Computer Based Self-Sustaining Aquaponics Water-Level Controller

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Abstract: The main objective of the research paper is to describe our computer based self-sustaining aquaponics water-level controller system. Our motivation was borne out of our collective desire to assist indigenous farmers in Abakaliki, Nigeria. Interestingly, an Aquaponic is a food production system which combines conventional aquaculture with hydroponics in a symbiotic environment. Fishes in the system produce waste that turns into nitrates and ammonia. This are not good for the fishes but is good fertilizer for the plants. As the plants take up these nutrients, they purify the water for the fishes in return. This system can be made to be truly self-sustaining by automating the control of the water levels. The full automation will be done by a computer system which is interfaced to the aquaponic system. When interfaced to the aquaponic system, it helps the system to determine when the water is no longer conducive. This work will be channelled towards automating and indigenising this solution so that Abakaliki farmers can benefit from it. The success of this work will reduce the complexity and cost of the industrial versions of the system in existence. It will also present this system as an attractive alternative income and food source to urban workers and entrepreneurial opportunity to job seekers. This will promote agriculture and productivity in Abakaliki, Nigeria where water is a limited resource. In all, this paper describes our solution, including the overall design, the technology involved and the benefits to farmers in Abakaliki, Nigeria.

Key words: Automation · Aquaponics · Water Level Controller · Self-Sustaining

INTRODUCTION

Today, there is huge advancement in technology as it concerns agriculture, aquaculture and hydroponics. Among these technological advancements is the Aquaponics. Interestingly, Aquaponics could be described as the integration of aquaculture and hydroponics. Aquaculture in this context is the breeding, rearing and harvesting of plants and animals in all types of water environment under controlled conditions. Hydroponics is best described as a technique of growing plants using mineral nutrient solutions in water without soil. In a related work [1], they opined that intensive agriculture and aquaculture present high economic and environmental impacts.

It is a system that encompasses an aquaculture which is a technology used in raising edible fishes and hydroponics which is a technique used in growing vegetables and herbs without a soil medium [2]. Therefore, an aquaponics is an eco-friendly system utilized to cultivate fish and grow crop without soil by using aquaculture and hydroponics [3].

These systems are not self-sustainable because they require the addition of fossil fertilizers or other supplemental nutrients so the plants can grow [4]. When hydroponics was successfully carried out in agriculture, the possibility of a complete aquaponics was seen. With hydroponics, plants are grown in a soilless medium, or an aquatic based environment. Hydroponic growing uses mineral nutrient solutions to feed the plants whose root is immersed in water, without soil. However, the nutrients would be provided from various other sources for these plants to grow. It was at this point that a combination of existing ideas was naturally carried out. Aquaculture was combined with hydroponics. Aquaculture being the source of nutrients to the hydroponic system. However, to sustain this system and to maintain the symbiotic uptake and release of nutrients from fish to plants, periodic monitoring of the aquaponics water level is crucial [5].

It is an undeniable fact that the aquaponics system is a technology that is becoming increasingly more popular across countries especially in poorer regions of the world where water is a limited resource [8]. With this technique

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in place, it is revolutionizing the methods for growing plants where the aquaculture concepts is established through the plant beds in a sustainable closed system [6]. Therefore, our collective goal is to build a self-sustaining aquaponics system an example of a living machine as it is a self-sufficient assembly of plants and animals that functions as an ecosystem producing food for people without creating waste products or pollution. When deployed, it would be economically friendly and self-sustaining. It would be capable of monitoring and controlling the most vital system parameters to guarantee optimum conditions for both plants and fish. This is a revolutionary way of growing food by farmers and it is also the most productive form of agriculture in our contemporary time.

System Components: This section of the paper describes in detail all the system components that were deployed in developing the self-sustaining aquaponics system.

7474 D Type Flip Flop: The 7474 is one of a set of Integrated Circuits in the 7400 family. It is a microchip that acts like a switch. It has 1 byte of memory to remember the status when it was last triggered. The "Dual Flip Flop" means there are two of these identical "switches" contained in the chip package. More modern variations of this unit are seen in many electronic devices, especially robotics.

These Integrated Circuits contain two independent D-type positive-edge triggered flip flop circuits. A low level at the preset or clear input pins set or resets the outputs regardless of the levels of the other inputs. When preset and clear are disabled (high logic level), data at the D input meeting the setup time requirements are transferred to the outputs on the positive-going edge of the clock pulse. Following the hold time interval, data at the D input may be changed without affecting the levels at the outputs.

Optocoupler: This is also called an opto-isolator, photocoupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light. Opto-isolators prevent high voltages from affecting the system receiving the signal.

An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED),

that converts electrical input signal into light, a closed optical channel (also called dielectrical channel) and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photoresistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a triac. Because LEDs can sense light in addition to emitting it, construction of symmetrical, bidirectional opto-isolators is possible. A slotted optical switch contains a source of light and a sensor, but its optical channel is open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor.

Relays: A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. It was used in the circuit to switch the water pump.

Methodology: Methodology is a well-defined combination of logically related practices, methods and processes that determine how best to plan, develop, control and deliver a project throughout the continuous implementation process until successful completion and termination. Methodology does not set out to provide solutions but offers the theoretical foundation or support for understanding which method, set of methods or so called "best practices" that can be applied to a specific case [7]. We did an in-depth study of the existing system and deployed the modularization approach as employed majorly in hardware project development.

Hardware and Software Specification: Every system developed has a certain specification of hardware and software that is required for proper functioning. But however, the water level regulated aquaponics system was primarily designed to be as self sustaining and independent as possible.

Justification of the Proposed System: By automating the water level in an aquaponic system and making it cost

effective, it will contribute to the overall efficiency of the system. This will solve some problems encountered by people using the mechanical system. Our system design ensures the adequate aeration of the aquaculture part of the aquaponic. This will prevent fish death from oxygen starvation and will reduce the owners' loss and increase income. Plants will have ample nutrient-rich water supplied on a regular, steady interval. The design will also introduce air into the plant bed for faster plant growth.

In all this system will improve the overall system and present it as an attractive alternative source of income to farmers in Abakaliki, Nigerians and in essence promoting the neglected agricultural sector. Alternative job source will be created with this resulting in decreasing unemployment and other vices associated with it in Abakaliki, Nigeria. With agriculture, fishing and farming embraced the problem of urban pollution will be half solved. As this is an eco-friendly system, global warming issues will be checked on its mass adoption.

System Design and Implementation: At this stage in the research work a proper understanding of the system was made. The practical way in which the system will work was both drawn and modelled. Various functional units that are very necessary for the system were identified, procured and assembled for the commencement of the circuit design. Google's Sketch-Up Pro 2014 was used to model the system to find an appropriate design that is both cost effective and functionally optimal.

Design Objectives and Considerations: Self-sustaining aquaponic water level controller is a solution system that automates the water movement in an aquaponic system. It regulates the water level automatically, making sure this is done optimally, regularly and timely.

The design objective is to create a prototype equipped with a circuit that monitors the water level in an aquaponic system and activate some functions in order to maintain it at an optimal performance level and condition.

For this to be achieved, on proper analysis, we found that these has to be in place:

- The fish section of the aquaponic must be considerably larger than the plant section. This will enable the fishes to still thrive optimally even when

substantial amount of water has been drawn out into the plant section. It will assist in the survival of the fishes.

- The plant section has to be situated at an elevation to the fish section. This is to enable the fish water to be aerated when the water drawn is returned to the fishes. However, there are various alternatives to this which could include; installing an air pump inside the fish tank, placing the pipe containing the water from the plants, such that it falls onto the fish water tank, aerating it in the process or one can do the aeration manually.

- Gravel or any other alternatives should be included in the plant section of the aquaponic to provide a surface area for the microorganisms to thrive and for the plant root to hold on to.

- Sensors will be inserted into the plant bed to determine the water level which would be controlled by the circuit.

No chemical is needed in this system so as to enable the circuit perform at its optimal capacity and for the fish and plant's health too.
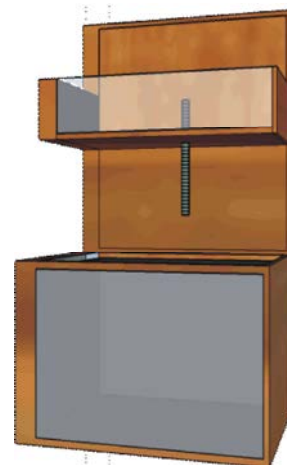

Fig. 1: Design of self-sustaining Aquaponics water level controller system

Interfacing Circuit Design: In integrated circuit design, elements must be meticulously planned and laid out before a chip can be manufactured if it is to be precise in its designed functionalities. In this section an explanation of the elements that make up the circuit for water level controller is discussed. The circuit diagram is seen below.
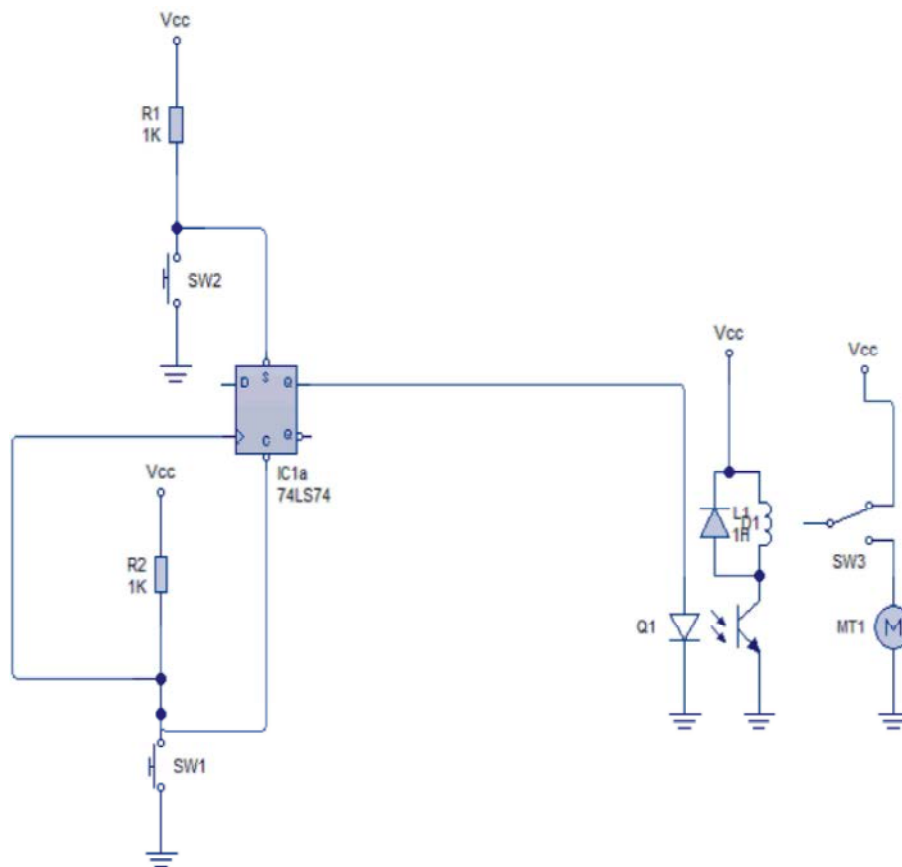
Fig. 2: Water Level Controller Circuit Diagram
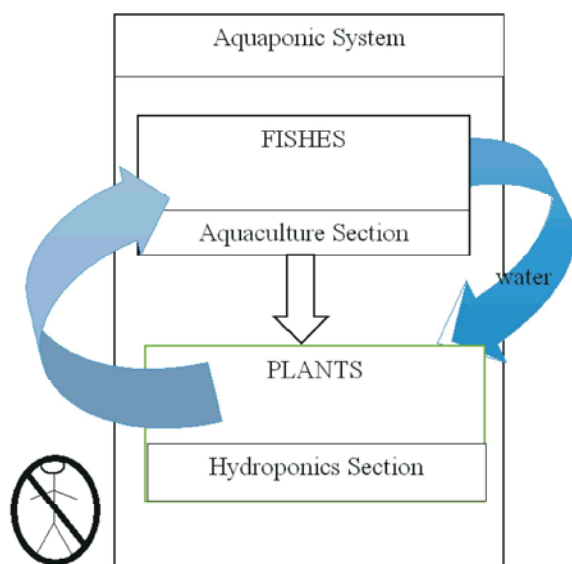
Block Diagram of the Proposed System:

Fig. 3: Block Diagram of the System

In the self-sustaining aquaponics system there will be two main parts involved. The first section of the self-sustaining aquaponics system is the aquaculture section for raising aquatic animals and the second part being the hydroponics section. It will replace the industrially sized components with affordable and efficient alternatives that are more suitable for use by rural dwellers in Abakaliki, Nigeria. It will make the system to require as little human interaction and intervention as necessary.

The fish waste-laden water from the fish tanks will be channelled to the tubs where the plants have their roots. When the plants absorb the nutrients they need from that water, they will basically cleanse it of toxins for the fish. Then that same cleansed water can be channelled back into the fish tanks.

System Flowchart: System flowchart is the pictorial representation of functional parts of a computer system. The sequence of execution of tasks are being elaborated by the use of a flowchart.
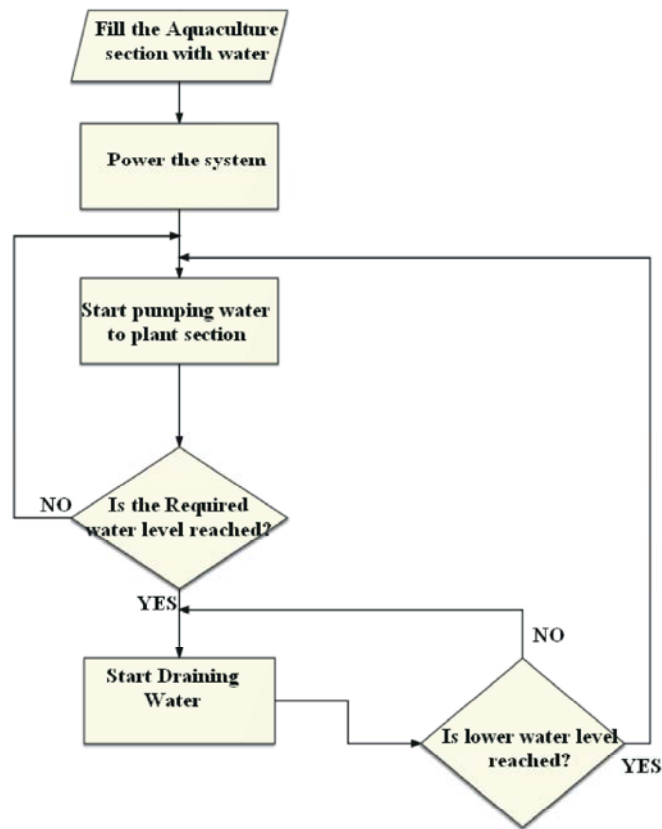
Fig. 5: System water control flowchart

System Testing: It is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. It takes the completed system as input and the result is checked for compliance with the set requirements. If this stage fails, it means that the system requires a modification or revision. The system was tested and the expected results achieved.

Summary of Achievement: After striving to correctly assemble the components on the breadboard, solder the components on the veroboard, test the units and components and test the completed system, we observed the result and found that the effort was worthwhile with the system achieving the desired results.

Even the packaging was a huge challenge on its own because we had to use a 3-D software that we had entirely no prior knowledge of. However the overall project was an eye opener that exposed us to a lot of other possibilities in the field.

Problems Encountered and Solution Adopted: The modelling of the system was a problem as the software to be used was somewhat technical. The design of the

overall packaging was not all easy. These problems apart, we could not find a suitably large pump for the system. Instead, we had to make usage of two small pumps and this drains more power and takes longer to fill. Constructing the packaging to be water tight was the biggest problem we face in the project development.

The final and most technical issue we had in the system design was on how to handle the back emf generated by the motor after it is switched on. Like the others, we resolve the problem by insertion of a capacitor looped with a diode to force the flow of current in a direction.

CONCLUSION

The research work as presented in this paper is on the design and development of a computer based self-sustaining aquaponic water level controller to enhance the operation of the traditional aquaponic food production system. The system was developed by interfacing the conventional aquaponic system to a computer-based circuitry that can automate the aquaponic system water levels. The benefits of our self-sustaining

aquaponics solutions are enormous when deployed in a developing country like Nigeria especially for farmers in Abakaliki. It can create employment and reduce crime when deployed. This system of agriculture will salvage our unemployed graduates and provide the nation with more healthy food and vegetables. It will alleviate cost of food production on rural farmers and therefore should be embrace by the country.

Recommendations: The best in this field is yet to come if pursue. This research is merely a stepping stone as to what that can be achieved in agriculture using minimal technology. However, some improvements can make the system even better. A better pump should be fitted to reduce the time needed for water refill in the plant section. Electronic sensors should be used to replace the mechanical water level sensor. In addition, an auto feeder unit should be introduced to feed the fishes for a truly self-sustained system. Solar power can be used to automatically recharge the battery instead of electricity.

With these enhancements implemented on this system, the success of agriculture and food production will not be parralled by any other sector.

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