and weight of a fish relative to time (length and weight are normalised to show the relation).

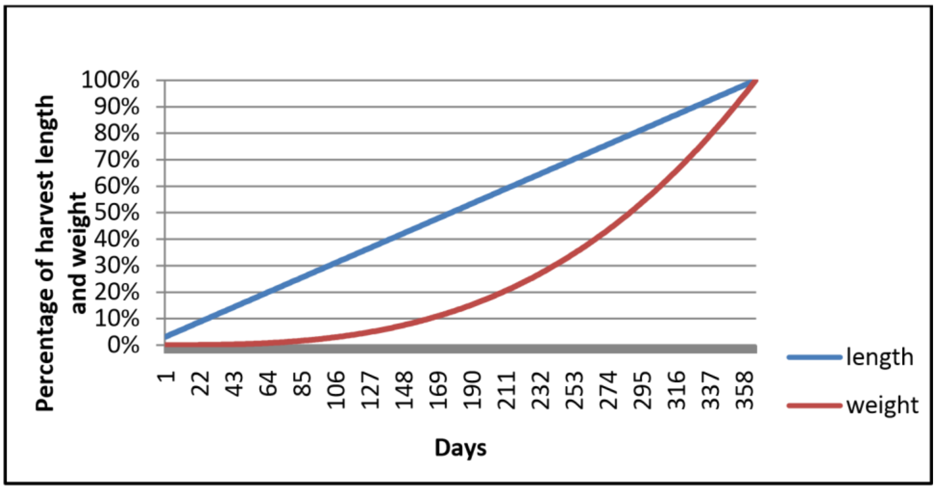


Fig 4.1 Normalised graph showing the relation between the length and weight of fish

The length and weight are mathematically related, as shown in the following formula:

$$WT(g) = \frac{K \times (L_{cm})^3}{100}$$

where: WT(g) = weight of fish in grams

K = condition factor

Lcm= length of fish in centimetres

The weight and length of the fish on day one of its life, as well as on the harvest day, are input values. Using these values, the value of K can be calculated. The value of K is influenced by the age of the fish, sex, stage of maturation, season, fullness of gut, type of food consumed, amount of fat reserve and degree of muscular development. The model developed in this thesis assumes that K is a constant. This assumption is a limitation of the model and is made so that the model can calculate the fishes' weight at certain stages of its lifespan.

The formula for this calculation is as follows:

$$K = \frac{WT(g) \times 100}{(L_{cm})^3}$$

For tilapia, this factor K usually ranges between 2.08 and 2.50. Once the condition factor is calculated, the weight at any given length can be calculated using the above equation.

The daily increase in length is calculated by taking the difference in length between the hatchling and harvest size fish and dividing it by the number of days it takes to reach harvest size, as shown in the formula below.

$$length\ increase\ (per\ day) = \frac{(harvest\ length - hatchling\ length)}{days\ taken\ to\ reach\ harvest\ length}$$

The model calculates several elements relating to the growth of the fish on a day-to-day basis. The initial length of the fish (as specified in the input data) is used as a starting point, and each subsequent day the length is incremented in accordance with the calculated growth per day.

$$length\ (day\ t) = inital\ length + (day\ t) \times length\ increase\ (per\ day)$$

Using the equation above, the weight of the fish on the corresponding day can be calculated.

The amount of feed fed on day(t) is determined by taking the product of the feed conversion ratio (FCR) and the difference in weight between day(t+1) and day(t).

$$mass\ feed\ fed = (weight\ (day(t+1)) - weight(day(t))) \times$$

$$FCR(\frac{kg\ dry\ feedfed}{kg\ wet\ weight\ gained})$$

4.1.5 Staggering production

Staggering production is a method of staging the production of the aquaculture component in such a way that the tanks contain batches of fish that are of different ages. A delay of several weeks between the ages of the various batches is planned. Staggering production is advantageous for several reasons. This method helps to optimise the utilisation of the fish-rearing tanks. The staggering of production also assists in optimising the production in another manner. This method of production decreases the variation of daily feed input by staging various batches of fish at various stages in time. This is advantageous to the hydroponic component of the system, where a stable level of nutrient loading is desired. Unstable nutrient loading levels could cause the plants to suffer from nutrient deficiencies. Managing the stock in this manner also results in more regular harvests compared to a situation where all the tanks are stocked with fish at the same time.

If a system breeds its fingerlings in-house, then moving the fish from one tank to the next at the most favourable times will be advantageous. The model has a separate functionality where it is possible to optimise the production staging of the fish batches. The optimal times to transfer the fish to a larger tank can be determined. The model shows the stocking densities at the start and finish of each production stage. This is used to determine the optimal time to transfer the batch of fish. It should be noted that most of the farms in the case studies have three or four large tanks, and no smaller tanks where fish could be bred or grown. In these cases, it is evidently not possible to optimise the movement of fish from one tank to another.

The staggering offsets each batch of fish by a pre-determined number of days. This results in the batches reaching harvest size at time intervals equal to the offsets.

4.1.6 Biofilter design calculations

The purpose of the following calculations is to verify that the system's biofiltration component has sufficient capacity to filter the water under the operating conditions specified by the input parameters. Insufficient biofiltration capacity would result in the build-up of the TAN in the system, and the subsequent deterioration of the water quality.

Several the input parameters are variable, and for this reason, three scenarios are calculated in each step. A minimum, maximum, and expected scenario is calculated. The variation in the input parameters is a result of the variation in daily feed, as well as the design parameters that are proportional to the feed. These design parameters are shown in Fig 4.2.

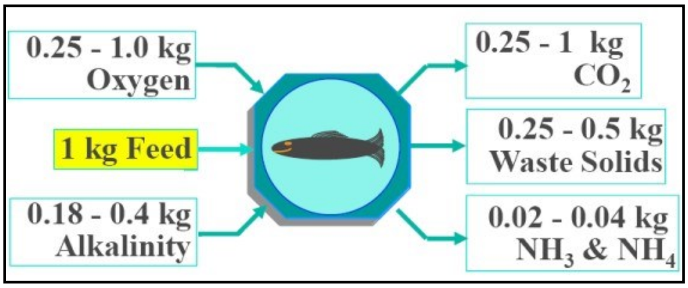


Fig 4.2 The relation between feed rate and design parameters

The steps required to design a biofilter are explained in section earlier.

The first step is to calculate the dissolved oxygen requirements of the system. The required oxygen is calculated based on the amount (in kg) of oxygen consumed by the system per kg feed used in the system.

A good starting point for oxygen required for a system is 1kg oxygen per kg feed used in the entire system. This includes oxygen used by all chemical reactions that consume oxygen in the system, including bacterial activity.

The contribution of oxygen consumption by the fish's metabolism is often estimated at 250 g oxygen per kg feed. In certain biofilter designs, the ambient atmosphere will supply sufficient oxygen for the nitrification process, as well as for any heterotrophic bacteria. If not, additional oxygen must be added to the system to ensure that the nitrification process is not constrained by dissolved oxygen levels.

The dissolved oxygen requirement is calculated as follows:

$$Dissolved\ O_2\ requirement\ \left(\frac{kg_{DO}}{day}\right) = kg\ O_2\ required\ per\ kg\ feed \times average\ daily\ feed\ rate(kg)$$

The average daily feed rate is calculated using the daily feed calculations performed in the biological growth model.

Water flow requirement: assume that dissolved oxygen (DO) level in the culture tank is 5mg/L. Measurement is taken from the effluent water, as this is the water that has the lowest DO level.

Most of the farms examined in the case studies have aerators in the culture tanks. This provides an additional source of oxygen to the oxygen provided by the influent water.

temperature (°C)	dissolved oxygen (mg / L)
10	10.92
12	10.43
14	9.98
16	9.56
18	9.18
20	8.84
22	8.53
24	8.25
26	7.99
28	7.75
30	7.53
32	7.32
34	7.13
36	6.95

Table 4.1 Oxygen saturation levels in fresh water at sea level atmospheric pressure.

The DO level of the influent water to the culture tank should be 7.75 mg/L. Using the mass balance equation from the reference, the flow rate can be calculated.

$$flow\ rate = \frac{Dissolved\ O_2\ requirement(\frac{kg_{DO}}{day})}{Dissolved\ O_2(\frac{mg}{l})\ (inlet) - Dissolved\ O_2(\frac{mg}{l})\ (outlet)} \times \frac{1\ day}{1440\ min} \times \frac{10^6 mg}{1\ kg}$$

The mass of TAN produced by the fish in the process of metabolising is calculated by multiplying the amount of TAN produced per kg by the feed rate.

$$mass\ of\ TAN\ produced = \frac{kg\ TAN\ produced}{kg\ feed} \times \left(\frac{kg\ feed\ fed}{day}\right)$$

Using the areal TAN removal rate specified, the surface area can be calculated using the following formula:

$$surface\ area\ required\ (m^2) = \frac{TAN\ production\ (\frac{kg\ TAN}{day})}{TAN\ removal\ rate\ (\frac{g\ TAN}{m^2.day})} \times \frac{1000g}{1kg}.$$

The volume of biofilter media required is calculated by dividing the surface area required by the specific surface area of the biofilter media.

$$volume\ of\ biomedia\ required(m^3) = \frac{surface\ area\ required(m^2)}{specific\ surace\ area\ of\ media(\frac{m^2}{m^3})}.$$

4.2 Hydroponic Component

The model calculates the production capacity of the hydroponic component. The surface area of the farm's hydroponic component is determined at the site visits.

$$surface\ area\ of\ hydroponic\ component(m^2) = \sum_{x=1}^{\text{number of growbeds}} (growbed(x)length(m) \times growbed(x)width(m)).$$

The productivity and value of the produce from the hydroponic component is calculated as follows. The production per square metre of the various plants is obtained from the reference below.

$$mass\ of\ production(kg) = production\ of\ plant\ \left(\frac{kg}{m^2}\right) \times surface\ area\ of\ hydroponic\ component(m^2)$$

$$value\ of\ production(R) = mass\ of\ production(kg) \times selling\ price\ \left(\frac{R}{kg}\right)$$

Production rates for the hydroponic component of an aquaponics system at the UVI are shown in table 4.2.

	annual production kg / m²	value R / m²
tomatoes	29.295	10.61
cucumbers	60.544	13.69
eggplant	11.230	8.20
genovese basil	30.272	287.00
lemon basil	13.183	139.61
osmin basil	6.836	81.85
cilantro	18.554	243.50
parsley	22.948	328.78
portulaca	17.089	267.87

Table 4.2 Production and economic data from the UVI aquaponics system

4.3 Water Flow Rates

Knowing something about water flow rates when planning an aquaponics system is important. Knowing what size of piping is required to achieve sufficient water flow through the system is important when building a system. The fish stocking density determines how fast the turnover rate of water that goes through the fish tank is required. The higher the density, the more turnover is required. Water turnover rate should be at least half of the fish tank volume if the stocking density is less than 15kg/m³. One fish tank volume per hour should be turned over when the stocking density is higher. When planning a commercial aquaponics system one fish tank volume per hour should be a minimum design criterion. This water turnover rate ensures that dissolved waste, for example ammonia, doesn't build up to toxic levels and the amount of dissolved oxygen will be adequate. Going to high turnover rates does introduce danger of having too high-water velocity for certain fish species. Having too high-water velocity means that the fish would have to swim against the current, and sometimes it can affect negatively on fish health. If the water velocity is too slow, the fish might not swim enough, and it can affect negatively on their health. Having sufficient water turnover rate of one fish tank per hour ensures that water quality requirements of the fish will be met.

When building a system, the amount of water that must be turned determines minimum size of piping and pump that must be used to achieve sufficient water turnover rate. The pipes should be oversized by 30% to ensure sufficient water flow even when solids build up in pipes over the time.

Water flow rates for different pipe sizes using Hazen Williams Formula – S.I. units. Pipe material is PVC. Hazen Williams Coefficient, C is 140. Pressure drops over the pipe length, DP is 140 kN/m^2 [14].

Pipe Length m	Water flow rate, m^3/hr							
	Pipe diameter, mm							
	12	20	25	40	50	65	75	100
1	5.6	21.5	38.6	133.0	239.2	477.0	694.9	1481
2	3.9	14.8	26.6	91.5	164.5	328.1	478.0	1019
4	2.7	10.2	18.3	62.9	113.2	225.6	328.7	700.5
6	2.1	8.2	14.7	50.6	90.9	181.3	264.1	562.8
12	1.5	5.6	10.1	34.8	62.5	124.7	181.6	387.1
30	0.9	3.4	6.2	21.2	38.1	76.0	110.7	236.0

Table 4.3 Water flow rates for different pipe sizes

Hazen Williams Equation as used in this spreadsheet:

Q = (3.763 x 10-6) C D2.63(DP/L)0.54

Q is the water flow rate in m^3/hr

D Is the pipe diameter in mm

L is the pipe length in m

DP is the pressure difference across pipe length L in kN/m^2

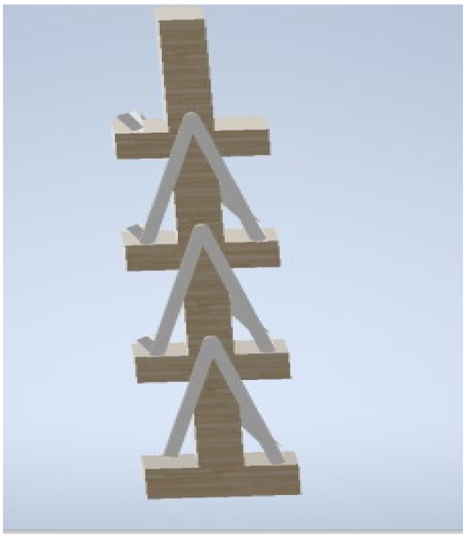
4.4 Description:

The invention is an integrated system of multiple cultivation finalized to fish fauna farms; each measure is provided as an example and should not be considered exhaustive. On a vertical rack anchored to uprights integral to the bases (interspersed with tub spaces), of approximately 0.22m x 1.5m x 0.02m (in any shape and material, wood, pvc, concrete, metals, ...),distance between each rack is 0.2m, a transparent tube of about 0.08cm or 0.1cm in diameter and 0.002m thickness (of any shape and material, corrugated, spiral, PVC, glass), with external UV protection, laid in a rectangular spiral in vertical semi-coplanar development, such as to involve semi-solid pipes on one side and on that opposite fluid-filled tubes. The half-full and full effect is obtained by a special elevation change (a portion of the diameter of the pipes) placed on one of the two short sides of the rectangle, on which the spiral develops vertically. In the upper part of the semi-full tubes, suitable containers of 0.04m diameter, 0.001or 0.002m of thickness are located to house seeds, as well as to favour germination and development of root systems. Breathing will be allowed by the semi air spaces approximately 0.02m is created, fed at the upper origin and in itinerant by the profusion through the containers of seeds and root systems contiguous to the air.

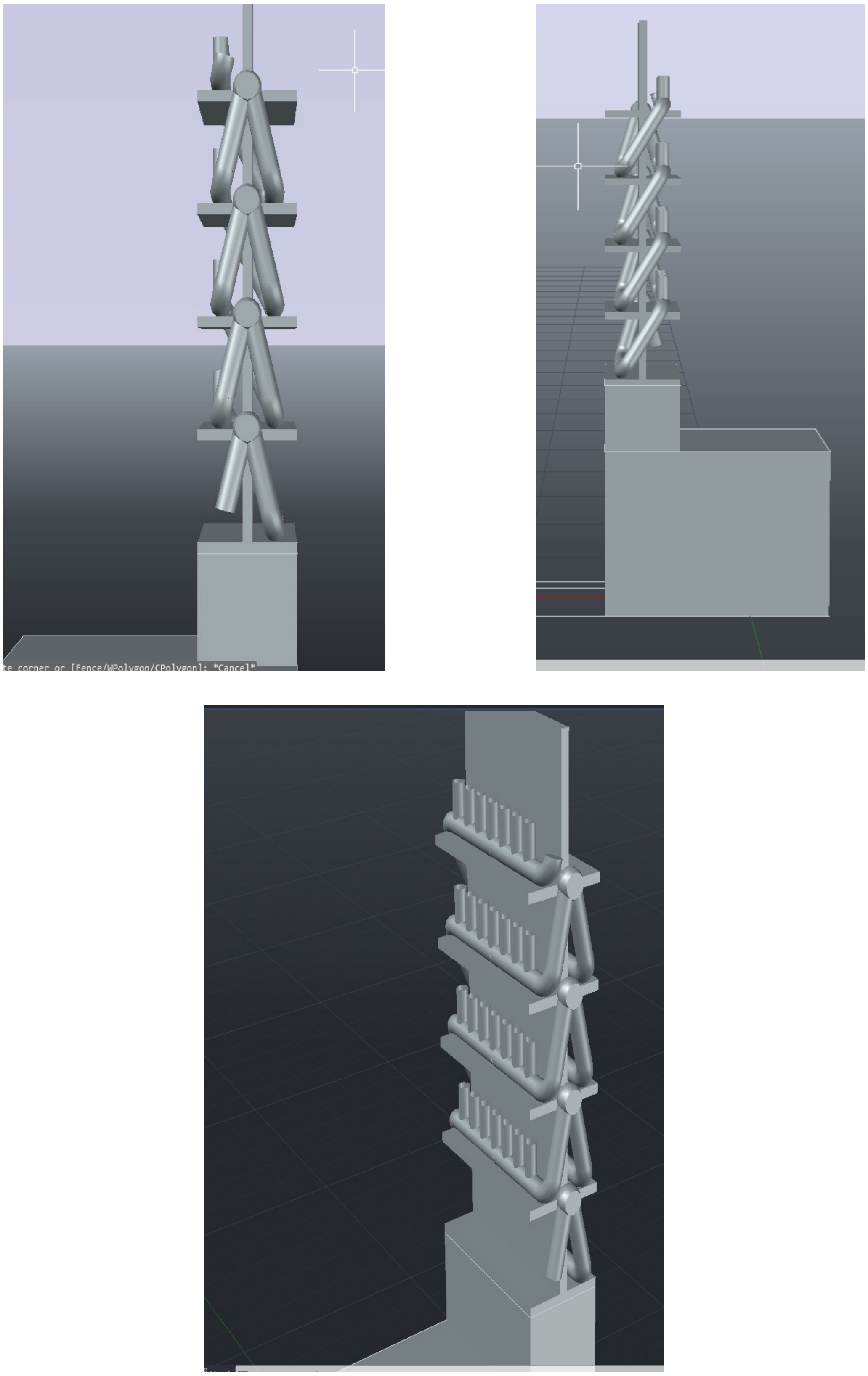
The respiration of these root systems will favour the production of CO2 in favour of the algae housed in the adjacent and underlying solutions, suitably agitated thanks to the overall periodic movement, moved from top to bottom by falling (after passing the relevant altimetric deltas). Movement that, during its periodicity, removes nitrates and other by-products through photosynthesis and algal growth, will bring regenerated water to the underlying fish fauna, housed in a suitable container/tank of 0.6m x 0.5m x 0.5m (structured by zones; for example, regenerated solution arrival area, permanence area for fauna development , collection area of saturated / dense wastewater solutions), together with the share of algal material not selected for different and perhaps priority purposes (feed / food / pharma / fuel)possibly after treatment with a specific sonotrode attached to suitable separators of 0.4m x 0.2m x 0.2m , as well as integrated with what is still appropriate (including the appropriate organic results of the horticultural and horticultural maintenance above).

The results after sampling of primary products (flowers, tomatoes or other), leaves, stems and more, can be suitably treated and integrated as much as the diets of the fish fauna should need for the pre-established purposes. The waters rich in fish waste are then brought back, after basic treatments (filters and other), to feed the rack from above, with appropriate periodic intervals (daily or hourly). Fluid handling will be entrusted to pumps, suitably sized and connected to sensors (levels, thermostats, light meters, ph. meters,etc.). The development of the processes will be governed, locally or remotely, by Raspberry pi or through any IoT devices according to procedures taken from veterinarians and agronomists by the products to be pursued [15].

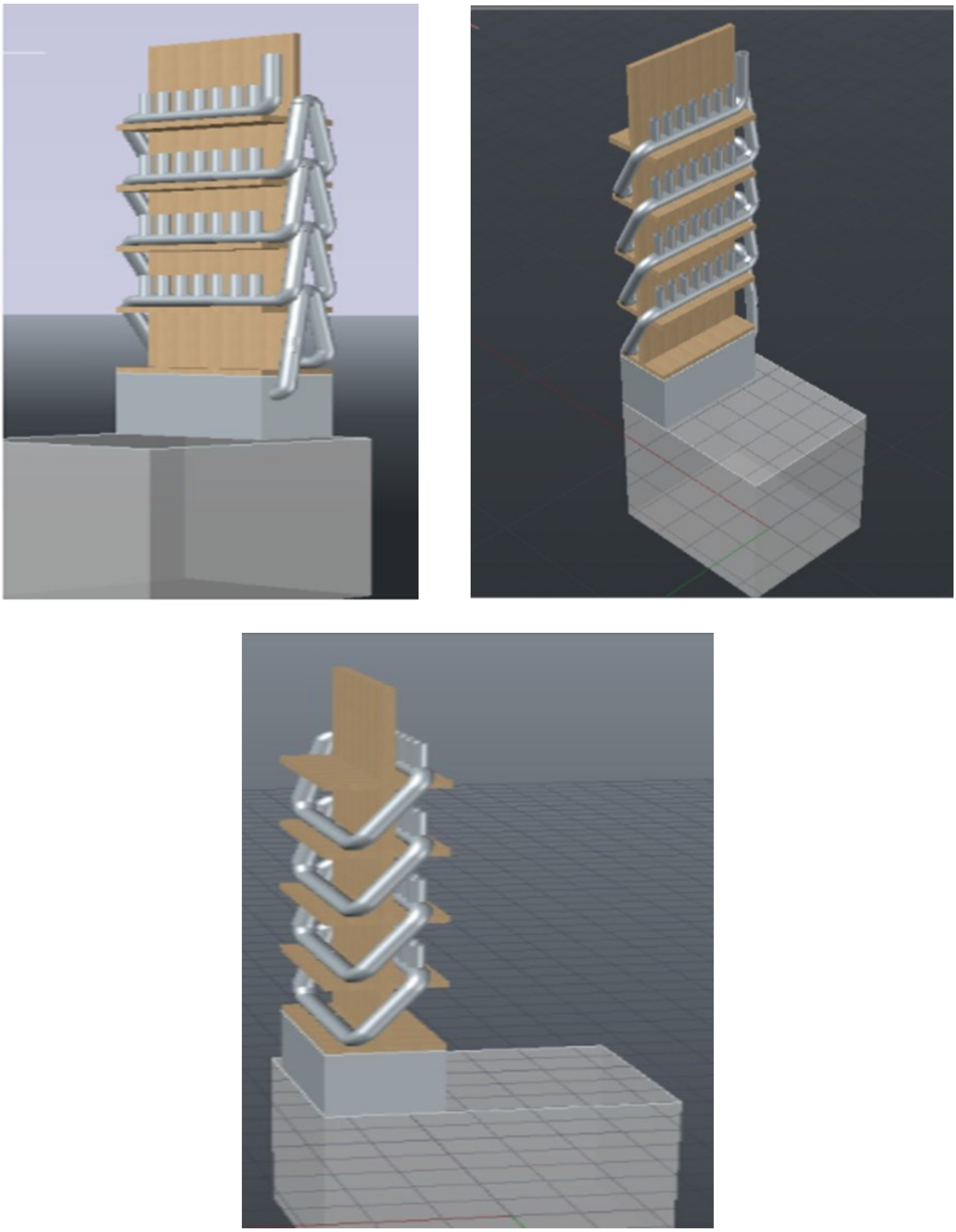
4.5 AutoCAD Drawings



FIRST STAGE OF DEVELOPMENT



SECOND STAGE OF DEVELOPMENT WITH SOME MODIFICATION



FINAL AUTOCAD MODEL

Fig 4.3 AutoCAD Diagrams

CHAPTER-5

HARDWARE DESCRIPTION

5.1 The Idea to Create the Raspberry Pi

The idea behind a tiny and affordable computer for kids came in 2006, when Eben Upton, Rob Mullins, Jack Lang, and Alan Mycroft, based at the University of Cambridge's Computer Laboratory, became concerned about the year-on-year decline in the numbers and skills levels of the A Level student applying to read Computer Science. From a situation in the 1990s where most of the kids applying were coming to interview as experienced hobbyist programmers, the landscape in the 2000s was very different; a typical applicant might only have done a little web design.

Thus came the idea of creating the device which kids could buy and learn programming or hardware on – The Raspberry Pi.

5.2 Initial Design Considerations

From 2006 to 2008 they created many designs and prototypes of what we now know as the Raspberry Pi. One of the earliest prototypes is shown below:

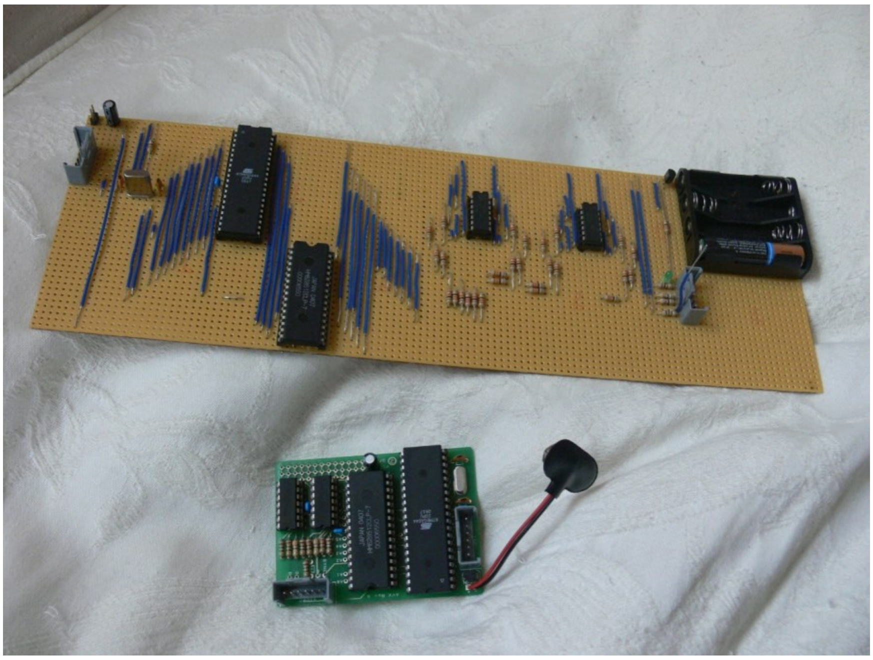


Fig 5.1 One of the earliest prototypes of the Pi

These boards use an Atmel ATmega644 microcontroller clocked at 22.1MHz, and a 512K SRAM for data and frame buffer storage.

By 2008, processors designed for mobile devices were becoming more affordable, and powerful enough to provide excellent multimedia, a feature which would make the board desirable to kids who wouldn't initially be interested in a purely programming-oriented device. The project started to look very realisable and feasible. Eben (now a chip architect at Broadcom), Rob, Jack, and Alan, teamed up with Pete Lomas, MD of hardware design and manufacture company Norcott Technologies, and David Braben, co-author of the BBC Micro game Elite, to form the Raspberry Pi Foundation to make it a reality. Three years later, the Raspberry Pi Model B entered mass production through licensed manufacture deals with Element 14/Premier Farnell and RS Electronics, and within two years it had sold over two million units!

5.3 Hardware

Hardware Layout

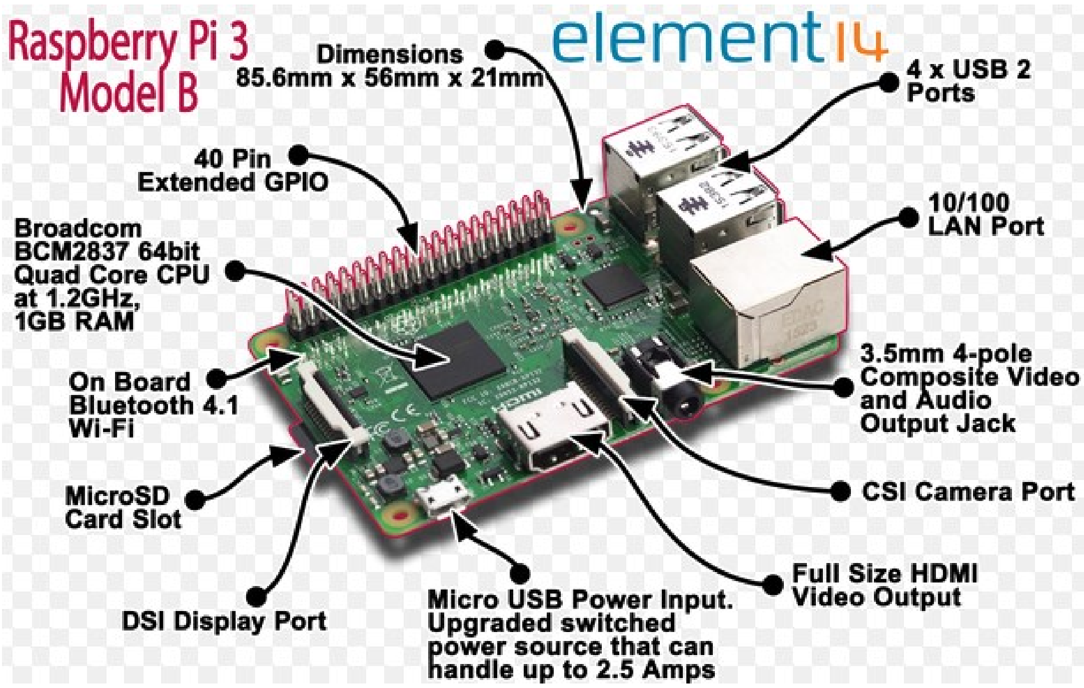


Fig 5.2 Block Diagram of Raspberry Pi3 [16][17]

5.3.1 A brief description of the components on the Pi.

1) **Processor / SoC (System on Chip)**

The Raspberry Pi has a Broadcom BCM2835 System on Chip module. It has a ARM1176JZF-S processor

The Broadcom SoC used in the Raspberry Pi is equivalent to a chip used in an old smartphone (Android or iPhone). While operating at 700 MHz by default, the Raspberry Pi provides a real-world performance roughly equivalent to the 0.041 GFLOPS. On the CPU level the performance is like a 300 MHz Pentium II of 1997-1999, but the GPU, however, provides 1 Gpixel/s, 1.5 Gtexel/s or 24 GFLOPS of general-purpose compute and the graphics capabilities of the Raspberry Pi are roughly equivalent to the level of performance of the Xbox of 2001. The Raspberry Pi chip operating at 700 MHz by default, will not become hot enough to need a heat sink or special cooling.

2) **Power source**

The Pi is a device which consumes 700mA or 3W or power. It is powered by a Micro USB charger or the GPIO header. Any good smartphone charger will do the work of powering the Pi.

3) **SD Card**

The Raspberry Pi does not have any on board storage available. The operating system is loaded on a SD card which is inserted on the SD card slot on the Raspberry Pi. The operating system can be loaded on the card using a card reader on any computer.

4) **GPIO**

GPIO – General Purpose Input Output

General-purpose input/output (GPIO) is a generic pin on an integrated circuit whose behaviour, including whether it is an input or output pin, can be controlled by the user at run time.

GPIO pins have no special purpose defined and go unused by default. The idea is that sometimes the system designer building a full system that uses the chip might find it useful to have a handful of additional digital control lines and having these available from the chip can save the hassle of having to arrange additional circuitry to provide them.

GPIO capabilities may include:

- GPIO pins can be configured to be input or output
- GPIO pins can be enabled/disabled
- Input values are readable (typically high=1, low=0)
- Output values are writable/readable
- Input values can often be used as IRQs (typically for wakeup events)

The production Raspberry Pi board has a 26-pin 2.54 mm (100 mil) expansion header, marked as P1, arranged in a 2x13 strip. They provide 8 GPIO pins plus access to I²C, SPI, UART), as well as +3.3 V, +5 V and GND supply lines. Pin one is the pin in the first column and on the bottom row.

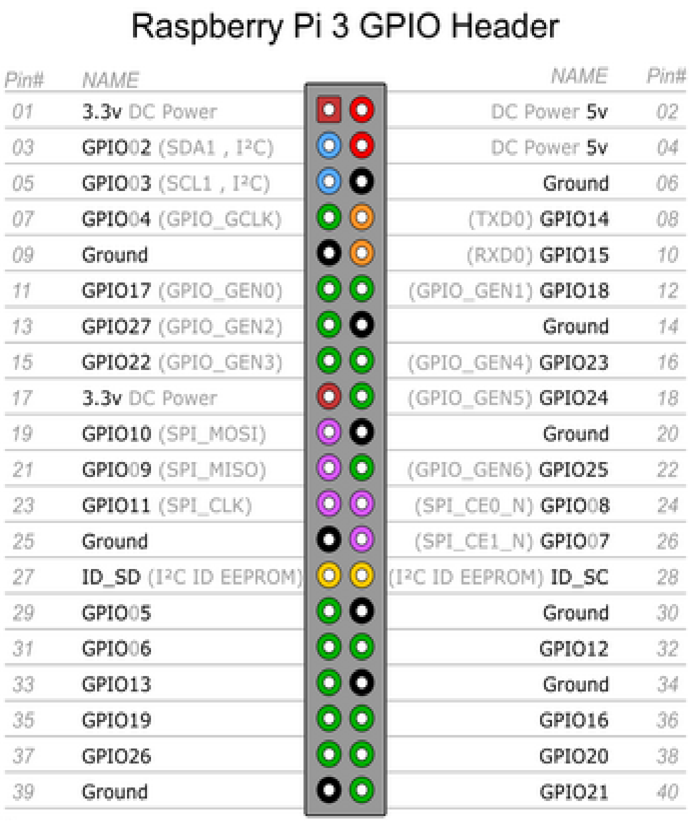


Fig 5.3 Raspberry Pi 3 GPIO Header [17]

5.3.2 Relay

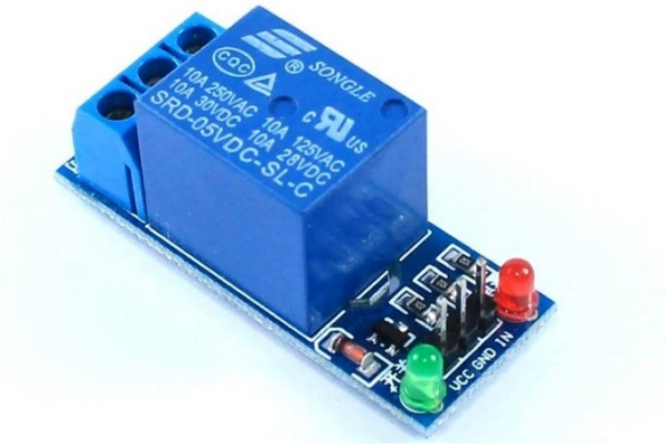


Fig 5.4 5V Single-Channel Relay Module [18]

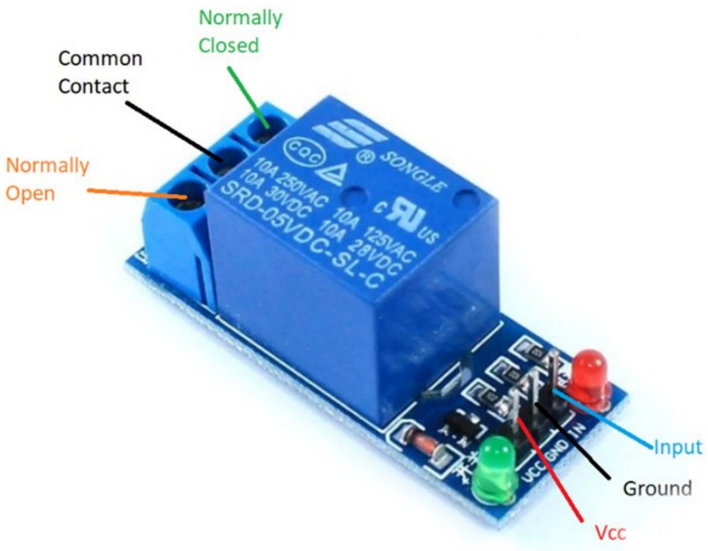


Fig 5.5 Single-Channel Relay Module Pinout

Relay is an electromechanical device that uses an electric current to open or close the contacts of a switch. The single-channel relay module is much more than just a plain relay, it comprises of components that make switching and connection easier and act as indicators to show if the module is powered and if the relay is active or not

Pin Number	Pin Name	Description
1	Relay Trigger	Input to activate the relay
2	Ground	0V reference
3	VCC	Supply input for powering the relay coil
4	Normally Open	Normally open terminal of the relay
5	Common	Common terminal of the relay
6	Normally Closed	Normally closed contact of the relay

Table 5.1 Single-Channel Relay Module Pin Description

1) **Single-Channel Relay Module Specifications**

- Supply voltage – 3.75V to 6V
- Quiescent current: 2mA
- Current when the relay is active: ~70mA
- Relay maximum contact voltage – 250VAC or 30VDC
- Relay maximum current – 10A

2) **Components Present on a 5V Single Channel Relay Module**

The following are the major components present on a relay module; we will get into the details later in this article.

5V Relay, Transistor, Diode, LEDs, Resistors, Male Header pins, 3-pin screw-type terminal connector, etc.

3)**Understanding 5V Single-Channel Relay Module**

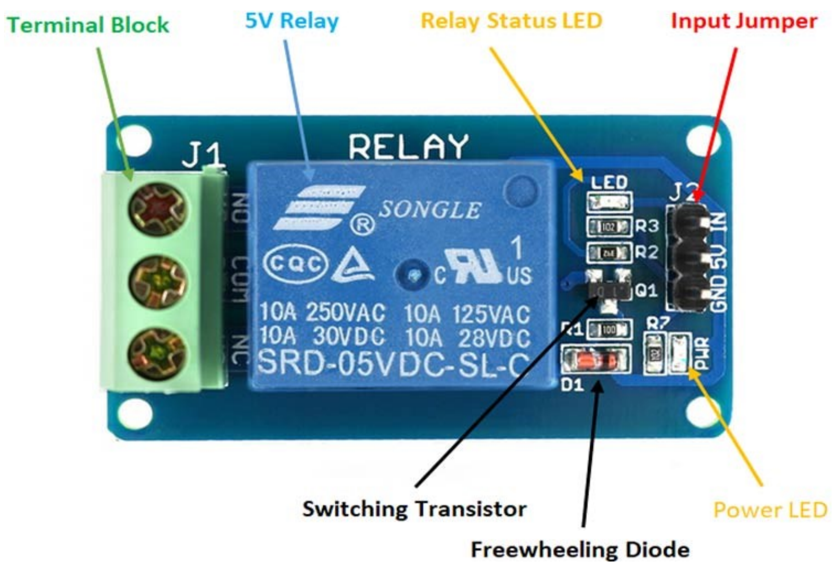


Fig 5.6 Relay Figure 1

The single-channel relay module is much more than just a plain relay, it contains components that make switching and connection easier and act as indicators to show if the module is powered and if the relay is active.

First is the screw terminal block. This is the part of the module that is in contact with mains, so a reliable connection is needed. Adding screw terminals makes it easier to connect thick mains cables, which might be difficult to solder directly. The three connections on the terminal block are connected to the normally open, normally closed, and common terminals of the relay.

The second is the relay itself, which, in this case, is a blue plastic case. Lots of information can be gleaned from the markings on the relay itself. The part number of the relay on the bottom says “05VDC”, which means that the relay coil is activated at 5V minimum – any voltage lower than this will not be able to reliably close the contacts of the relay. There are also voltage and current markings, which represent the maximum voltage and current, the relay can switch. For example, the top left marking says “10A 250VAC”, which means the relay can switch a maximum load of 10A when connected to a 250V mains circuit. The bottom left rating says “10A 30VDC”, meaning the relay can switch a maximum current of 10A DC before the contacts get damaged. The 'relay status LED' turns on whenever the relay is active and provides an indication of current flowing through the relay coil.

The input jumper is used to supply power to the relay coil and LEDs. The jumper also has the input pin, which when pulled high activates the relay.

The switching transistor takes an input that cannot supply enough current to directly drive the relay coil and amplifies it using the supply voltage to drive the relay coil. This way, the input can be driven from a microcontroller or sensor output. The freewheeling diode prevents voltage spikes when the relay is switched off.

The power LED is connected to V_{CC} and turns on whenever the module is powered.

How Does a Relay Work?

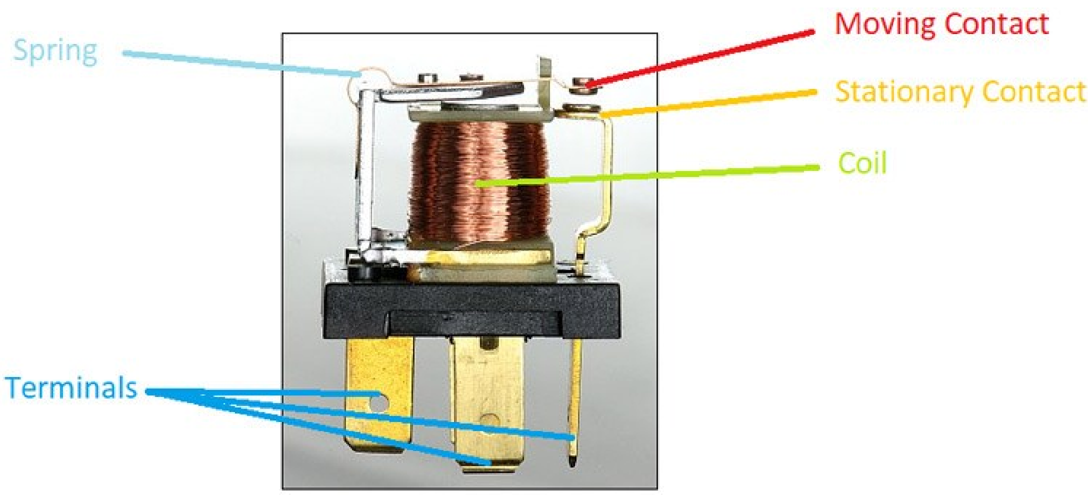


Fig 5.7 Relay Figure 2

The relay uses an electric current to open or close the contacts of a switch. This is usually done using the help of a coil that attracts the contacts of a switch and pulls them together when activated, and a spring pushes them apart when the coil is not energized.

There are two advantages of this system – First, the current required to activate the relay is much smaller than the current that relay contacts are capable of switching, and second, the coil and the contacts are galvanically isolated, meaning there is no electrical connection between them. This means that the relay can be used to switch mains current through an isolated low voltage digital system like a microcontroller.

Internal Circuit Diagram for Single Channel Relay Module

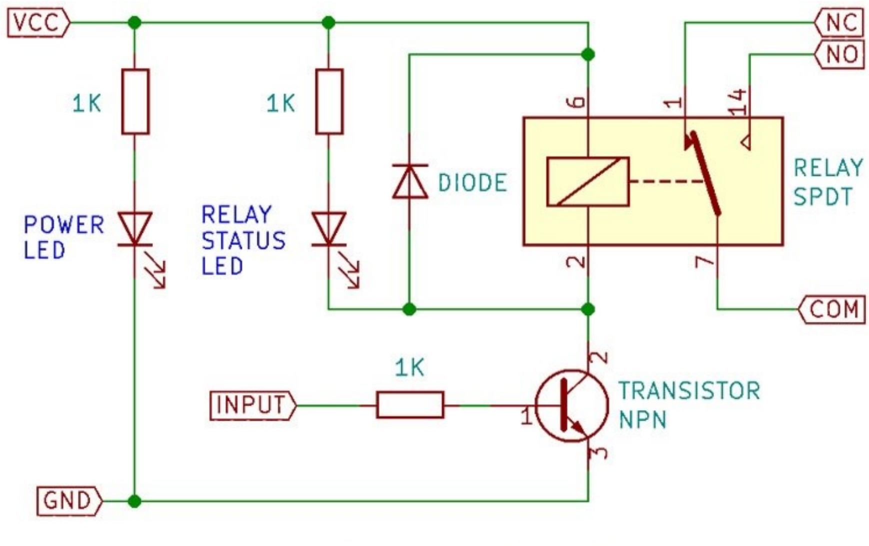


Fig 5.8 Relay Module Basic Schematic

The circuit on the PCB is quite simple.

The extra components apart from the relay are there since it would not be possible to drive the relay directly from the pins of a microcontroller, digital logic or a sensor. This is because although the coil consumes much less current than the currents it can switch, it still needs relatively significant current – low power relays consume around 50mA while higher power relays consume around 500mA. The coil is also an inductive load, so when the coil is switched off, a large flyback voltage is developed which can damage the device turning it on and off. For this reason, a flyback diode is added anti-parallel to the relay coil to clamp the flyback voltage.

LEDs can be added to this basic circuit to act as indicators, and sometimes even optical isolation is added to the input to further improve the isolation.

How to use Single-Channel Relay Module

Relay modules like this one are commonly used to drive mains loads from a microcontroller like the Arduino or a sensor. In cases like this, the common circuit diagram would be as follows.

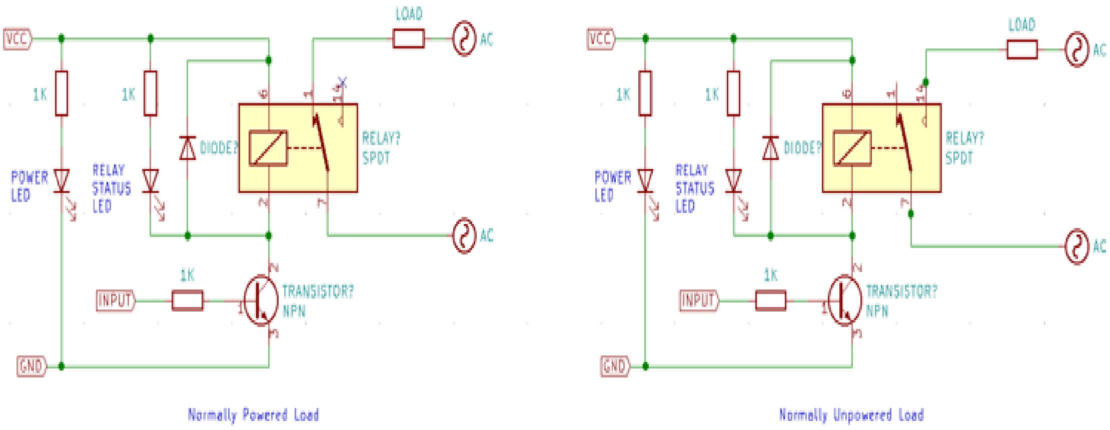


Fig 5.9 Normally Powered/Unpowered Load

For simple on/off applications, the relay can be connected as shown above. One terminal of mains is connected to common, and the other is connected to NO or NC depending on whether the load should be connected/disconnected when the relay is active.

Check out the image below to see how the relay module is connected to a microcontroller and mains source and load.

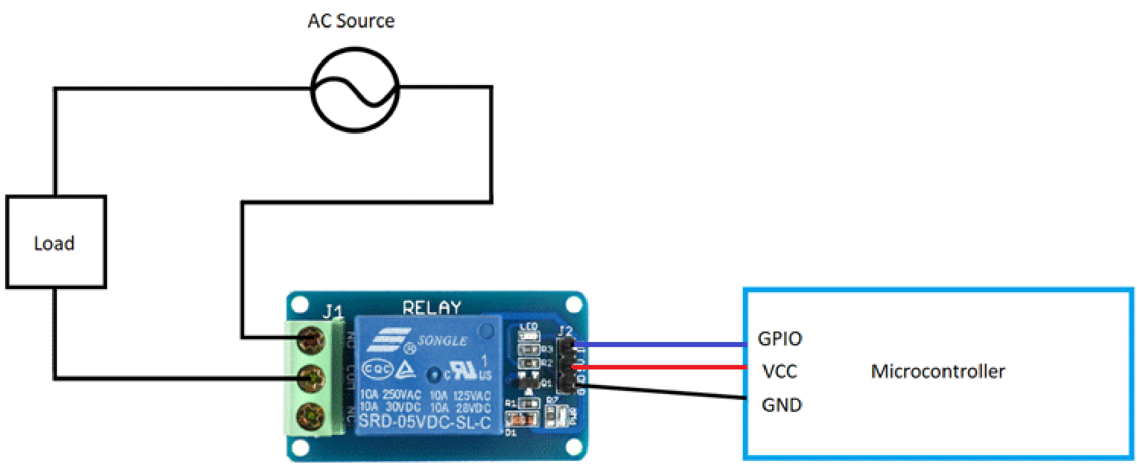


Fig 5.10 Relay Figure 3

The mains wiring is screwed to the terminal block, and the microcontroller can be connected using jumper cables.

Single-Channel Relay Module Basic Trouble Shooting

If the relay does not switch on, i.e., no audible clicking sound is heard:

- The contacts might be stuck - Check by physically shaking the relay, if a light clicking sound is not heard, then tap the relay hard, in most cases, this should 'unstick' both the contacts.
- If the contacts do click when the relay is shaken, then the transistor or the flyback diode might be damaged and must be replaced.

Single-Channel Relay Module Applications

- Mains switching
- High current switching
- Isolated power delivery
- Home automation

5.3.3 Electric Solenoid Water Air Valve Switch

12V DC Solenoid Water Air Valve Switch (Normally Closed) – 1/2″ controls the flow of fluid (liquid or air) and acts as a valve between high-pressure fluid. There are two ½" (Nominal NPT) outlets. Normally, the valve is closed. When a 12V DC supply is applied to the two terminals, the valve opens, and water can push through.

Fig 5.11 Water Air Valve Switch

The valve works with the solenoid coil which operates electronically with DC 12-volt supply. As it is a normally closed assembly, it opens the flow of fluids as soon as it is powered ON and stops/blocks the flow when the supply voltage removed [20].

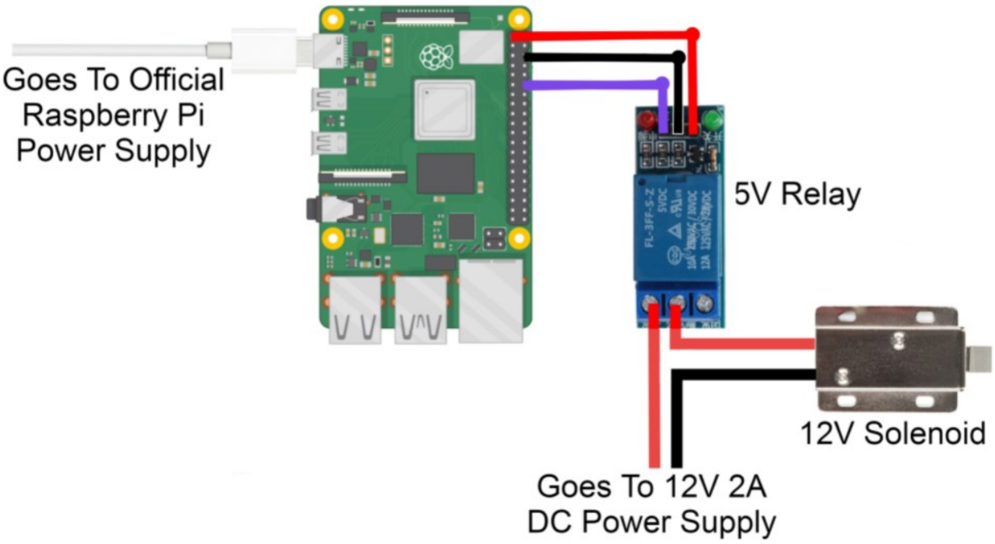


Fig 5.12 Raspberry Pi Interface with Solenoid Water Air Valve Switch

Specifications

1. Rated Operating Voltage: 12V DC
2. Rated Current: 1A
3. Operation Mode: NC (Normally Closed)
4. Pressure: 0.02 – 0.8MPa
5. Max fluid temperature: 100°C

5.3.4 Brushless Submersible Pump

This is a Brushless Submersible Pump that can be useful where the pumping of water is required. The pump has a brushless motor, which runs completely submersible and noiseless. This pump can work at a voltage of 220V-240VAC, so it makes it easy to use anywhere. The pump has built-in brushless motor drives so there is no need for any external drivers.

Fig 5.10 Submersible Pump

Specifications

- Voltage - 220v~240v; frequency - 50/60hz
- power / watt - 5.0w; water output - 300 l/h

5.3.5 LCD Display:

16x2 LCD modules are very commonly used in most embedded projects, the reason being its cheap price, availability, programmer friendly and available educational resources. 16x2 LCD has 2 horizontal line which comprising a space of 16 displaying character. It has two types of register inbuilt that is

- Command Register
- Data Register.

Command register is used to insert a special command into the LCD. While Data register is used to insert a data into the LCD. Command is a special set of data which is used to give the internal command to LCD like Clear screen, move to line 1 character 1, setting up the cursor etc [21][22][23].

HD44780 LCD Features and Technical Specifications

- Operating Voltage is 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning can display alphabets and numbers
- Consists of two rows and each row can print 16 characters.

- Each character is built by a 5×8-pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters
- Available in Green and Blue Backlight

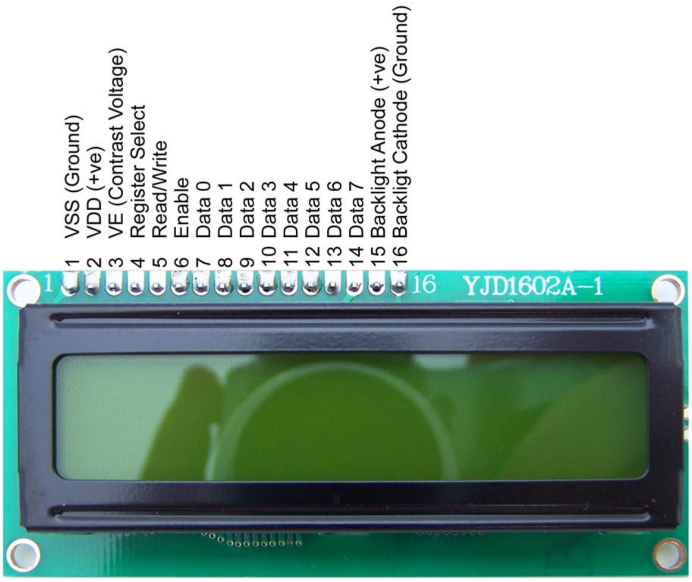


Fig 5.14 16 x 2 LCD display

16x2 LCD Module has 16 pins, which can be divided into five categories, Power Pins, contrast pin, Control Pins, Data pins and Backlight pins. Here is the brief description about them:

Category	**Pin NO.**	**Pin Name**	**Function**
Power Pins	1	VSS	Ground Pin, connected to Ground
	2	VDD or Vcc	Voltage Pin +5V
Contrast Pin	3	V0 or VEE	Contrast Setting, connected to Vcc thorough a variable resistor.
Control Pins	4	RS	Register Select Pin, RS=0 Command mode, RS=1 Data mode
	5	RW	Read/ Write pin, RW=0 Write mode, RW=1 Read

			mode
	6	E	Enable, a high to low pulse need to enable the LCD
Data Pins	7-14	D0-D7	Data Pins, Stores the Data to be displayed on LCD or the command instructions
Backlight Pins	15	LED+ or A	To power the Backlight +5V
	16	LED- or K	Backlight Ground

Table 5.1 16x2 LCD Module pin description

Sr.No.	Hex Code	Command to LCD instruction Register
1	01	Clear display screen
2	02	Return home
3	04	Decrement cursor (shift cursor to left)
4	06	Increment cursor (shift cursor to right)
5	05	Shift display right
6	07	Shift display left
7	08	Display off, cursor off
8	0A	Display off, cursor on
9	0C	Display on, cursor off
10	0E	Display on, cursor blinking
11	0F	Display on, cursor blinking
12	10	Shift cursor position to left
13	14	Shift cursor position to right
14	18	Shift the entire display to the left
15	1C	Shift the entire display to the right
16	80	Force cursor to beginning to 1st line
17	C0	Force cursor to beginning to 2nd line
18	38	2 lines and 5x7 matrix

Table5.3 Important Command Codes for LCD

5.3.6 MCP3208 8 channel ADC (analogy to digital converter):

The MCP3208-CI/P is an 8 channel, 12bit Analogue to Digital Converter (ADC) with SPI interface in 16 pin DIP package. This ADC combines high performance and low power consumption in a small package by making it as an ideal for embedded control applications. Applications for the MCP3208 include data acquisition, instrumentation and measurement, multi-channel data loggers, industrial PCs, motor control, robotics, industrial automation, smart sensors, portable instrumentation, and home medical appliances.

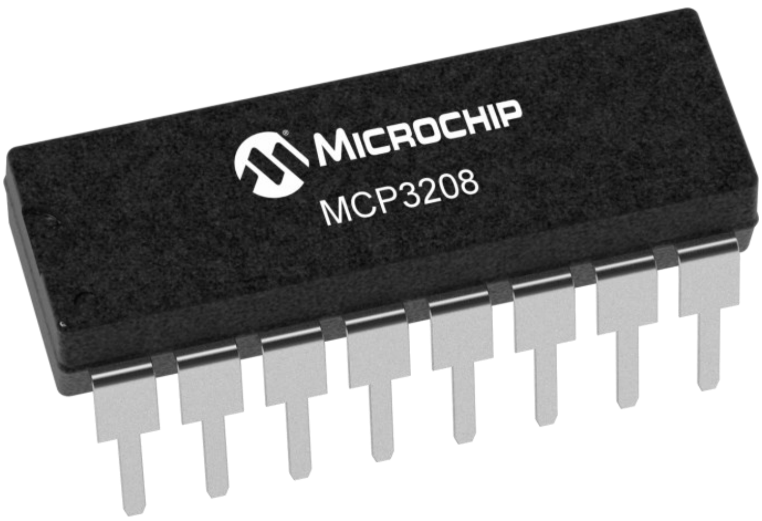


Fig 5.15 MCP3208 Microchip

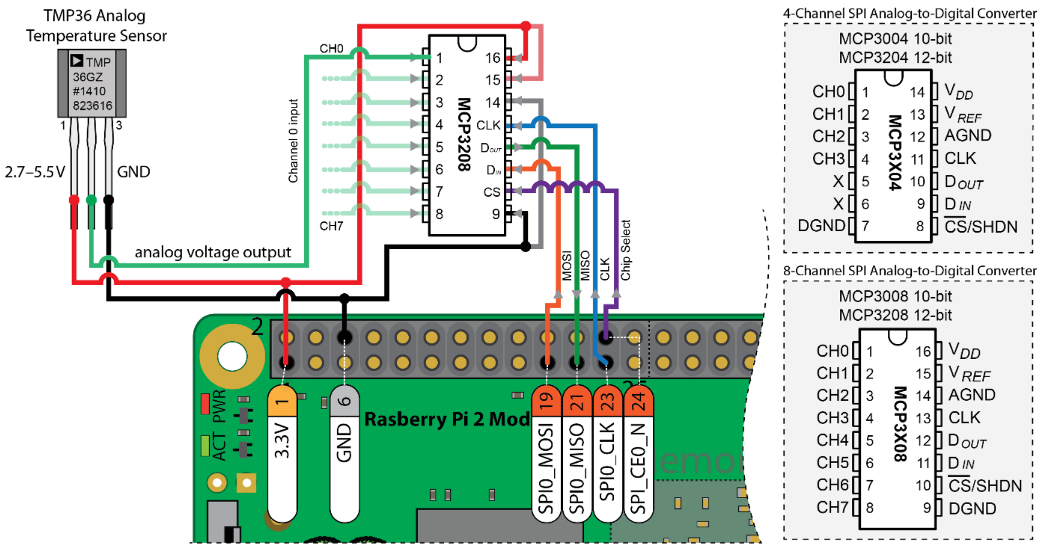


Fig 5.16 PIN DIAGRAM AND INTERFACE WITH RASPBERRY PI

5.3.7 Sensors:

1. DS18B20 Digital Temperature sensor.

The DS18B20 is one type of temperature sensor, and it supplies 9-bit to 12-bit readings of temperature. These values show the temperature of a particular device. The communication of this sensor can be done through a one-wire bus protocol which uses one data line to communicate with an inner microprocessor. Additionally, this sensor gets the power supply directly from the data line so that the need for an external power supply can be eliminated. The applications of the DS18B20 temperature sensor include industrial systems, consumer products, systems which are sensitive thermally, thermostatic controls, and thermometers [24].

Specification:

- Operating voltage: 3-5V
- Measuring Range: -55°C to +125°C
- Accuracy: ±0.5°C
- Resolution: 9-bit to 12-bit

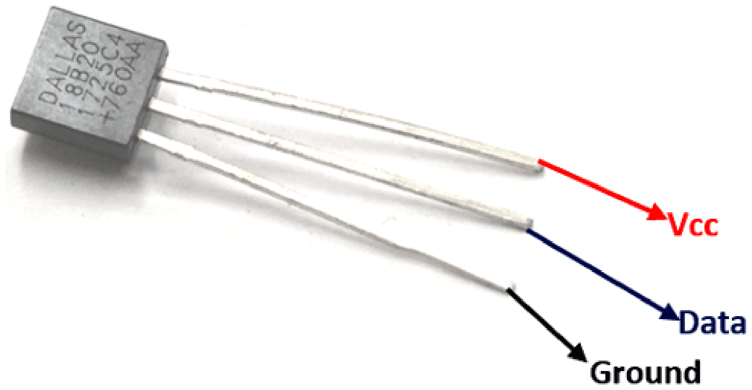


Fig 5.17 DS18B20 Temperature Sensor

2. PH sensor:

This sensor gives the output signal corresponding to the hydrogen ion concentration that is measured by pH electrode. Because it can be directly connected to controller, and then you can observe the pH value at any time. This device can be used for pH measurements, such as wastewater, sewage, and other occasions [25][26].

Specifications:

- Working Voltage 5V.
- Measure Range 0~14PH.
- PH sensor output range -414.12mV ~ 414.12mV
- Measure Accuracy <15 mV
- Temperature Range 0~60 ℃

Fig 5.18: PH Sensor

3. Turbidity sensor.

Turbidity sensors measure the amount of light that is scattered by the suspended solids in water. Turbidity sensors are used in river and stream gaging, wastewater and effluent measurements, control instrumentation for settling ponds, sediment transport research, and laboratory measurements. Turbidity sensor detects water quality by measuring the levels of turbidity, or the opaqueness. It uses light to detect suspended particles in water by measuring the light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water. As the TTS increases, the liquid turbidity level increases.

Specifications

- Rated Voltage: DC 5V (between No #1 & Ground)
- Operating Temperature Range: -10°C ~ 90°C
- Rated Current: 30 mA
- Insulation Resistance: in 100 MΩ by 500V DC

Fig 5.19 Turbidity Sensor

4. Conductivity sensor:

Electrical Conductivity is a good way to measure the nutrient concentration in your Aquaponics System. That is a measure of the water borne nutrients available to the plants. It should be noted that it is not a complete measurement of nutrient in an Aquaponics System, as there are organic nutrients present that an EC meter will not measure. However, over time, the overall measurement is a very useful one. Conductivity helps you to determine if you are getting the balance between the fish food given or placed in the system, to plant growth.

Specifications:

- Sensor type: Two electrodes sensor
- Electrode material Platinum
- Conductivity cell constant: 1 ± 0.2 cm-1

Fig 5.20 Conductivity Sensor

CHAPTER 6

SOFTWARE DESCRIPTION

6.1. RASPBERRY PI OS:

6.1.1. Introduction:

Raspbian is a free operating system based on Debian optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make your Raspberry Pi run. However, Raspbian provides more than a pure OS: it comes with over 35,000 packages pre-compiled software bundled in a nice format for easy installation on your Raspberry Pi. The initial build of over 35,000 Raspbian packages, optimized for best performance on the Raspberry Pi, was completed in June of 2012. However, Raspbian is still under active development with an emphasis on improving the stability and performance of as many Debian packages as possible.

6.1.2. Preparing Your Sd Card For The Raspberry Pi

The SD card contains the Raspberry Pi's operating system (the OS is the software that makes it work, like Windows on a PC or OSX on a Mac). This is very different from most computers, and it is what many people find the most daunting part of setting up their Raspberry Pi. It is very straightforward— just different!

The following instructions are for Windows users.

- Download the Raspberry Pi operating system (The recommended OS is called Raspbian)
- Unzip the file that you just downloaded
- Right click on the file and choose "Extract all".
- Follow the instructions—you will end up with a file ending in .img
- This .img file can only be written to your SD card by special disk imaging software.

6.1.3. Download The Win32diskimager Software.

- Download win32diskimager-binary.

- Unzip it in the same way you did the Raspbian .zip file
- You now have a new folder called win32diskimager-binary You are now ready to write the Raspbian image to your SD card.

6.1.4 Writing Raspbian to the SD Card

Run the file named Win32DiskImager.exe (in Windows Vista, 7 and 8 we recommend that you right-click this file and choose "Run as administrator"). You will see something like this:

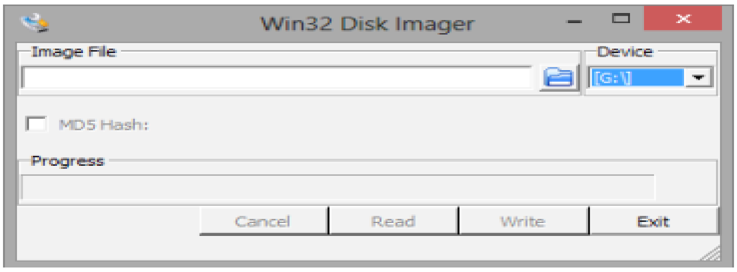


Fig 6.1 Win32 disk imager

- Plug your SD card into your PC
- In the folder you made in step 3(b),
- If the SD card (Device) you are using isn't found automatically then click on the drop-down box and select it
- In the Image File box, choose the Raspbian .img file that you downloaded
- Click Write
- After a few minutes you will have an SD card that you can use in your Raspberry Pi

6.1.5 Booting Your Raspberry Pi for The First Time

- insert SD card in to raspberry pi b+ board
- On first boot you will come to the Raspi-config window
- Change settings such as time zone and locale if you want
- Finally, select the second choice: expand_rootfs and say 'yes' to a reboot
- The Raspberry Pi will reboot, and you will see raspberry pi login:
- Type: pi
- You will be asked for your Password
- Type: raspberry

- You will then see the prompt: pi@raspberry ~ $
- Start the desktop by typing: startx
- You will find yourself in a familiar-but-different desktop environment.
- Experiment to start a new python project.

6.2. IDLE PYTHON PROGRAMMING

IDLE is the standard Python development environment Its name is an acronym of "Integrated Development and Learning Environment". It works well on both Unix and Windows platforms. it has a Python shell window, which gives you access to the Python interactive mode. It also has a file editor that lets you create and edit existing Python source files. The IDLE IDE (Integrated Development Environment) is included.

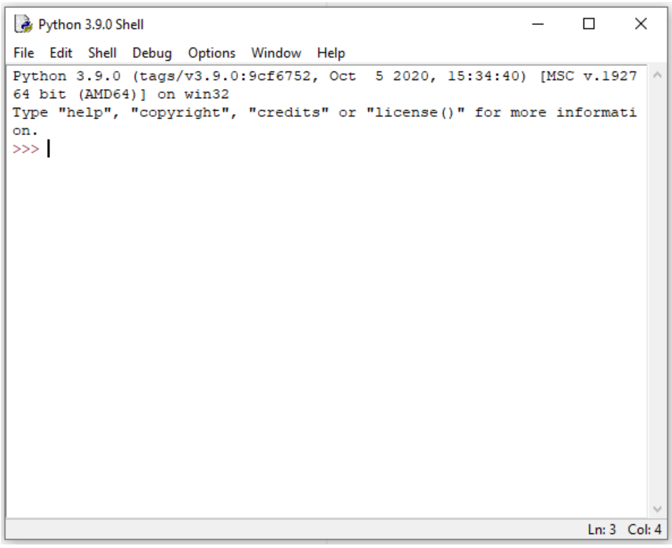


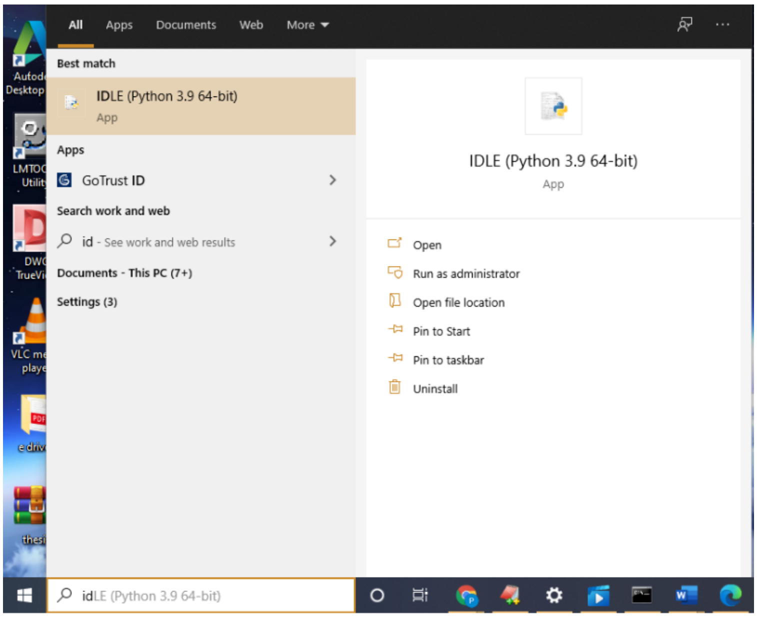
Fig 6.2. Python shell

Starting Programming With IDLE:

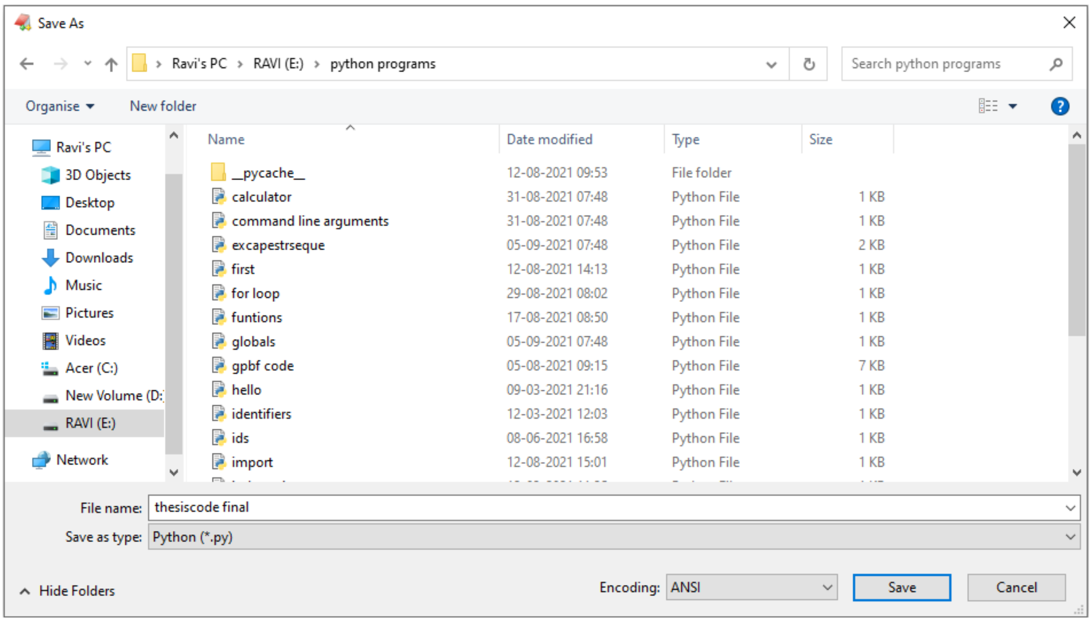
Run IDLE which will open the Python Shell window.

Select Menu > File > New Window

To run it select Menu > Run > Run Module and you should see your program appear in the Python Shell window.



1. Start IDLE (see screen above). You will then see a window entitled "Python Shell"
2. From the Python Shell window, select **New Window** from the **File** menu.
3. You will see a window entitled "Untitled
4. From the **File** menu, select **Save As**, and select a folder to save your Python program file.



Select a folder to save your file in.
In the **File name:** text box, type: program1.py
Then click on the **Save** button. You will then see a blank editor window ready for you to type in your Python program.

To run this program, select **Run Module** from the **Run** menu You should see a reminder to save the Source (your program).

Click on OK to save. Then you will see your program running in a Python Shell window.

Python is a widely used general-purpose, high-level programming language. Its design philosophy emphasizes code readability, and its syntax allows programmers to express concepts in fewer lines of code than would be possible in languages such as C++ or Java. The language provides constructs intended to enable clear programs on both a small and large scale. Python supports multiple programming paradigms, including object oriented, imperative and functional programming or procedural styles. It features a dynamic type system and automatic memory management and has a large and comprehensive standard library. Python interpreters are available for installation on many operating systems, allowing Python code execution on a wide variety of systems. Using third-party tools, such as Py2exe or Python installer, Python code can be packaged into stand-alone executable programs for some of the most popular operating systems, allowing the distribution of Python-based software for use on those environments without requiring the installation of a Python interpreter.

C Python, the reference implementation of Python, is free and open-source software and has a community-based development model, as do nearly all of its alternative implementations. C Python is managed by the non-profit Python Software Foundation.

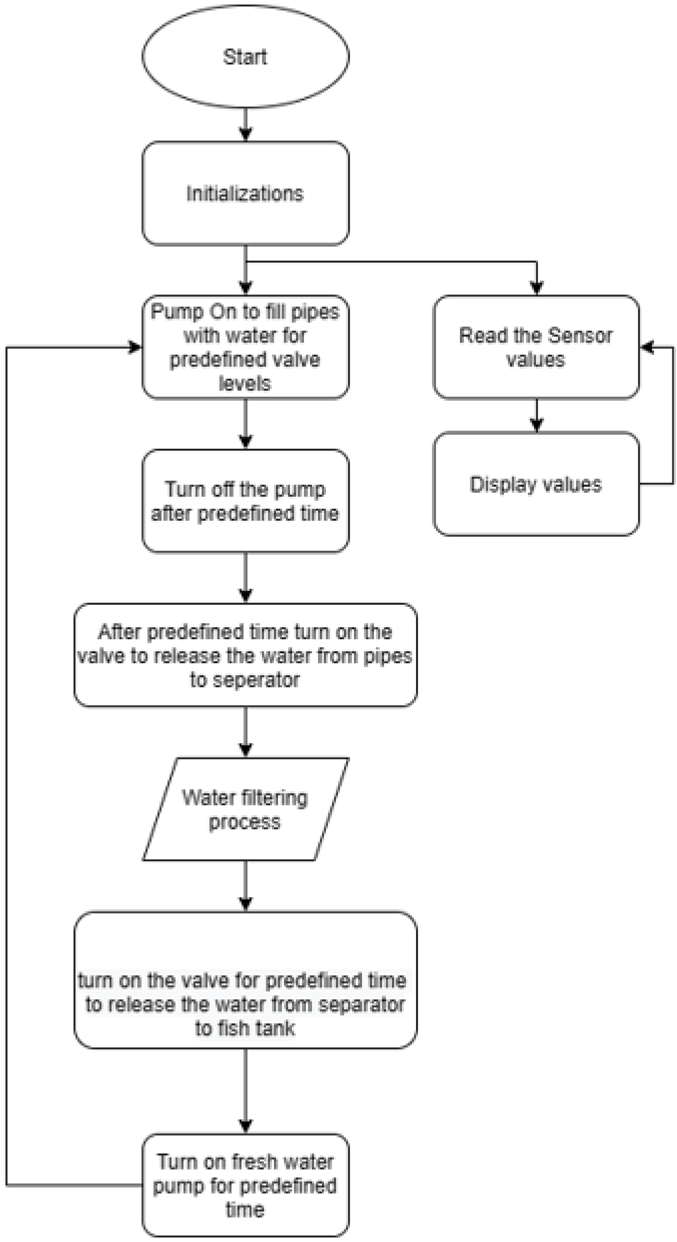


Fig 6.3 Program flow diagram

PROGRAM:

```
import RPi.GPIO as GPIO
import time
import datetime
import os
import io
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
os.system('modprobe w1-gpio')#ds18b20
os.system('modprobe w1-therm')
 base_dir = '/sys/bus/w1/devices/'
device_folder = glob.glob(base_dir + '28*')[0]
device_file = device_folder + '/w1_slave'
def read_temp_raw():
    f = open(device_file, 'r')
    lines = f.readlines()
    f.close()
    return lines
```

```python
def read_temp():
    lines = read_temp_raw()
    while lines[0].strip()[-3:] != 'YES':
        time.sleep(0.2)
        lines = read_temp_raw()
    equals_pos = lines[1].find('t=')
    if equals_pos != -1:
        temp_string = lines[1][equals_pos+2:]
        temp_c = float(temp_string) / 1000.0
        temp_f = temp_c * 9.0 / 5.0 + 32.0
        return temp_c, temp_f


# Define GPIO to LCD mapping
LCD_RS = 11
LCD_E  = 5
LCD_D4 = 6
LCD_D5 = 13
LCD_D6 = 19
```

```
LCD_D7 = 26


#MCP3208
clk = 10
din = 27
dout = 22
cs = 17


pump=2
pump2=16
valve1=3
valve2=21
valve3=12
valve4=9
valve5=4


# Define some device constants
LCD_WIDTH = 16    # Maximum characters per line
LCD_CHR = True
```

```
LCD_CMD = False

LCD_LINE_1 = 0x80 # LCD RAM address for the 1st line
LCD_LINE_2 = 0xC0 # LCD RAM address for the 2nd line

# Timing constants
E_PULSE = 0.0005
E_DELAY = 0.000

GPIO.setup(valve1, GPIO.OUT)
GPIO.setup(valve2, GPIO.OUT)
GPIO.setup(valve3, GPIO.OUT)
GPIO.setup(valve4, GPIO.OUT)
GPIO.setup(valve5, GPIO.OUT)
GPIO.setup(pump, GPIO.OUT)
GPIO.output(pump,0)
GPIO.setup(pump2, GPIO.OUT)
GPIO.output(pump2,0)
GPIO.output(valve1,0)
```

```
GPIO.output(valve2,0)

GPIO.output(valve3,1)

GPIO.output(valve4,0)

GPIO.output(valve5,0)

lvl_sens1=20

lvl_sens2=16


def main():

  # Main program block


  GPIO.setwarnings(False)

  GPIO.setmode(GPIO.BCM)       # Use BCM GPIO numbers

  GPIO.setup(LCD_E, GPIO.OUT)  # E

  GPIO.setup(LCD_RS, GPIO.OUT) # RS

  GPIO.setup(LCD_D4, GPIO.OUT) # DB4

  GPIO.setup(LCD_D5, GPIO.OUT) # DB5

  GPIO.setup(LCD_D6, GPIO.OUT) # DB6

  GPIO.setup(LCD_D7, GPIO.OUT) # DB7
```

```
GPIO.setup(clk, GPIO.OUT)

GPIO.setup(din, GPIO.OUT)

GPIO.setup(dout, GPIO.IN)

GPIO.setup(cs, GPIO.OUT)



GPIO.setup(lvl_sens1, GPIO.IN)

GPIO.setup(lvl_sens2, GPIO.IN)



# Initialise display

lcd_init()



lcd_byte(0x01,LCD_CMD)

lcd_string("   WELCOME",LCD_LINE_1)

time.sleep(2)

time.sleep(2)

lcd_byte(0x01,LCD_CMD)

ii=0

GPIO.output(pump,1)

time.sleep(40)
```

```
GPIO.output(pump,0)

while True:

  temperature=int(read_temp()[0])

  phval=(adc(0)*(5/4096))*3.5

  tbval=(adc(1)*(5/4096))*1.5

  cdval=(adc(2)*(5/4096))



  lcd_byte(0x01,LCD_CMD)

  lcd_string("T:" + str(temperature) + "'C" + " PH:" +str(phval,LCD_LINE_1)

  lcd_string("TB:" + str(tbval)  + " CD:" + str(cdval) ,LCD_LINE_2)

  time.sleep(3)



  print ("Temp: %d" %temperature)

  print ("PH:  %d " %phval)

  print ("TB:  %d " %tbval)

  print ("CD:  %d " %cdval)

  time.sleep(1)

  ii=ii+1
```

```
if(ii==290):            #RACKS TO SEPERATOR
    GPIO.output(valve3,0)


if(ii==300):            #RACKS TO SEPERATOR 50L COMPLETED
    GPIO.output(valve3,1)
    GPIO.output(valve4,0)  #seperater to waste water tank


if(ii==304):
    GPIO.output(valve4,1)
    GPIO.output(valve5,0)
if(ii==310):
    GPIO.output(valve5,1)
    GPIO.output(pump,1)
if(ii==410 ):
    GPIO.output(pump,0)
    GPIO.output(pump2,1)
if(ii==411 ):
    GPIO.output(pump2,0)
```

```
        ii=0

    if(GPIO.input(lvl_sens1)==0):
        GPIO.output(valve1,1)
    else:
        GPIO.output(valve1,0)

    if(GPIO.input(lvl_sens2)==0):
        GPIO.output(valve2,1)
    else:
        GPIO.output(valve2,0)

def adc(k):

    i = 0
    bt0 = 0
    bt1 = 0
    bt2 = 0
    val = 0
```

```
x = 0

A=0

C=0


GPIO.output(clk, False)

GPIO.output(cs, True)

GPIO.output(cs, False)


x = (k*4)+0x60

A = x>>4

C = x<<4


mask=0x80


while(mask>0):


   GPIO.output(clk, True)

   if(A & mask):

      GPIO.output(din, True)
```

```
    else:
        GPIO.output(din, False)

    GPIO.output(clk, False)

    if(GPIO.input(dout)==True):

        bt0 |= mask
    mask>>=1

mask=0x80

while(mask>0):

    GPIO.output(clk, True)
    if(C & mask):
        GPIO.output(din, True)
    else:
        GPIO.output(din, False)
```

```
    GPIO.output(clk, False)

    if(GPIO.input(dout)==True):

        bt1 |= mask
    mask>>=1

mask=0x80

while(mask>0):

    GPIO.output(clk, True)
    if(0x00 & mask):
        GPIO.output(din, True)
    else:
        GPIO.output(din, False)

    GPIO.output(clk, False)
```

```
        if(GPIO.input(dout)==True):

            bt2 |= mask

        mask>>=1

    GPIO.output(cs, True)

    val = (bt1 & 0x0f)

    val = ((val<<8) | bt2)

    return val

def lcd_init():

  # Initialise display

  lcd_byte(0x33,LCD_CMD) # 110011 Initialise

  lcd_byte(0x32,LCD_CMD) # 110010 Initialise

  lcd_byte(0x06,LCD_CMD) # 000110 Cursor move direction

  lcd_byte(0x0C,LCD_CMD) # 001100 Display On,Cursor Off, Blink Off

  lcd_byte(0x28,LCD_CMD) # 101000 Data length, number of lines, font size
```

```
 lcd_byte(0x01,LCD_CMD) # 000001 Clear display
 time.sleep(E_DELAY)

def lcd_byte(bits, mode):
 # Send byte to data pins
 # bits = data
 # mode = True  for character
 #        False for command

 GPIO.output(LCD_RS, mode) # RS

 # High bits
 GPIO.output(LCD_D4, False)
 GPIO.output(LCD_D5, False)
 GPIO.output(LCD_D6, False)
 GPIO.output(LCD_D7, False)
 if bits&0x10==0x10:
   GPIO.output(LCD_D4, True)
 if bits&0x20==0x20:
```

```
  GPIO.output(LCD_D5, True)

if bits&0x40==0x40:

  GPIO.output(LCD_D6, True)

if bits&0x80==0x80:

  GPIO.output(LCD_D7, True)



# Toggle 'Enable' pin

lcd_toggle_enable()



# Low bits

GPIO.output(LCD_D4, False)

GPIO.output(LCD_D5, False)

GPIO.output(LCD_D6, False)

GPIO.output(LCD_D7, False)

if bits&0x01==0x01:

  GPIO.output(LCD_D4, True)

if bits&0x02==0x02:

  GPIO.output(LCD_D5, True)

if bits&0x04==0x04:
```

```
    GPIO.output(LCD_D6, True)
  if bits&0x08==0x08:
    GPIO.output(LCD_D7, True)

  # Toggle 'Enable' pin
  lcd_toggle_enable()

def lcd_toggle_enable():
  # Toggle enable
  time.sleep(E_DELAY)
  GPIO.output(LCD_E, True)
  time.sleep(E_PULSE)
  GPIO.output(LCD_E, False)
  time.sleep(E_DELAY)

def lcd_string(message,line):
  # Send string to display
 message = message.ljust(LCD_WIDTH," ")
```

```
  lcd_byte(line, LCD_CMD)

  for i in range(LCD_WIDTH):
    lcd_byte(ord(message[i]),LCD_CHR)

if __name__ == '__main__':

  try:
    main()
  except KeyboardInterrupt:
    pass
  finally:
    lcd_byte(0x01, LCD_CMD)
    lcd_string("CLOSED !",LCD_LINE_1)
    GPIO.cleanup()
```

6.3 DEPRECIATION

Depreciation is non-cash deduction which occurs in the profit and loss statement. As a result, depreciation has cash flow consequences because it influences the tax bill. The way depreciation is computed for tax purposes is thus the relevant manner to calculate depreciation for feasibility study decisions.

The various components that comprise the aquaponics system depreciate at different rates and should be calculated as such. By researching the depreciation rates used in other aquaponics business plans in the literature, the depreciation for the components in the case studies are determined.

The annual depreciation is calculated by dividing the value of the asset by the lifespan of the asset.

$$annual\ depreciation = \frac{value\ of\ asset}{lifespan\ (years)}$$

6.3.1 Capital expenditure

Using the depreciation rates from the section above, the point in time when an asset needs to be replaced can be determined. The cost of replacing the asset is incurred to the system at such time.

6.3.2 Operating expenses

The operating expenses are divided into direct production costs, and overheads costs. The direct (or variable) costs are feed cost for the grow out stock, costs for additives, chemical testing equipment, organic pesticides, seedlings, and either feed cost for the broodstock, or fingerling restocking cost (depending on the design of the system).

Overhead costs (otherwise known as fixed costs) are insurance, electricity, capital purchases, labour, and maintenance.

Normally labour is a cost for these systems, but in the case studies the owners perform the labour tasks themselves. The model has an input for labour cost, but this value is set to zero for the case studies.

6.3.3 Sales

The sales are calculated by determining the times when the products are ready for sale. The mass of fish harvested, as well as the selling price, are used to calculate the revenue of the aquaculture component. The revenue generated from the hydroponic component of the system is calculated using the production rates from table 3, as well as the selling price.

6.3.4 Cash flow

The cash flow statement incorporates the operating expenses as well as the sales sheet. Loan repayments, as well as loan interest, is also deducted from the cash flow. Inflation of all the elements is factored in at this stage. Some of the elements which are expected to have inflation rates that are expected to vary from the average inflation (such as feed cost and electricity cost) have separate inflation rates that can be adjusted at the input data.

6.3.5 Profit and loss statement

The profit and loss statement follows a specific format. The gross profit is calculated by deducting the direct cost of sales from the income value. Net profit before income and tax is calculated by deducting overhead costs, as well as depreciation. Deducting interest provides the net profit before tax. Deducting tax provides the net profit.

$$gross\ profit = sales - cost\ of\ sales$$

$$net\ profit\ before\ interest\ and\ tax = gross\ profit - overhead\ costs - depreciation \ldots (36)$$

$$net\ profit\ before\ tax = net\ profit\ before\ interest\ and\ tax - interest$$

$$net\ profit = net\ profit\ before\ tax - tax.$$

6.4 Financial Indicators

Several financial indicators are used in the feasibility model. The Net Present Value (NPV) and Internal Rate of Return (IRR) are two of the most popular financial indicators used in financial management. The IRR, however, is a not suitable indicator for ventures such as these because of the nature of the cash flows that the systems experience. The financial indicator that is used the most in this thesis is therefore the NPV. Appendix C contains a detailed description of the financial indicators used in this thesis, describing the method of calculation, advantages, and disadvantages of each.

CHAPTER-7

CONCLUSION AND FUTURESCOPE

At the end of this project, we can conclude that the technique of integrated cultivation system is a viable alternative to the traditional farming techniques in terms of water and land usage and running costs. Although in an agricultural country, where agricultural land is in abundance, but the shortage of water is a big issue, and it needs to be catered for this integrated cultivation and integrated cultivation is the way to solve this issue.

One of the main aims of this project is to design and develop integrated cultivation system and to bring this system to urban areas, where people have a busy life, hence the need of automation of this technique is extremely important. This project provides smart suggestions and smart monitoring system to the users and makes it easier for them to grow their organic food in their homes and enjoy cheap and healthy food.

From the practical implementation of this technique, we can conclude that this technique requires a pre-matured aqua-culture, and pre-matured plants of suitable sizes. So that they can survive in sunlight and fishes can survive the temperature and pH changes in water, resulting from changing in the environment.

At the end we conclude that this technique is one of the best countermeasures against the threat of global hunger and famine in African countries and this technique should be adopted at an industrial scale to reap benefits at a national and international level.

7.1 Future scope

Although the proposed system is Automatic and stand-alone, it can still be improved in multiple areas by utilizing the useful recommendation provide in this section below.

The user is limited to using the Raspberry Pi to check the values and states of the plants. This can easily be made more friendly and effective by connecting the Raspberry Pi to the internet. An online server will be required to store each value, separately, for every user. The user can then access the graphs, and the current state of the system through the android application by using his/her registered username and password.

Furthermore, the user can be able to control the system from the application, once connected to the net. Exhausts can be used to control the air flow through the system and provide the crops with enough amount of carbon dioxide and oxygen, as required for their growth. Water sprinklers can be used in front of the exhausts, which will help to increase the humidity and drop the temperature for optimum plant growth.

For days with low sunlight hours, or systems placed indoors; incandescent lamps with high light intensity can be used to compensate the light deficiency. However solar panels will be required to provide the lamps with high amounts of power. Red and Blue LEDs with high light intensity and a ratio of 3 red to 1 blue will be more efficient. The plants, however, will still require at least 8 hours of rest in the dark, to process the carbohydrates produced.

Live feed of the plants can also help in improving the system. The image feed can be used in image processing techniques to check the plants for yellow spots – that indicate deficiency on nutrients –, wilting etc. This can help identify is the plants require more care or are ready for harvest.

The crops should not be added in the system, until the aquaculture is pre-mature, and the fish are excreting enough nutrients. Otherwise, the plants will not properly adapt to the system and their growth will be inhibited.

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