A DIGITAL TEMPERATURE REGULATION SYSTEM FOR AN AQUARIUM

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ABSTRACT

Aquarium water temperature is an important factor in the health of your fish. This is particularly true when breeding fish, treating diseases, and even when selecting fish to keep together. Freshwater tropical fish are those that require heated water, generally in the range of 75-80°F (24-27°C). Because many homes are not kept in that temperature range day and night, these fishes require a heated aquarium. This paper is about a digital temperature regulation of an aquarium, which is a circuit through which the temperature of a fish container is linearly controlled depending on the temperature of water/environment. This circuit makes use of heating elements which goes OFF/ON when the temperature in the water becomes high/low or reaches a temperature higher or lower than a preset value. The temperature sensor used is a thermistor with a negative temperature coefficient NTC in which its resistance falls as the operating temperature increases. The thermistor is a very sensitive device to heat; as such, it can be used in a way that an increase in temperature will lead to change in its resistance.

Keywords: Aquarium, Negative Temperature Coefficient thermistor, Tropical fish

INTRODUCTION

Fishes survive in natural water under any condition as it is assumed that natural waters have natural temperature regulation, but in fish pond, nevertheless, they find it difficult to survive and even fertilize in harsh weather conditions like cold season (Figuera & Booth, 2010). This is because as the temperature of the environment changes, so that of the water too by convection. It is imperative to digitally regulate the temperature of the container at low cost and much lower power consumption for better food production to the masses, hence, economic development and agriculture.

The rapid development of today's technology is as a result of the expansion in the field of engineering. In keeping to technological advancements in the world, most electrical devices are being modified or improved to ensure the comfort of users.

For the purpose of convenient management and breeding flexibility, a modern farming industry is paramount. Here, to fulfil the multiple functions needed for an outdoor pool, a multifunctional aquarium equipped with a control system is need (Chiu, 2010).

Consequently, to demonstrate the automatic tropical fish breeding system, a small aquarium model is assessed.

2.0 COMPONENTS AND METHOD

With thorough understanding of the components characteristics which were configured together to make up the circuit design, the thermistor is the main component which senses the temperature of the water while the heater heats it and the pump helps in circulating the water so as to get a uniform temperature throughout the container. The heater turns ON when it senses a decrease in temperature and goes OFF when the temperature increases. Hence, the temperature of the water is never too cold or too hot.

2.1THERMISTOR

Sensors are generally energy conversion components. Temperature sensors convert energy in form of heat to electrical form. The importance of temperature sensors is it allows electronic circuits to detect and measure temperature. Several temperature sensing techniques are currently in widespread usage. The most common of these are RTDs (resistance temperature detectors), thermocouples, thermistor and sensor ICs.

Resistive sensors use a sensing element whose resistance varies with temperature. A Platinum RTD (Resistance Temperature Detector) consists of a coil of platinum wire wound around a bobbin, or a film of platinum deposited on a substrate. In either case, the sensors resistance-temperature curve is a nearly-linear function. RTDs are used in a variety of precision sensing applications.

RTDs have drawbacks in some applications. For example, the cost of wire-wound platinum RTD tends to be relatively high. Also, self-heating can occur in these devices. The power required to energize the sensor raises its temperature, which affects measurement accuracy. Thermistor is just another type of resistive sensors.

A thermistor is an electronic component that exhibits a large change in resistance with a change in its body temperature. The word "thermistor" is actually a contraction of the words "thermal resistor".

A thermistor is a thermally sensitive resistor whose resistance value changes with change in operating temperature. Because of self-heating effect of current in a thermistor, the device changes resistance with changes in current. Thermistors, which are essentially semiconductors, exhibits either a positive temperature coefficient (PTC) or a negative temperature coefficient (NTC) but the latter in used in this project.

If a thermistor in PTC, its resistance increases as the operating temperature increases. Conversely, if a thermistor is an NTC, its resistance decreases as its operating temperature increases. How much the resistance changes with changes in operating temperature depends on the size and construction of the thermistor.

When an NTC thermistor is connected in an electrical circuit, power is dissipated as heat and the body temperature of the thermistor will rise above the ambient temperature of its environment. The rate at which energy is supplied must equal the rate at which energy is lost plus the rate at which energy is absorbed (the energy storage capacity of the device).

$$\frac{dH}{dt}=\frac{dHl}{dt}+\frac{dHA}{dt} \quad \text{--} \quad (1)$$

The rate at which thermal energy is supplied to the thermistor in an electrical circuit is equal to the power dissipated in the thermistor.

$$\frac{dH}{dt}= P= I^2R= EI \quad \text{--} \quad (2)$$

The rate at which thermal energy is lost from the thermistor to its surroundings is proportional to the temperature rise of the thermistor.

$$\frac{dHl}{dt}= \delta\Delta T= \delta\ (T-T_A) \quad \text{--} \quad (3)$$

Where: the dissipation constant (δ), is defined as the ratio, at a specified ambient temperature, of a change in the power dissipation of a thermistor to the resultant body temperature change.[5]

2.2 **THE 555 TIMER**

The **555 timer** is an **integrated circuit** (chip) implementing a variety of timer and **multivibrator** applications. It was produced by Signetics Corporation in early 1970. The original name was the SE555/NE555 and was called "The IC Time Machine". The 555 gets its name from the three 5-KΩ resistors used in typical early implementations (Intersil, 2000).

The figure below gives a diagram of a simple 555 timer:

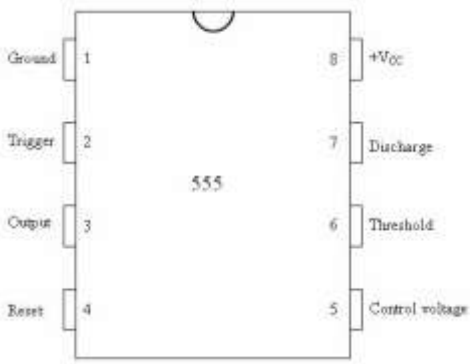

Fig 2.0 Pin out diagram of 555 Timer

The following were calculated t_{high}, t_{low}, T and F.

$T_{charging} = 0.693(R_A + R_B)C$ --- (4)

$= 0.693(100K + 39K)\ 47\mu F = 5s$

$T_{discharging} = 0.693 R_B C$ -- (5)

$= 0.693 \times 39 \times 10^3 \times 47 \times 10^{-6}$

$= 1.3\ s$

$$T = t_{charging} + t_{discahrging} = 5 + 1.3 = 6.3s$$

ICs and the 555 timer must be protected from the brief high voltage 'spike' produced when an inductive load such as a relay coil is switched off. The standard protection diode must be connected 'backwards' across the relay coil as shown in the full circuit diagram.

However, the 555 require an extra diode connected in series with the coil to ensure that a small 'glitch' cannot be fed back into the IC. Without this extra diode monostable circuits may re-trigger themselves as the coil is switched off! The coil current passes through the extra diode so it must be a 1N4001 or similar rectifier diode capable of passing the current, a signal diode such as a 1N4148 is usually **not** suitable (Abrar, 2017).

The input and output pin functions are described briefly below and there are fuller explanations covering the various circuits:

- Astable - produces a square wave
- Monostable - produces a single pulse when triggered
- Bistable - a simple memory which can be set and reset
- Buffer - an inverting buffer (Schmitt trigger)

The 555-Timer in Astable multivibrator mode is shown on fig 2.5

An astable circuit produces a 'square wave'; this is a digital waveform with sharp transitions between low (0V) and high (+Vs). Note that the durations of the low and high states may be different. The circuit is called an astable because it is not stable in any state: the output is continually changing between 'low' and 'high'.

The time period (T) of the square wave is the time for one complete cycle, but it is usually better to consider frequency (f) which is the number of cycles per second.

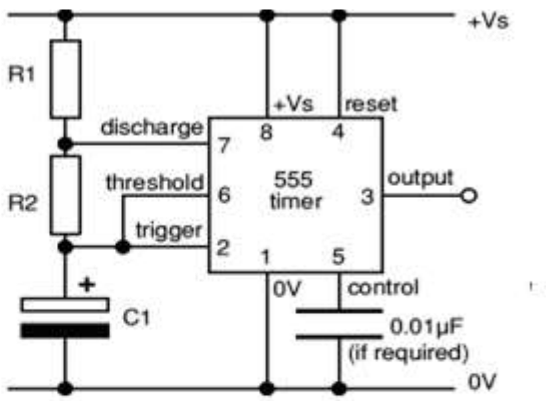

Fig. 2.1(a) Astable multivibrator

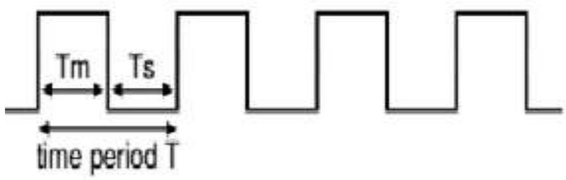

Fig. 2.2(b) Output wave form of Astable multivibrator

2.3 **TRANSISTOR AS A SWITCH**

When a transistor is used as a switch it must be either **OFF** or **fully ON**. In the fully ON state the voltage V_{CE} across the transistor is almost zero and the transistor is said to be **saturated** because it cannot pass any more collector current Ic. The output device switched by the transistor is usually called the 'load'.

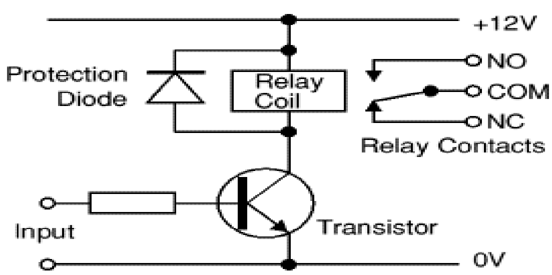

Fig. 2.3 Transistor as a switch.

The power developed in a switching transistor is very small:

- In the **OFF** state: Power = $I_C \times V_{CE}, but\ I_C = 0$, so the power is zero.

- In the **full ON** state: Power $= Ic \times V_{CE}, but\ V_{CE} = 0$ (almost), so the power is very small.

This means that the transistor should not become hot in use and you do not need to consider its maximum power rating. The important ratings in switching circuits are the **maximum collector current Ic(max), maximum breaking current I_B(max)** and the **minimum current gain h_{FE}(min)**(Vodovozov,2010). The transistor's voltage ratings may be ignored unless you are using a supply voltage of more than about 15V.

2.4 **ICL7107 ANALOG-TO-DIGITAL CONVERTER**

ICL7107 are high performance, low power, 31/2 digit A/D converters. Included are seven segment decoders, display drivers, a reference, and a clock. The ICL7106 is designed to interface with a liquid crystal display (LCD) and includes a multiplexed backplane drive; the ICL7107 will directly drive an instrument size light emitting diode (LED) display.

ICL7107 bring together a combination of high accuracy, versatility, and true economy. It features auto zero to less than 10μV, zero drift of less than 1μV/oC, input bias current of 10pA (Max), and rollover error of less than one count. True differential inputs and reference are useful in all systems, but give the designer an uncommon advantage when measuring load cells, strain gauges and other bridge type transducers (Intersil, 2000).

The ICL7107 is designed to work for both ±5V supplies. However, if a negative supply is not available, it can be generated from the clock output with 2 diodes, 2 capacitors, and an inexpensive IC.

The features of ICL7107 Analog-to-digital converter are listed below:

- Guaranteed Zero Reading for 0V Input on All Scales
- True Polarity at Zero for Precise Null Detection
- 1pA Typical Input Current
- True Differential Input and Reference, Direct Display Drive - LCD ICL7106, LED lCL7107
- Low Noise - Less Than 15μV_{P-P}
- On Chip Clock and Reference
- Low Power Dissipation - Typically Less Than 10mW
- No Additional Active Circuits Required
- Enhanced Display Stability
- Pb-Free Plus Anneal Available (RoHS Compliant)

The pinouts of the ICL7107 is shown below:

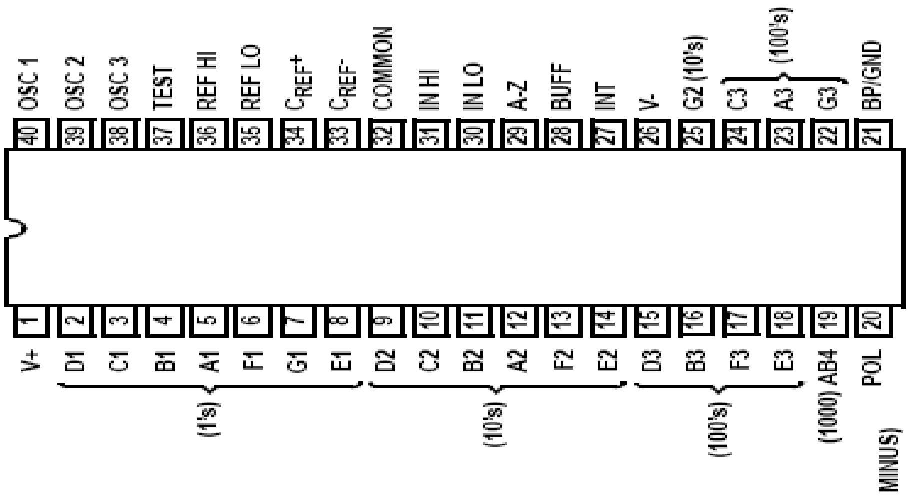

Fig 2.4 Pin outs of ICL7107

2.5 **CIRCUIT DESCRIPTION**

The thermistor TH senses the temperature in the fish container. Since the thermistor is an NTC (negative temperature coefficient), its resistance decreases as the temperature increases and vice versa. As the temperature falls (i.e the thermistor cools) the voltage at the inverting input of IC2 falls below that of the non-inverting input and hence the output voltage of the IC2 goes high and switches ON the transistors TR1 and energizes relay RL1 and switch on the heater. At the same time the same output from IC2 switches on TR2, energizes RL2 and then switches on the pump. A diode is connected in parallel to the relay to eliminate the back e.m.f that will be generated by the relay coil when currents are suddenly broken. The 555 timer is used so that its output will drive the pump even when the heater is not ON so as to have uniform temperature in the water.

As the temperature of the thermistor changes, the resistances changes hence a change in voltage at the non-inverting input of the IC2, this voltage change is fed to the ADC ICL7107 to be converted into digital form through its positive input terminal. A common anode seven segment display is connected to the 2s and 3s pins of the ADC.

2.6 PERFORMANCE EVALUATION AND RESULT

A test was carried out to know the time taken to heat the water from a minimum temperature of 19^0C to a maximum of 27^0C. This is done so as to get an estimate of the power of the heating element that will be able to heat a bigger pond of volume of about $2.1m^3$. The two heating elements of power 40W each are connected in series across the mains. The resistance of each heating element will be:

$$P = \frac{V^2}{R} \text{ --- } (6)$$

$$40 = \frac{240^2}{R}$$

R = 1.440KΩ

The resistance of each heating element is therefore 1.440KΩ.

Since they are connected in series, the voltage across each heating element will be:

$$V = \frac{R}{R_{eq}} V_s \text{ --- } (7)$$

$$V = \frac{1440}{1440+1440} \times 240 = 120V$$

The power of each heating element is therefore:

$$P = \frac{V^2}{R} = \frac{120^2}{1440} = 10W$$

Therefore, the total power of the two heating elements is 20W.

The table for the test is given below:

S/N	Time (mins)	Temperature(^{0}c)	Power(W)
1	0	19.1	20
2	10	21.0	20
3	10	22.7	20
4	10	24.5	20
5	10	26.9	20

Table.1 Temperature, time and power

The volume of the container used for this design is $0.0073m^3$ and the heating element used is 20W.

For a larger fish pond of volume of about $125.0m^3$, the power of the heating element will be:

P = $\frac{125.0\times20}{0.0073} = 342.5kW$

Therefore, a $342.5kW$ heating element will be suitable for heating a fish pond of volume $125.0m^3$.

2.7 CONCLUSION

From the result, it was clearly seen that the high temperature coefficient, small size, ability to operate over wide range temperature are good properties of the thermistor. Also the ability of the thermistor to withstand electrical and mechanical stress produces accurate variation in the comparator input.

However, small variation is a reasonable difference that is created at the output of the Op-Amp. The device therefore gives a control of temperature to a variation in degrees from 22℃ to 27℃.

The choice of comparator makes the circuit very stable since there is no feedback. In addition, the gain is very high compared to a close loop system. For high sensitivity, the thermistor should make a good thermal contact.

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