AUTOMATIC TIME REGULATOR FOR SWITCHING ON AN AERATION DEVICE FOR AQUACULTURAL PRODUCTION SYSTEMS

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Abstract

Automation allows machines and systems to control themselves and perform their tasks in a productive, efficient, and accurate manner with minimal human intervention. Aeration devices such as air pump are used to supplement dissolved oxygen in aquaculture systems so as to maintain dissolved oxygen optimum standard. The need to aerate the pond at odd hours due to diurnal limit, save cost and human labor, necessitated the design of an automatic time regulator circuit, which controls the switching on and off of an aeration device at a pre determined and selected time interval (5mins., 10mins., 20mins., 30mins., and 40mins.) This design, though limited to five time intervals, switches on and off an aeration device with little human intervention, thereby providing an automated solution of aerating any aquacultural production system.

Keywords: automation, aeration, aquacultural systems

1. Introduction

Like most organisms, aquatic animals need oxygen for their survival. This oxygen is needed in dissolved form since the organism lives in water. In ponds and other outdoor systems, photosynthetic activity in the water during the day is the primary source of oxygen for aquatic life. However, at night, the photosynthetic plants compete with other aquatic organisms for oxygen. This coupled with bio-degradation of organic matter, and the fact that aquatic animals expend considerable energy for respiration result to low dissolved oxygen.

Low dissolved oxygen is by far the most common water quality problem in fish production, because without sufficient oxygen, aquatic organisms will not survive, regardless of good nutrition and otherwise near-optimum environmental conditions. Thus, dissolved oxygen above certain levels is essential not only for the maintenance of life, but also for good health and growth. Artificial aeration, which is a means of adding dissolve oxygen to a pond, particularly a densely stocked pond is of paramount importance since it balances the oxygen requirement of the aquatic organism [1].

In aquaculture, maintaining dissolved oxygen in water at a level that is suitable for fish is an important activity for involved personnel. Fish oxygen-consumption rate increases with available oxygen concentration up to a critical concentration, (For instance, below 4mg/l is level of no excess activity; the critical level, from 5mg/l to 10mg/l is the oxygen consumption standard; that is level of full activity). Above this critical concentration, fish engages in normal physiological activity. Dissolved oxygen level below critical concentration may result in reduced fish growth or even mortality [1]. Furthermore, as air components dissolve into water, a point is reached where no more can be added. This point is called saturation point. For oxygen the approximate saturation level at 500F is 11.5mg/l, at 700F, 9mg/l and at 900F, 7.5mg/l. Concentration above the recommended level can also be harmful to aquatic life. For instance, fish in waters containing excessive dissolved gases may suffer from "gas bubble diseases". Hence adequate dissolved oxygen is necessary for good water quality in any aquacultural production systems.

Oxygen transfer to water represents significant economic cost in most aquacultural systems. This oxygen transfer can be achieved by several different methods such as mechanical or gravity aeration and pure oxygen injection [2]. For example, air pumps are used under the diffused-air-systems to introduce fine, medium and coarse-bubble into aquacultural systems.

Dissolved oxygen levels can be maintained by aeration, but the response time for taking corrective measure is short. This makes it critical to have a rapid and reliable method of measuring dissolved oxygen concentrations so as to activate aeration device when needed. Aeration devices which are most times incorporated into indoor aquacultural systems are designed to run continuously once powered until it is manually switched off. With manual control it is difficult to keep aeration time constant, this also increases the cost of production due to the energy requirement [3]. It also creates some difficulty in maintaining adequate dissolved oxygen since the possibility of over saturation of gases is not ruled out. Hence, stabilization of the time for aerating a pond through air pumps using an automatic time regulator is of paramount importance.

This study, therefore, aim at developing an automatic time regulating circuit that will power an aeration device at a pre determined time interval. This will invariably lead to the automation of the aquaculture system involved.

2. Methodology

2.1. Design considerations

The dissolved oxygen level was determined based on diurnal limit; which is daily fluctuation in oxygen production. This result to depletion of dissolved oxygen at night time and early morning. This becomes a limitation as manual aeration will be inconvenient to perform at these times. Hence, the automatic system was designed to meet up with such limitation so that it can be set to operate at specific time periods. Some of the factors considered in the design of the system include:

- Cost of System: A compromise had to be made between cost of automating an aeration device or manual operation. The price of designing or purchasing one, if unreasonably too costly, may defeat the goal of automation. Hence, efforts were made to make the design cheap without effect on its efficiency.

- Overall cost in the aquacultural product: Because of poor precision and other factors that come into play in manual aeration techniques, loss in aquacultural production systems are higher. The automated design reduces cost due to error or loss and even human factor.

- Durabililty: The system was designed to be durable, hard-wearing.

- Flexibility: The system is readily adaptable.

- Ease of use: This particular factor comes into play from the stand-point of the user.

Regardless of technical knowledge of the user, it is easy to operate also easy to maintain. This makes the job of the aquaculture personnel easy.

- Minimal human intervention: This is the highlight of the design. It is automated and can function on its own once it has been powered on and the timing is set. It can be left to perform its functions on its own with high efficiency and precision.

2.2. Circuit design and analysis

2.2.1. Mode of operation

All electronic components are powered by a direct current (dc) voltage source instead of an alternating current (ac) voltage source, since ac voltage source is a varying voltage that does not favour the operation of electronic components. Therefore a rectifier circuit was used to convert the ac voltage from the mains to a useable dc voltage. This circuit is composed of a full wave rectifier, a filter and a regulator integrated circuit.

The design was limited to five time intervals and this was initiated with an oscillator designed to give pulse outputs at given intervals. The 555 - time integrated circuit (IC) oscillator was used to achieve this. It produces an output pulse at a determined time interval by using the datasheet guiding the operation of the integrated circuit [4].

The pulse from the oscillator was used to trigger a decade counter integrated circuit. This decade counter was used to manipulate the setting of different time interval for switching a transistor switch that was connected with a dc relay that does the actual switching ON of the load [5]. Between the decade counter and the transistor also lie some logic gate integrated circuits that are to manipulate the switching time that controls the switching on of an aeration pump.

2.2.2. Circuit analysis

The design was divided into blocks for easy understanding of the circuit and to ensure accuracy in system organisation. The blocks are; the power block, control block and the load block as illustrated in figure 1 below.

Power Supply Block:

A block diagram of a general-purpose *electronic power supply* is shown in Figure 2. Each block represents a specific power supply function.

Transformer: A transformer is commonly used to step the line voltage up or down to a desired value. In this case, our desired value is 12v.

Rectifier: The primary function of a power supply is to develop dc for the operation of electronic devices. Most power supplies are initially energized by ac. This energy must be changed into dc before it can be used. The process of changing ac into dc is called rectification. The rectification function of a modern power supply is performed by solid-state diodes.

Filtering: The output of a half- or full-wave rectifier is pulsating direct current. This type of output is generally not usable for most electronic circuits. A pure form of dc is usually required. The filter section of a power supply is designed to change pulsating dc into a pure form of dc. Filtering takes place between the output of the rectifier and the input to the load device.

Regulator: The dc output of an unregulated power supply has a tendency to change value under normal operating conditions. When a stable dc voltage is required, power supplies must employ a voltage regulator.

Load: This would be the circuit or system that the power supply is designed for.

Design Parameters

Rectifier performance parameters: The performance of the rectifier section of the power supply block was evaluated in terms of the following parameters.

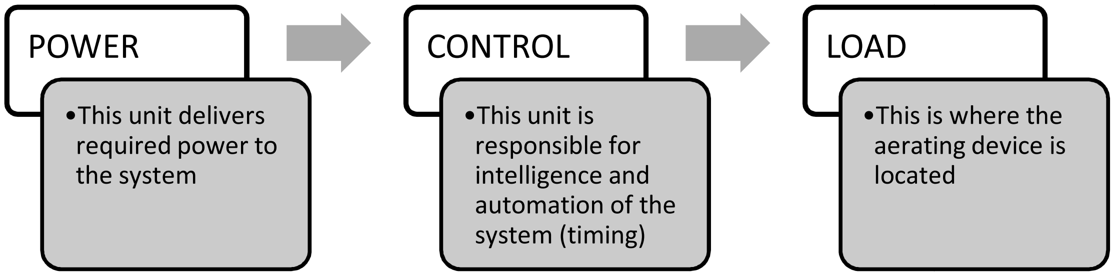

Figure 1: Block diagram showing different stages that make up the system.

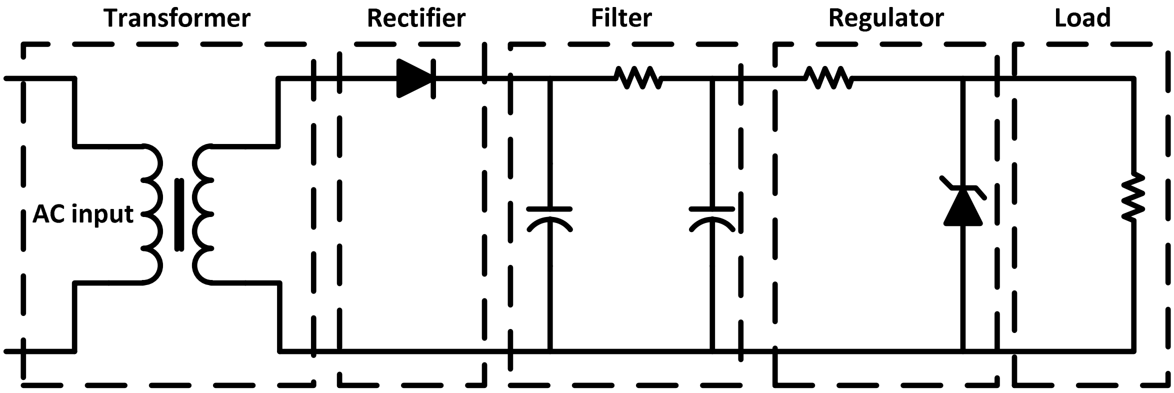

Figure 2: Functional block diagram of an electronic power supply [6].

Voltage relationships;

Average load voltage: The average value of the load voltage V_L is V_{dc} and it is defined as:

$$V_L = \frac{1}{T}\int_0^T V_L(t)\partial t \tag{1}$$

Voltage at transformer out (V_s) is defined as:

$$V_s = V_m sinwt \tag{2}$$

Where: V_m, is the peak voltage of the diodes; But angular frequency of the source is given by Therefore, for half-wave:

$$V_{Lac} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \partial(\omega t) \tag{3}$$

$$V_{Lac} = \frac{V_m}{\pi} = 0.318V_m$$

In the case of a full-wave rectifier, $V_L(t) = V_m \mid sinwt \mid$ for both the positive and negative half-cycle. Equation (1) can be written as

$$V_{Lac} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \partial(\omega t) \tag{4}$$

Full-wave $V_{Lac} = \frac{2V_m}{\pi} = 0.636V_m$ Where V_{dc} = Average load voltage V_m = peak voltage output Calculating the Average load voltage for the implemented circuit we have,

$$V_{Lac} = 2 \times \frac{15}{\pi} = 9.55V$$

Root-mean-square load voltage V_L is V_L given by:

$$V_L = \left[\frac{1}{T}\int_0^T V_L^2(t)\partial t\right]^{\frac{1}{2}} \tag{5}$$

In the case of a full-wave rectifier $V_L(t) = V_m|\sin\omega t|$ for both positive and negative half-cycle hence equation (5) can be written as

$$V_L = \sqrt{1/\pi \int_0^{\pi} (V_m \sin\omega t)^2 \partial(\omega t)} \tag{6}$$

Therefore full-wave $V_L = \frac{V_m}{\sqrt{2}} = 0.707V_m$ V_L = root-mean-square (rms) value of load voltage V_L

V_m = peak a.c. voltage output

Calculating the root-mean-square value of the load voltage VL for the implemented circuit we have

$$V_L = 0.707 * 15 = 10.61V$$

The root-mean-square value of the a.c. component of the load voltage V_L is given by

$$V_{L(ac)} = \sqrt{V_L^2 - V_{Ldc}^2} \quad (7)$$

Therefore,

$$V_{L(ac)} = \sqrt{10.61^2 - 9.55^2} = 4.63V$$

Ripple factor Becomes:

$$Y = \frac{V_{Lac}}{V_{Ldc}} = \frac{4.623}{9.55} = 0.484$$

Current Relationships;

The average value of load current i_L is $i\partial c$ and because load R is purely resistive, it can be found as

Assuming load resistance R to be purely resistive i.e. i_{dc} can be found as:

$$i_{dc} = \frac{V_{dc}}{R} \quad (8)$$

The root-mean-square value of load current is found as

$$i_L = \frac{V_L}{R} \quad (9)$$

The currents can be found if the value of load resistance is known. From the specification of the transformer, the maximum current that could be drawn from the transformer was 300mA for safe operation.

The transformer steps down the 220V ac voltage from the mains to a 30V output with centre taped of 15-0-15V. Because the output voltage is ac voltage there was a need to rectify the alternative voltage to dc voltage before using it to safely power the discrete components.

The two diodes D1 and D2 are for the rectification of the ac output voltage. In practice, it have been observed that the voltage after rectification is not as direct as in the ideal case and still could not be used to power our discrete electronic component without damage.

In order to further make the dc. voltage more close to its ideal state, a filter capacitor C whose size depends on the amount of voltage and current that is expected to pass through was employed. The current output is dependent on the size of the load which was considered before the proper design of the circuit. The output voltage is tied at 12V ± 0.25V.

Control Block

In oscillator modeling, the duration of output pulse from the oscillator is determined mainly by the value of R1, R2 and C5 in the circuit diagram. The relationships are;

$$T_{ON} = (R_1 + R_2)0.693C_5$$

$$T_{OFF} = R_2C_5.0.693 = 0.693R_2C_5$$

In other to get a starting 5 minutes T_{ON} and T_{TOFF} we use $C5 = 1000\mu$f, R1 = 10kΩ and R2 = 420kΩ

Working gives

$$T_{ON} = (10 \times 10^3 + 420 \times 103) \times 0.693 \times 1000\mu = 4.9665mins.$$

$$T_{OFF} = 420 \times 10^3 \times 0.693.1000 \times 10^{-6} = 4.851mins$$

The C_6 is a voltage control capacitor that was connected to pin 5 of the oscillator integrated circuit. The pulse from the output pin 3 is fed into the pin 14 of the decade counter with ten output terminals [5].

The *555 timer IC* is an integrated circuit (chip) used in a variety of timer, pulse generation and oscillator applications. In the monostable mode, the 555 timer acts as a "one-shot" pulse generator. The pulse begins when the 555 timer receives a signal at the trigger input that falls below a third of the voltage supply. The width of the output pulse is determined by the time constant of an RC network, which consists of a capacitor (C) and a resistor (R)[7]. The output pulse width can be lengthened or shortened to the need of the specific application by adjusting the values of R and C. This is how the timing of the pump is controlled.

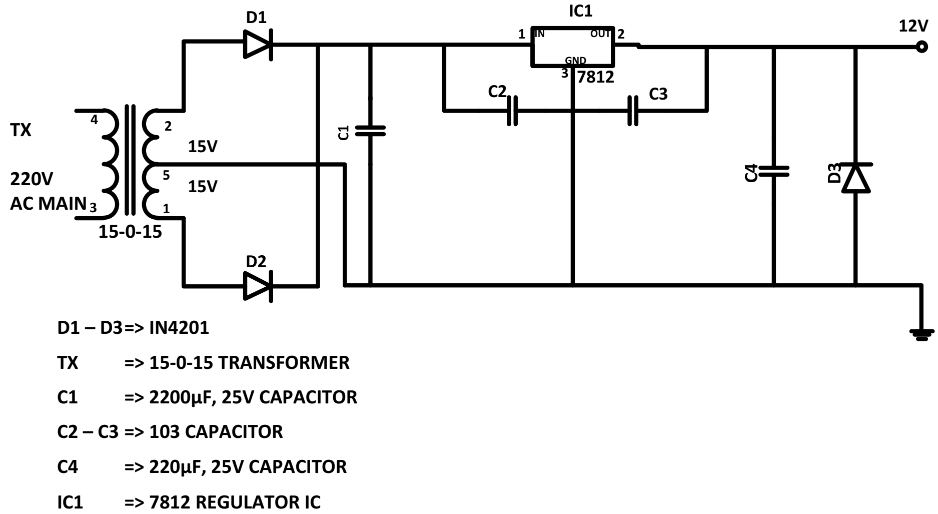

Figure 3: Schematic diagram of 12V power supply unit.

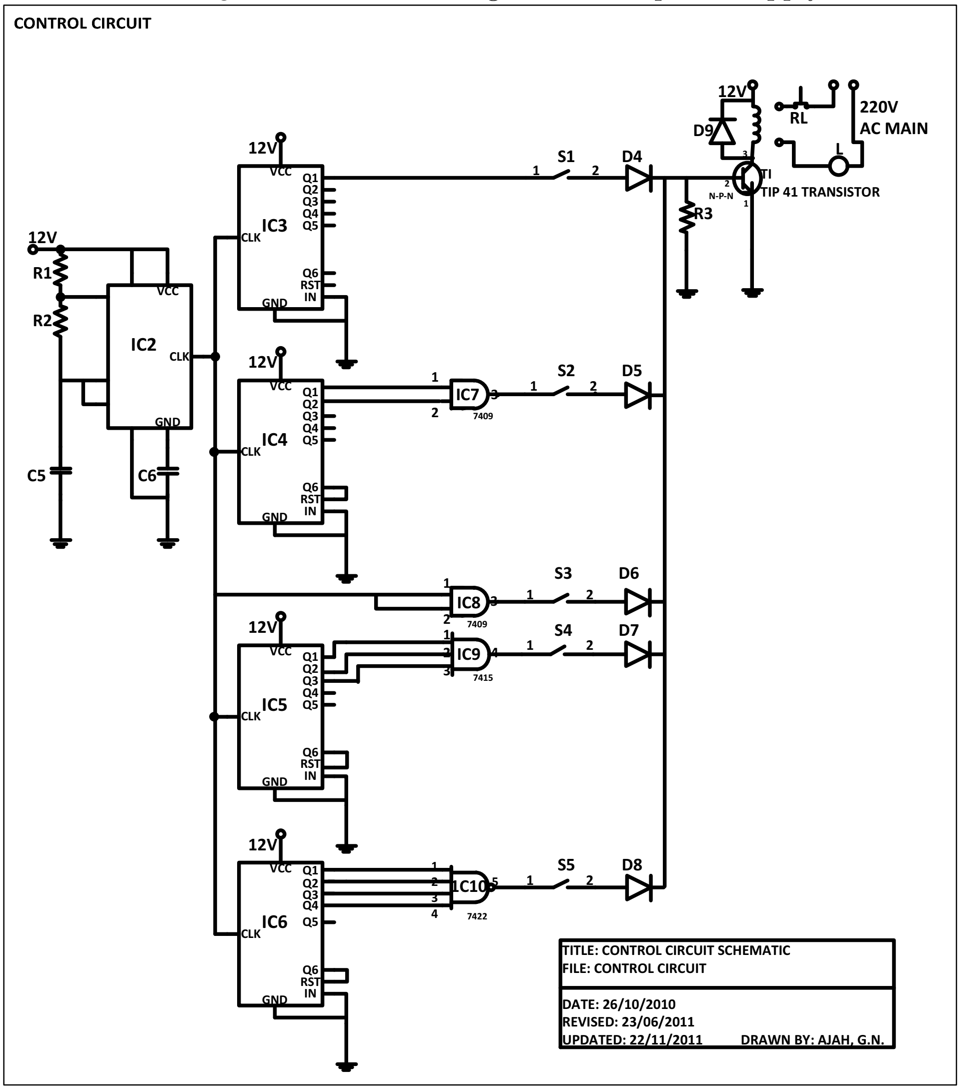

Figure 4: Schematic diagram of control circuit.D4-D9 => IN4201, R1 => 10K, R2 => 420K, IC2 => 555-TIMER IC, IC3-IC6 => OR-GATE IC, => RL => 6V RELAY, TI => TIP41 TRANSISTOR, L => LOAD, S1-S5 => UP-DOWN SWITCH.

Load Block

The load block was composed of a transistor switch, a relay and a protective diode. The transistor acts as a switch that triggers the relay when a current is supplied at the base. With this block any ac dependent component could be run comfortably. For this study the load was an air pump used in aerating an aquarium.

3. Conclusion

This study has developed an automatic time regular for switching on and off an air pump for aeration of aquacultural production systems at 5 different set time interval. The development is a prototype which can be improved to supplement and maintain dissolved oxygen in aquacultural production systems. The prototype performs adequately in switching on and off of the aeration device at the selected time interval. This development can help in automating the system and improving yield, since dissolved oxygen is one of the most important parameters in fish culture systems.

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