

# **DESIGN AND CONSTRUCTION OF AN AUTOMATIC EGG INCUBATOR**

**BY**

**DILLUM, NGWALDI MARTIN**

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## DEDICATION

This project is dedicated to Almighty God, my parents and my siblings.

# DECLARATION

I, DILLUM NGWALDI MARTIN, hereby declare that this work was done by me under the supervision of Dr. JACOB TSADO, and has never been presented elsewhere for the award of a degree, I also hereby relinquish the copyright to the Federal University of technology, Minna

**DILLUM NGWALDI MARTIN**

.....  
Name of Student

**DR. JACOB TSADO**

.....  
Name of Supervisor

*Dillum Ngwaldi Martin* 14-NOV-2010  
.....  
Signature and Date

*Dr. Jacob Tsado* 15/11/2010  
.....  
Signature and Date

*Engr A.G. Rasi*  
.....  
Name of H.O.D

*Dr. G.I. Igbal*  
.....  
Name of External Examiner

*Ally (Jan 11, 2011)*  
.....  
Signature and date

*[Signature]* 1/12/10  
.....  
Signature and date

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## ABSTRACT

This project presents the design and construction of an automatic egg incubator. The construction makes use of a temperature sensor (LM35) in conjunction with a microcontroller (AT89C51) in the sensing, monitoring and regulation of the temperature within the incubator enclosure. The temperature sensor senses the temperature in the enclosure and relays it to the microcontroller via an Analog-to-Digital converter. The microcontroller compares the sensed temperature with a pre-programmed temperature range ( $37^{\circ}\text{C}$ - $39^{\circ}\text{C}$ ). If the temperature sensed is higher than the maximum temperature, the microcontroller switches off the heating element and vice-versa.

The microcontroller was programmed to switch on a high torque motor which drives a mechanical system which eventually turns the eggs. The eggs were also turned periodically a number of times determined by the programmed time interval between each turning. The enclosure was constructed in such a way that allows good ventilation. Humidity was maintained by putting water on a container and placing it somewhere in the enclosure.

Testing of the project showed that the temperature was regulated within the range of  $37^{\circ}\text{C}$ - $39^{\circ}\text{C}$  and the eggs were turned five times a day.

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## CHAPTER ONE

### INTRODUCTION

An incubator is an apparatus, which simulates the poultry bird by means of temperature, humidity and ventilation regulation as well as automatic turning of egg for embryo development into chick. Incubation is the term used to describe the process of applying heat to an egg so that the embryo contained within develops into a chick [19].

Aviculturists of today have three options regarding the incubation of eggs and the procedure accordingly differs somewhat in each case. Each option has some advantages and some disadvantages as compared to the other two. These options are as follows:

1. Incubation and hatching by the hen (natural incubation).
2. Incubation and hatching by a broody domestic hen (natural incubation by a surrogate mother).
3. Incubation and hatching by artificial means (incubation with electronic incubators).

Four factors are of major importance in incubating eggs artificially: temperature, humidity, ventilation and automatic turning mechanism of these factors temperature is the most crucial. However humidity tends to be over looked and causes many hatching problems. Extensive research has shown that the optimum incubator temperature is 37°C-39°C when the relative humidity is 60 per cent concentration of oxygen should be above 20 per cent. carbon dioxide should be below 0.5 per cent.

There are two types of incubators commonly used:

1. Forced-air incubators which have fans, to circulate the air.
2. Still-air incubators which have no fans so the air is allowed to stratify.

The forced air incubator is the type of incubator given to us to test its working efficiency by setting eggs for embryo development into chick. The type of incubator

should be set 60 – 65% relative humidity. The still air incubators are smaller and air flow is hard to manage. Humidity should be 60 – 65% (80 - 90°F wet bulb) during incubation and 60 – 70% (92 – 97°F wet bulb) at hatching time. It is very easy to overheat the egg in still air incubators and difficult to maintain proper humidity. The incubator given to us is powered electrically; this is one of the major obstacle experiences due to unavailability of electricity during testing. In the absence of electricity, a kerosene lamp is used as another source of heat the aim is to keep the eggs as warm as possible until the power return, for this reason the lamp has been re-design in such a way that the optimum level of carbon dioxide in the incubator atmosphere is 0.5 per cent with range of 0.4 – 0.6 per cent. High levels of carbon dioxide are toxic and hence could kill the embryos. Because of this a stand by generator is preferable as a source of power for immediate take over in case the main power is interrupted.

An incubator should be operated in a location free from drought and direct sunlight. An incubator should also be operated for several hour with water placed in a pan to stabilize its internal atmosphere before egg are set. The incubation must be ventilated that each unit receives freely air from the outside and discharge its stale air to the outside. In the same way the movement of people and equipment has to be carefully designed and managed to give the same clean flow principle. The conditions under which the eggs are stored before incubation need good control. The optimum range is 13°C - 16°C (55°F - 65°F) with a high relative humidity of 75 – 80 per cent, in order to maintain such condition all farm eggs stores should be well insulated and preferably equipped with an appropriate air conditioners if the eggs are to be stored for long. Pre incubation storage should not go for more than seven days but limit of four days is preferable since up to this limit there is almost no loss in hatchability if storage conditions are good.

We have been discussing artificial incubator, in which it out class the natural method of hatching eggs using hen. Below are the advantages and disadvantages of the two methods:

The advantages of the natural method are as follows:

1. They are used for small number of eggs.
2. It has a higher percentage of hatching eggs.
3. There are no maintenance costs.

Its disadvantages are as follows:

1. Broody hen sitters are not always available.
2. There is a danger of pests when the hen may get tired.
3. It cannot hatch large number of eggs for commercial purpose.

On the other hand the artificial method has more advantages over the natural method of hatching, these are:-

1. It is used for large number of eggs.
2. The machine can be used anytime.
3. It has no danger of pest.
4. It does not get tired.

All the same there are some disadvantages of such, these are:

1. There is a lower percentage hatch.
2. It has a maintenance cost.

When the two methods are compared, there is more advantage of the artificial method. By so doing, we decide to construct a simple type of hatching incubator for

peasant farmers which is electrically operated. It is less in complexity and small enough to transport.

## **1.1 AIM AND OBJECTIVE**

1. To control the temperature of the incubator automatically.
2. To ensure that the eggs in the incubator are turned using an automatic turning mechanism.
3. To maintain a relative humidity of a standard incubator.

## **1.2 METHODOLOGY**

The method of achieving the aims and objective of the project is based on the existing facts and findings about incubators. Based on the research of temperature, humidity, ventilation and automatic turning of egg mechanism are crucial factors which influence hatching gravity of the incubator.

## **1.3 SCOPE OF THE PROJECT**

The design of the project concentrates mostly on chicken eggs, as chicken are the most common poultry birds. However the incubator will be suitable for incubating the eggs of all other poultry since their basic requirement are similar, and for this reason, the egg tray size has been adjusted to accommodate any poultry eggs.

## **1.4 STATEMENT OF THE PROBLEM**

Incubation methods employed by most local farmers are not efficient: hence the need for a more effective means is required by the farmers. This project provides effective and relatively cheap means of egg incubation.

## CHAPTER TWO

### LITERATURE REVIEW

It appears that people probably domesticate chickens over 4000 years ago, after centuries of hunting the wild jungle fowl. The early domesticated fowls were also used in religious ceremonies dedicated to the sun. In ancient India these chickens were sacrificed to the sun God. Cocks were pitted together to fight originally as a kind of fertility ritual as an attempt by primitive people to ensure many children, bountiful crops and adequate livestock [12].

However, the history of incubation may be traced back right from the existence of man. Normally, under normal conditions all birds incubate their eggs and hatch the fertilised one when due. But due to certain factor that cause a decline in the population of birds, such as killer disease, unwillingness of some birds to incubates their eggs, increased rates of predation, reduction of suitable habitat and competition for nesting sites, the early man realised the need to find new ways of increasing the rate at which both egg and chicks were produced. Meanwhile man managed to come up with a number of skills to mention but the most popular ones includes;

- a) Replacing an egg laid by a particular bird with that of another bird. This area may have been gotten from a small majority of birds that do not hatch their eggs with the heat of their own bodies. They drop their eggs into the nest of birds of other species and then give little or no further attention to their progeny. The brood parasites include a number of cuckoos widespread over the world and more sparingly represented in the new world, the cow birds of America, the parasitic weaver bird and honey guides of America, and the black headed duck of southern America.

- b) Digging an inverted T – like hole underground about 2 feet deep at their usual firewood cooking stand, after which they placed the eggs inside cotton sack and inserted through one end of the opposite horizontal opening and then poured in ash until top hole is filled.

Basically, they cooked three times a day, so if they were to cook, the sack would be pulled to the opposite opening back to its initial position during the next cooking. It is therefore evident that the problem of killer disease, and unwillingness of some birds to sit on their eggs were solve in (a) above. However another problem is created as the replaced eggs have to be thrown away or eating as food when the embryo has not begun early development which rendered the egg uneatable.

In cognisance to the above problem the early man improvised amongst others, solution above (b) above. Here the advantages were both ventilation and turning requirements were achieved through the two opposite horizontal openings and pulling of sack respectively. The set back of this method was the heat supplied was based on estimation as such that temperature which the eggs were been subjected to, might be greater or less than the required. For this reason the efficiency of this method was small. The size and type of incubator selected depends on the needs and future plans of each producer. Many different models are available. For continuous settings, separate incubator and hatchery units are recommended. If all eggs in the unit are at the same stage of incubation, a single unit can be used. Locate the incubator and hatchery units indoors to protect them from major weather changes. It is essential that the room has a good ventilation system to supply plenty of fresh air. Keeping the units indoors makes it easier to maintain uniform temperature and humidity. Incubators are machines, which artificially provide the egg with the correct, controlled environment for the developing

chick. Depending on complexity, an incubator will give varying degrees of control over temperature, humidity, egg turning, fresh air flow and hygiene, while providing a secure place for the eggs.

Incubators may be classed as Forced draft, still air and Contact types according to how air is circulated. Contact incubators are a new generation of machines designed to mimic natural incubation much more closely. Forced-air incubators have fans that provide internal air circulation. The capacity of these units may be very large. The still-air incubators are usually small without fans for air circulation. Air exchange is attained by the rise and escape of warm, stale air and the entry of cooler fresh air near the base of the incubator. Recommended temperatures vary between the two incubators, so follow the manufacturer's recommendation that accompany the units.

## **2.1 FORCED DRAFT INCUBATOR**

The forced draft machine was developed to overcome temperature gradient problems throughout the incubator. In a forced draft incubator a fan is used to circulate the air, which gives a uniform temperature throughout the machine. The air temperature surrounding the egg is therefore constant and positioning of the thermometer and temperature sensor is less critical. Eggs, too, can be of differing size and set in trays at different levels. Using a forced draft incubator also allows the use of a Wet Bulb Thermometer (explained in more detail later), which can be used for the accurate reading of humidity. It is of more importance to control humidity in a forced air machine to prevent the higher airflow drying the eggs. Most of today's large incubators are the forced-air type. They have fans that circulate the air in the incubator and around the eggs. Manufacturers of these incubators usually provide operating instructions for each particular type of incubator [4].



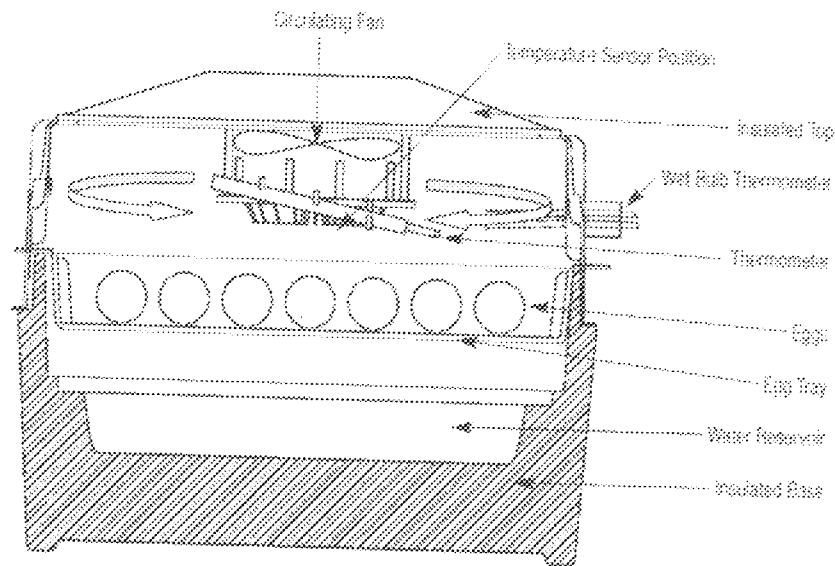


FIG 2.9: FORCED DRAFT INCUBATOR

## 2.2 STILL AIR INCUBATOR

Still air incubators are the most basic form of incubator. A still air incubator is basically an insulated box consisting of:-

- A Heating element
- A Thermostat or temperature controller to control temperature
- Egg tray
- A thermometer to measure the air temperature
- A tray for water
- Some machines may have a hygrometer for humidity measurement
- Some machines may have turning mechanism for automatic turning of eggs

The air inside a still air incubator is circulated by convection. As the air is heated it expands and rises to the top of the incubator. The amount of airflow achieved in a still

air machine is therefore determined by the ratio of air temperature inside the box to outside. The lower the air temperature outside the box the greater the airflow inside. To achieve good air circulation, air inlets are usually positioned in the base and top of the incubator. Inside a still air incubator, the warm air moves towards the top so different temperatures will be recorded at different levels (see example diagram below). It is therefore important that a still air incubator is kept on a level surface and that eggs are all of similar size [4].

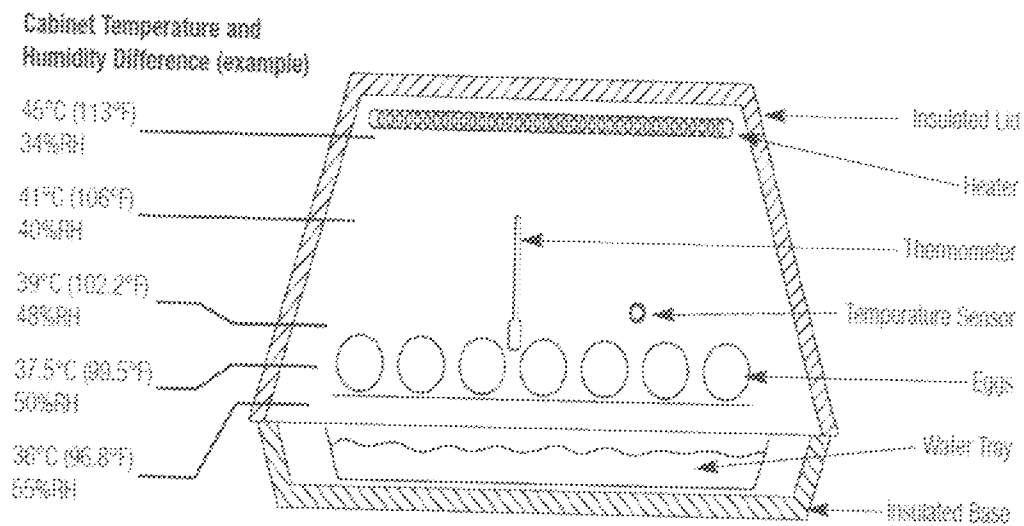


FIG 2.1 STILL AIR INCUBATOR

Most still-air incubators are small, but some may hold up to 100 eggs or more. As they do not have fans in them, air does not circulate as it does in the forced-air incubators. Therefore the operating temperature for still-air incubators is higher than for forced-air incubators.

### 2.3 CONTACT INCUBATOR

Contact Incubation mimics the natural incubation process that occurs in the nest. The most striking difference between natural and artificial incubation is the fact that the

natural parent provides warmth by contact rather than surrounding the egg with warm air. This may not at first sight seem significant but important research studies carried out by J. Scott Turner at New York State University and the University of Cape Town has revealed major unsuspected differences in thermal behaviour of eggs incubated by contact rather than convection. Crucially, eggs in a forced draft incubator have near uniform temperature throughout incubation; there will be some increase in embryonic temperature towards the end of incubation as a result of increased metabolism but otherwise the whole egg will remain near incubator air temperature. By contrast, eggs incubated naturally or by contact, have significant temperature differences. Heat is entering the egg over a relatively small brood patch, which is therefore warmer than other regions of the egg and is being lost from most of the remaining shell area, which is cooler[6].

In contact incubation, the embryo temperature tends to fall at later stages of incubation as a result of the embryo 'sovn blood circulation which becomes significantly more important than embryonic metabolism in determining temperature distribution and heat flow within the egg, quite contrary to previous understanding which assumed metabolism to be dominant and cause egg temperature to rise. The inevitable fact that the embryo grows larger and must move from its original position on top of the yolk sack downwards in the egg to cooler regions also tends to reduce embryonic temperature as incubation progresses. These important findings emphasise surprising differences between natural and artificial incubation, but there are others. Eggs in nature are certainly subjected to a cycle of warming and cooling coupled with ventilation as the parent bird leaves the nest to feed and defend territory, etc.[6].

The methods of incubation lead to the establishment of a standard apparatus called an incubator which simulates the broody bird with the entire incubation requirement. Eggs may be naturally or artificially incubated. The incubation period for fowls is 21 days

according to (Thear and Fraser, 1986). The method used does not affect the quality of the chicken hatched. There are also two main methods used;

1. The natural method of incubating.
2. The artificial method of incubating.

## 2.4 NATURAL INCUBATION

Incubation means that the eggs are kept warm at a constant temperature of  $39.5^{\circ}\text{C}$  for a period of 21 days, after which it hatches. Natural incubating as mentioned is provided by the hen. The hen provides heat by lying on the eggs that is 'brooding'. While cold is provided when a hot brood spot develops on the breast of the hen. The method provided by the hen has been so much studied and so humidity and temperature are provided. The hen turns the eggs to give them equal amount of heat and ventilation. (Joy and Wibberley, 1969). Natural incubation is the incubation performed by a bird, be it a pheasant that laid the eggs, a surrogate pheasant parent, or some type of nesting chicken. The hen pheasant can be left with the job of incubation and hatching the eggs, and subsequently brooding them also. Many hens will do a very satisfactory job since their instincts for these processes have not yet been erased due to domestication as has happened in many poultry [2].

The main advantage of this procedure is that one does not have to worry about the correct temperature and relative humidity, turning of the eggs and the preservation of the instincts in the succeeding generations. Also, there is less contact with man and the chances of being adversely imprinted are reduced. The chicks are called to food by the hen and they start feeding, without any problems. The preservation of the instincts including those related to breeding and the natural fear of and vigilance against man are factors which may be of importance if the progeny are to be released in the wild

subsequently. If a female parent will not incubate the eggs, which is usually the case with many pheasant species in captivity, or also when the eggs are pulled sequentially to enhance lying, then the eggs ideally should be placed with a surrogate parent to obtain the initial seven to ten days of natural incubation.

## 2.5 ARTIFICIAL INCUBATION

This method has been found useful and of good quality, large scale commercial hatcheries are equipped with various types of automated artificial incubators, which are now operating in almost all tropical countries. In Southeast Asia, the old artificial hatching method are still been practiced. The old artificial hatching system used by the Chinese in Malaysia is well desired by Thunaisinghan and Wah (1971). The results obtain is compared and is found to be quite good with the records from modern incubators, hatching rate of 75 to 85 being normal. Williamson and Payne (1959). Similar information is from Joy and Wibberley (1969) in their book 'Tropical agricultural handbook' in which its states that artificial incubating is provided by the incubator.

As studied in natural methods eggs get most at a temperature of  $39.5^{\circ}\text{C}$ . Incubator been provided with the necessary conditions such as box, thermometer to tell the temperature, tray containing water for humidity. Artificial incubator are operated 48hrs, and temperature adjusted  $39.5^{\circ}\text{C}$  before the eggs are placed in a tray (i.e. egg tray) and finally into the incubator. We have been using electronic incubators, both still-air and forced-air, as a routine matter, since we began keeping and breeding exotic pheasants and game birds. We believe we have a better control on the various parameters, affecting proper incubation, such as temperature, relative humidity, turning of the eggs, diseases and hatching.

We have found that the success of small incubators lies in their being located in a suitable room, where temperature and humidity do not change that much. We have installed most of our incubators in our cellar where both the temperature and humidity remain practically the same year round. Also, there is good ventilation with fresh air providing the right environment for artificial incubation. Artificial incubation is convenient when there is a constant supply of steady voltage. In general, when there is a steady voltage of the mains supply AND the voltage fluctuations are only very small, then artificial incubation is far more practical than natural incubation [2].

## **2.6 UNDERSTANDING THE EGG MEANT FOR ARTIFICIAL INCUBATION**

The two most critical factors in incubating an egg artificially are incubation temperature and proper egg weight loss from the time it is laid until it hatches. Egg weight loss can be in part controlled by regulating the incubator humidity. Eggs from all species of birds should lose 18% of the fresh egg weight by the time they hatch.

### **2.6.1 TEMPERATURE**

The most satisfactory results are sourced when the temperature ranges from 37.2°C to 39.4°C. The exact temperature depends on the incubator type the age of the eggs in the incubator. The optimum temperature is 37.3°C – 38.3°C (98.6°F – 100.4°F) in forced air incubators and approximately 38.4°C – 39.4°C (100.6°F – 102.4°F) in still air incubators. Within a moderate range, incubator temperature directly influences the rate of embryonic development. If relatively low, it leads to delayed hatchability and if high, it hastens hatching.

Proper incubation temperature is critical for ensuring the maximum hatchability of the eggs as well as the best physical condition of the chicks that hatch. Variation from the optimum temperature affects growth rate and incidence of embryonic mortality and deformity. Use of suboptimal conditions is evidenced by poor hatching success or by chicks hatching with unrestricted yolk sacs, poor vigour, and developmental problems. We have successfully hatched galliforms eggs in "Grumbach and Multihatch" forced-air incubators maintained at temperatures ranging from 37.6-37.8 degrees Celsius. The optimum temperature seems to be 37.7 degrees Celsius. We have found that developing eggs are very vulnerable to overheating but are somewhat less affected by short periods of cooling. Safe incubator operation therefore requires a double temperature control system consisting of a primary and secondary, or override, thermostat [14].

## **2.6.2 HYGIENE**

Strict hygiene is a vital part of good and successful incubation. We clean all incubators before the beginning and at the end of each breeding season using a good disinfectant. Also, the eggs are disinfected before putting them in the incubators, so they cannot easily transmit pathogen organisms to the incubation room. For this we fumigate the incubation room and incubators using potassium permanganate crystals and formaldehyde. In recent years, we have hatched many chicks in forced-air incubators. One has to be extremely careful with the build-up of "fluff" on the fan in the incubator. It is necessary to clean each incubator down thoroughly after each hatch. Disease control in the incubation room and units is only possible when applying good hygienic and health standards. It is not difficult to understand that under the above mentioned environmental conditions, not only the embryos in the eggs do grow well, but also the micro-organisms which are transported with the eggs [14].

### **2.6.3 AUTOMATIC TURNING OF EGGS**

Egg-turning during incubation is important as it prevents the developing embryo from sticking to the shell membranes, a problem which develops if the egg lies too long in the same position. A survey of the poultry literature indicates that for optimal hatchability an egg should be turned at least eight times every 24 hours. Many incubators with automatic turning mechanisms, including the Grumbach's, turn the eggs once every hour or so as installed by the breeder. Regardless of the number of times an egg is turned each day, the interval between turnings should be evenly spaced throughout the twenty-four hour period. In addition, the eggs would be turned in alternate directions, as turning in only one direction will increase embryo mortality. Eggs can of course be turned by hand if desired, but maintaining regular turning intervals is frequently difficult if one is not always around twenty-four hours per day to monitor the incubators.

Automatic turning is, therefore, an important feature of the incubator. We automatically turn the eggs in the Grumbach incubators at least 4 times per day. The "Grumbach" turning-mechanism consists of a sliding grid assembly and an enclosed motor-gear assembly, as shown in the various pictures [14].

### **2.6.4 CANDLING**

Candling is a technique which facilitates observation of the inner contents of an egg without opening the shell. Useful not only to determine fertility and the extent of incubation, candling can provide information about the condition of the egg shell and air cell as well as the condition and position of the embryo. If an egg is held against light, the developing embryo, with its blood vessels and the air cell at the broader end are seen. The examination becomes easier if a small light-box made of either wood or metal carrying a 40 watt electric bulb and a small window appropriate to the size of the egg is used in a



full-darkened room. The blood vessels can be seen as thin red lines after about 72-84 hours of incubation. All infertile eggs will appear clear and these are to be rejected from the incubator, as also eggs with cracked shells.

We perform candling on regular basis (at least 2 times per week) to keep track of the change air-cell and ultimately on the egg weight loss. However, candling is more an art than a science and much can be learnt from experience. Candler's are commercially available but plans for home-made models can also be found in some books written for the lay poultry breeder. If a home-made Candler is constructed, it is best to use a light bulb no larger than 40 watts to prevent the egg from being exposed to excessive heat. Candling lamps are lights with a concentrated beam that may be shone through the shell of the egg to illuminate the egg contents. This allows the size of the airspace to be determined which offers a guide to the weight loss rate. If the air space is larger than expected too much water is being lost and the humidity in the incubator should be increased to reduce the rate of water loss [14].

### **2.6.5 HUMIDITY**

It is important to keep a pan of water inside the incubator at all times. The pan should be more than half the size of the egg tray and always under the eggs. This helps to regulate the relative humidity in the incubator. An adequate level of moisture in the air around the eggs maintains the water balance between the eggs and the air and prevents the internal membranes from drying up. At the same time ensures the required rate of diffusion of oxygen and carbon dioxide out. If however the relative humidity is too high, which is rarely the case in properly ventilated still air incubators, the diffusion of oxygen is impeded and the embryo dies, a common condition known as dead in the shell. Humidity can be supplied from a pan of water placed in the bottom of the incubator. A

cake pan approximately 11/2" deep is sufficient. The dimensions of the cake pan should be somewhat smaller than those of the ice chest so that it may be easily removed. The ideal moisture level is about 50 – 55 per cent relative humidity (83 to 87°F) on a wet bulb thermometer for the first 18 days of incubation. For the last three days it should be about 65 per cent (89 to 90°F wet bulb). Some variations above or below the ideal level will not drastically affect hatchability. To increase the humidity the last three days an extra pan should be set in the incubator or a wet sponge should be put in the incubator.

An excellent method to correct humidity is to candle the eggs at various stages of the incubation. Necessary humidity adjustment can be made as a result of the candling inspection. Measuring weight loss during incubation is another way of checking relative humidity. Hen's eggs should be 11 – 13 per cent of their initial weight up to point of hatching. Eggs are weighted at regular intervals and the projected weight loss calculated. If it is below 11 per cent, the air cell is too small and action should be taken to decrease humidity and if it is above 13 per cent, humidity increment is necessary. The relative humidity can also be measured using a wet and dry bulb hygrometer [13].

### **2.6.6 SUFFICIENT VENTILATION**

Ventilation is needed to rid the incubator of ammonia or other noxious substances arisen perhaps from the spoilage of some eggs or remaining after fumigation of incubator. The average size egg consumes 5.11m<sup>3</sup> of oxygen and emits 2.81m<sup>3</sup> of carbon dioxide throughout incubation period. To meet these respiratory needs there should be 21 per cent oxygen inside the incubators, as in normal air. Towards the end of the incubation, carbon-dioxide is also needed to active sufficient muscle tone for the embryo to peck its way out of the shell in preparation for emergence. However, too much carbon dioxide is toxic.

The optimum level of carbon dioxide in the incubator atmosphere is 0.5 per cent with range of 0.4 – 0.6 per cent.

This emphasis need for good ventilation and particularly the necessity of keeping the ventilation outlet well open during incubation. The proper ventilation of the incubator is most important. There is a 3/8" inlet at each end between the level of the eggs and the water pan. Two outlets 3/8" in size are provided, one in the front door and one in the rear wall. It is important to restrict the outlet one-half by pasting tape over half of the hole. When the first chick has hatched, remove the tape from both outlets. This will increase the rate of air flow. All clear eggs showing blood rings or streaks be removed from the incubator. If eggs are candled during the early stages of incubation, it will be difficult to determine whether the egg was fertile; embryo that die early soon decompose and are not easily distinguished from rotten eggs[13].

## CHAPTER THREE

### DESIGN CALCULATION

This project is a microcontroller presentable temperature monitoring and regulating system and is built/design around the under-listed subsystems.

- i. 5-volt system power supply
- ii. LM35 temperature sensor
- iii. 8-bit system microcontroller
- iv. 8-bit ADC0804 analogue-to-digital converter
- v. 4-digit 7-segment multiplexed display
- vi. Two 6V – 10A pc relay
- vii. 256 byte-24C02 HC EEPROM

### 3.1 POWER SUPPLY

A 5-volt regulated DC supply voltage is required by the logic element for operation. This 5-volt supply was derived from a 12V, 0.5A step-down transformer, a bridge rectifier, and a 7805 5-volt regulator as shown in figure 3.0 below.

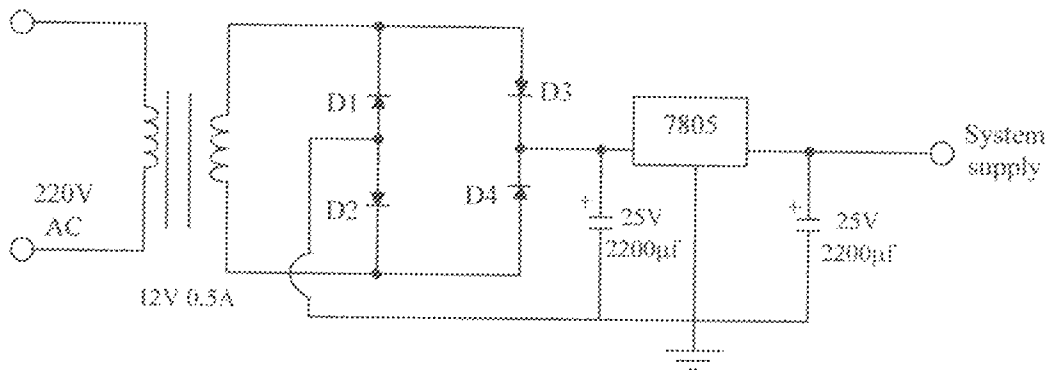


FIG 3.0: BRIDGE RECTIFIER AND A 7805 5-VOLT REGULATOR.

The 12 volt AC transformer secondary voltage was designed to give out a pulsating DC voltage of amplitude  $[(V_{rms} \times \sqrt{2}) - 1.4]$  volt. For a 12-volt AC voltage, the

DC is and amplitude of  $(12\sqrt{2} - 1.4) = 15.5$  volts. The DC voltage is smoothed by 25V, 2200 $\mu$ f capacitor of value derived from the expression:

$$Q = CV = IT \dots\dots\dots \text{eqn 3.0}$$

V = Maximum AC ripple on the DC voltage

C = Value of smoothing capacitance

I = Maximum load current

t = Period of the rectified DC voltage

I = the system current drain computed from the cumulative current drawn by the separate subsystem.

ADC 0804: 5mA

8951 microcontroller: 15mA

7-segment display: 280mA

Relay: 13mA

LM35 (operational) 10mA

24C02: 2mA

Summation of I = 330mA. The minimum input voltage into the regulator is 7V (for a regulated 5-volt output). On a 15.5V peak DC voltage, the maximum AC ripple allowable is 8.5 volt.  $t = 1/2f$  for a full-wave bridge rectifier  $F = 50\text{Hz}$ .

Therefore,

$$C = \frac{It}{V} = \frac{0.33 \times 0.5}{8.5} = 0.0194\text{f} \dots\dots\dots \text{eqn 3.1}$$

A 2200 $\mu$ f capacitance is employed to improve the system specifications. The 5-volt regulator is introduced has a maximum output current of 1A, with a minimum input voltage of 20V.

### 3.2 TEMPERATURE SENSOR LM35

Is a centigrade temperature sensor. An integrated circuit temperature sensor is used to convert the ambient temperature to voltage. The LM35 device is a 3 Pin circuit housed in a plastic package and has the electrical specification is listed below:

- Output that is directly calibrated in degree centigrade
- 10.0mv/°C scaled output voltage
- 0 – 100°C measurement range
- Low self-heating (0.08°C in still air)
- Guar accuracy of 0.50C at 25°C

The device is shown below

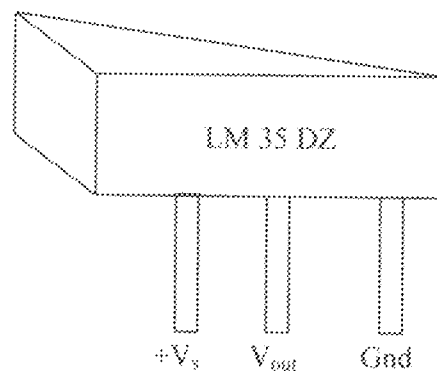


FIG 3.1: LM 35 TEMPERATURE SENSOR.

### 3.3 8-BIT ANALOG TO DIGITAL CONVERTER (0804 ADC)

The LM35 temperature sensor output is an analogue voltage that is a linear function of the sensed temperature. To extract meaningful information from the analog signal, a form of analogue-to-digital conversion was required.

An 8-bit ADC0804 analogue-to-digital converter is used to convert the analog voltage to its digital equivalent. The 0804 is a 20-pin device employing successive approximately register technique. The device has the specifications stated below:

- Resolution 8-bits
- Conversion time 100 $\mu$ s
- Differential analogue voltage input
- On-chip clock generator
- No zero adjust required
- 0V to 5V analogue input

Voltage range with single 5V supply

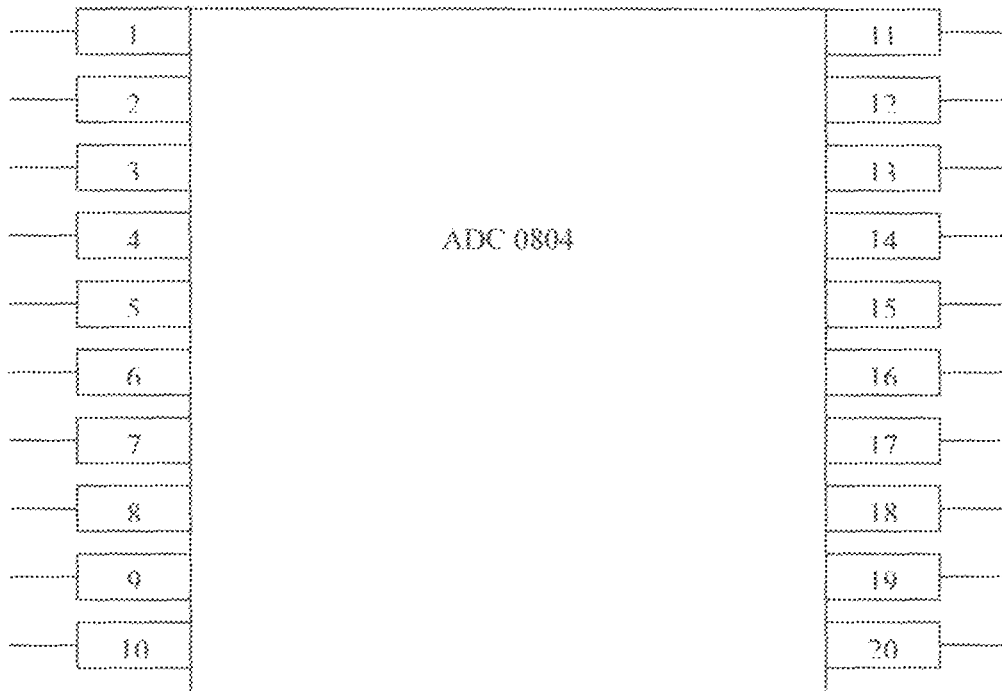


FIG 3.2: PIN DIAGRAM OF ADC 0804



Table 3.3: ADC DATA SHEET

Pin No.	Symbol	Input/output or Power	Description
1.		Input	Chip select line from microcontroller control
2.		Input	Read line from microcontroller control
3.		Input	Write line from microcontroller control
4.		Input	Interrupt line from microcontroller interrupt input
5.		Output	Analogue voltage (+ve input)
6.		Input	Analogue voltage (-ve input)
7.		Input	Analogue ground
8.		Power	Digital ground
9.		Input	LSB data output
10.		Power	Data output
11.		Output	Data output
12.		Output	Data output
13.		Output	Data output
14.		Output	Data output
15.		Output	Data output
16.		Output	Data output
17.		Output	Data output
18.		Output	LSB data output
19.		Input	Connect external resistor for clock
20.		Power	+5v power supply and primary reference voltage

The device was configured to run off a clock source of frequency given by the relation:

$$F = \left[ \frac{1}{1.1RC} \right] \text{ Hz} \dots\dots\dots \text{eqn 3.2}$$

R = Resistance connected between Pin 19 and Pin 4

C = Capacitance connected from Pin 4 to ground

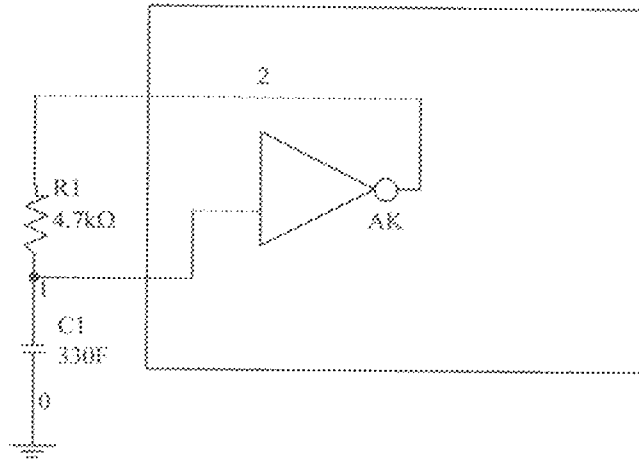


Fig. 3.3: ADC INPUT PIN CONNECTION

The device has a minimum clock specification of 100 KHz and a minimum of 1.4MHz. A 47pF capacitance is connected from Pin 4 to ground, producing a clock of frequency.

$$F = \left[ \frac{1}{1.1 \times 10000 \times 47 \text{ pF}} \right] = 1.93 \text{ MHz}$$

The ADC is interfaced with the system controller over Port 1 (P1). It is designed with a full scale reference voltage of 2.56V. Since it is an 8-bit device, a 10mV change at the input produces corresponding 1LSB bit change at the output.



3. Writes the decimal equivalent to the 7 segment display
4. Responds to key press that provides user control
5. Stores and loads user setting in non-volatile memory

The controller is a fully stable CMOS device with 4KB of on-chip rewritable and reprogrammable flash memory, 128 bytes of internal RAM, 32I/O pins, and numerous on-chip hardware functionalities. The device is programmed in assembly language for maximum flexibility.

### 3.5 5-DIGIT 7-SEGMENT DISPLAY

For real time communication of system status with the human world, a visual display system is incorporated. This display was a 5-digit 7-segment common anode multiplex display. The circuitry connection for the display is as shown below interfaced to the system control over P0 and P2.

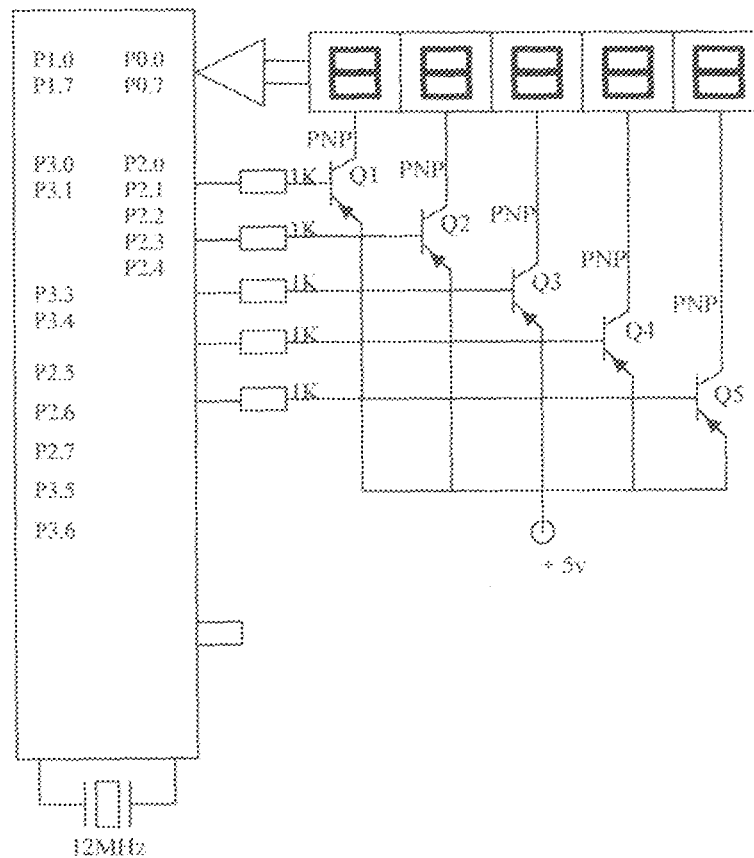


Fig. 3.5: 5-DIGIT 7 SEGMENT COMMON ANODE DISPLAY INTERFACE WITH MICROCONTROLLER

A multiplexed arrangement is used to save on the number of I/O pins needed to connect the display to the system control. A common-anode display type was utilized since the 8951 microcontroller can sink current more than it can source. For a multiplexed

display, all the common segments are connected in parallel. i.e. all common alphabets on the 7-segment display are joined together, and their common is being switched rapidly at a certain frequency switching on one and switching on another but the persistence of vision makes us see it as being light on contentiously. Individual control is done through selectively addressing the display position with PNP transistor 25A1015GR used as a driver.

#### DISPLAY ADDRESSING INVOLVES:

1. Turning off all digit drivers (01-05).
2. Placing the binary marks of the data to be displayed in the common data path (P0).
3. Turning on the digit driver associated with the desired display position.
4. Delaying a bit for persistence.
5. Repeating the above steps for the remaining data.

The rate of display refresh is greater than 50Hz individual digit addressing is not observed. Rather, a multi digit display with each digit seeming separately addressed is observed.

### **3.6 HEATER POWER CONTROL**

To regulate the temperature inside of the enclosure or modulated AC power delivery to a heating element was utilized. A triac AC power switch was used to alter the duty cycle of the AC voltage applied to the heating element as shown below.

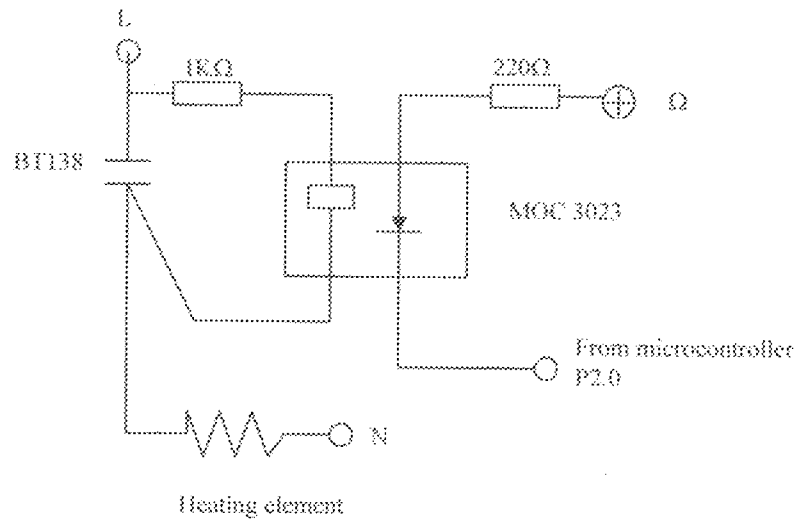


Fig. 3.6: CONTROLLED HEATER SYSTEM

A 1000-watt heater was used to temperature elevation to prevent very rapid temperature changes associated with static on/off power switching, the power developed in the heater was pulse width modulated by controlling the number of AC cycles applied to the load as a function of the measure enclosure temperature. A burst five approach was utilized for the power control.

The power developed in the heating element is given by the relation:

$$P = \frac{V^2}{R} \dots\dots\dots \text{eqn 3.4}$$

But V is controlled from full off to full on by the control software.

For a pulse-width modulated power system, the voltage across the load shown in Fig. 3.6 is given by the relation:

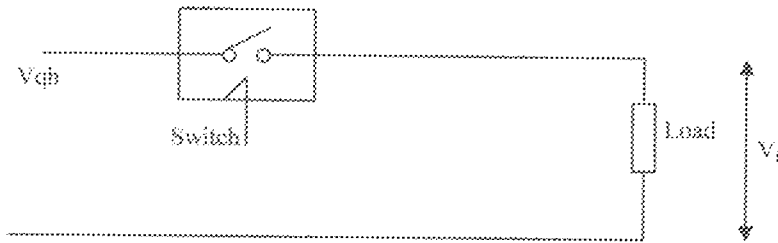


Fig. 3.7: VOLTAGE CHOPPER.

$$V_L = \frac{V_{in} T_{ON}}{T} = V_{in} \times \text{Duty cycle}$$

$$P = \frac{V_L^2}{R_L} = \left( \frac{V_{in} T_{ON}}{T} \right)^2 / R_L$$

$$P \propto V_{in} D$$

By varying the ON-time of the AC wave form applied to the load, the power is directly controlled. A controlled heating arrangement was employed to prevent temperature overshoots above the upper temperature threshold set by the user.

For a 1000-watt 240V heating element, the following calculations were deduced:

$$\text{If } V_{in} = 220V; P_{out} = 1000W$$

Halving  $V_{in}$  reduces the power in the load by a factor of 4. A maximum duty cycle of 75% was chosen, with a minimum duty cycle of 5%. The power in the load was software adjusted to lie between 5% and 75% depending on the measured system temperature. At high temperature approaching the upper temperature setting, the load power drops to about 5%, eliminating overshoot. At low temperature, about 75% power is developed in the load.

The load power was thus made an inverse function of the system temperature. To ensure a uniform (laminar) air flow, a 12volt DC fan was positioned to blow air over the heating element.

Given a 1000watt, 220v heating element



$$P = V^2/R, R = V^2/P \dots \dots \dots \text{eqn 3.5}$$

$$= 220^2/1000 = 48.4\Omega$$

Therefore resistance of heating element is 48.4Ω.

The power control circuit only allows 20% of the total number of cycles.

Therefore voltage supplied to heater

$$= \frac{20}{100} \times 220 = 44V$$

$$\text{Power dissipated or supplied} = \frac{V^2}{R} = \frac{44 \times 44}{48.4} = 40 \text{ watts}$$

### 3.7 MOTOR CONTROL

To ensure power embryo development, a motorized egg holder was utilized. The holder was adjusted approximately every 4 to 5 hours by the software. The motor adjust tuning was also stored in the non-volatile memory and loaded at system start-up.

### 3.8 DESIGN CALCULATION

For an n-digit multiplexed display the segment current required to produce the same brightness in such a segment would be as if it were individually connected to a part segments. A segment's chosen as 10mA, a digit multiplexed display would require 40mA per segment. This n-fold increase in segment current is to counter the current discontinuity caused by the time slicing due to multiplexing. A 15mA forward current was selected for each segment the required pulsed current therefore is  $5 \times 15mA = 75mA$ .

The total alphabet used is 8 giving a total current of  $8 \times 75mA = 600mA$

(8 i.e. alphabet a, b, c, d, e, f, and g with decimal point)

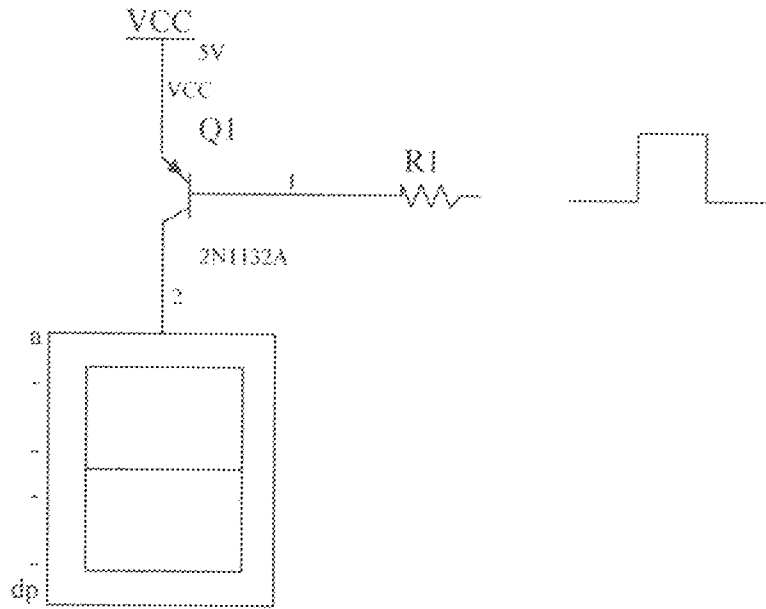


Fig.3.8: 7 SEGMENT DISPLAY.

The transistor used for digit control must therefore be capable of handling this value of pulsed current.

$$I_c = \text{Total segment current} = 600\text{mA}$$

$$I_c = \beta I_B$$

The 2N1132A transistor has a  $\beta$  typically 200

$$I_B = \frac{I_c}{\beta} ; \quad I_B = \frac{0.6}{200} = 0.003\text{A}$$

$$R_B = \frac{V_{CC} - V_{BE} - V_{OL}(8951)}{I_B}$$

$$R_B = \frac{5 - 0.7 - 0.2}{0.003} = \frac{4.1}{0.003} = 1366\Omega$$

A 2.2K $\Omega$  base resistance was used instead the system control also interfaced with electromechanical relays via PNP transistor.

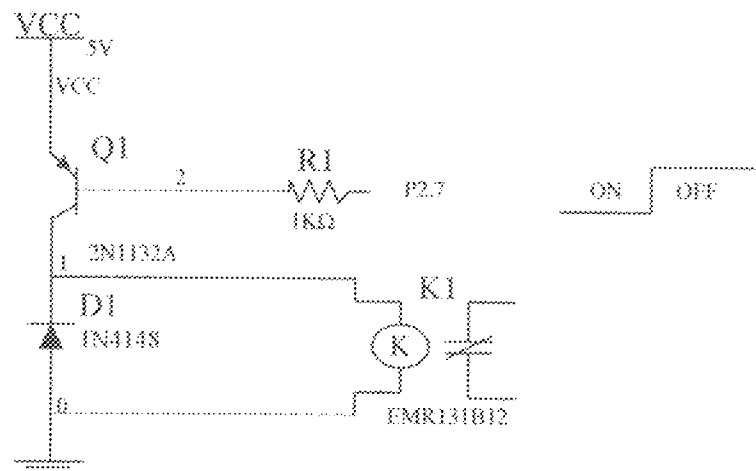


Fig. 3.9: RELAY DIAGRAM

A 6-volt 10A contact current relay is used to switch power into the heating element when the sensed temperature fall below the lower limit press by user and a second relay is used to turn on a cooling unit when the sensed temperature exceed the upper preset temperature. The relay has coiled resistance of 400Ω, at 6V.

$$I_{\text{relay}} = \frac{V}{R} = \frac{6}{400} = 15\text{mA}$$

The current is also the collector current of the PNP transistors using equation (A):

$$I_B = \frac{1.5 \times 10^{-2}}{2 \times 10^2} = 0.75 \times 10^{-4} = 75\mu\text{A}$$

$$R_B = \frac{V_{CC} - V_{BE} - V_{ol}(8951)}{I_B}$$

$$R_B = \frac{5 - 0.7 - 0.2}{75\mu\text{A}} = \frac{4.1}{75\mu\text{A}} = 54.667\Omega$$

A 1K ohms resistor is employed to allow for reliable switching correction at all times.

### 3.9 NON-VOLATILE MEMORY

A 256-byte electrically erasable programmable read only memory (EEPROM) with a communication interface is used to hold the user pre-set temperature value. The device diagram is shown below:

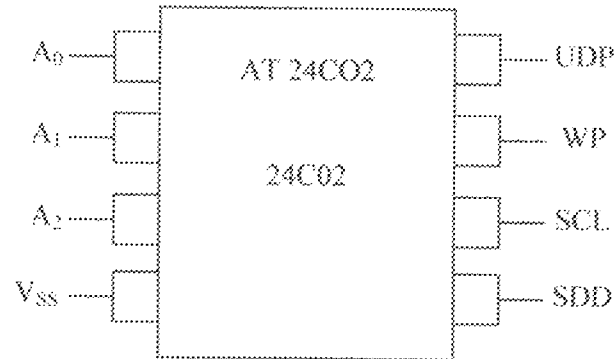


FIG.3.10: NON-VOLATILE MEMORY PIN OUT.

If during this writing operation the memory device is not detected, the message "EER2" is displayed indefinitely until the memory is reinserted.

### 3.10 SOFTWARE OVERVIEW

The control software executes the following module:

- i. Load the pre-set at power.
- ii. Get temperature.
- iii. Compare temperature with pre-set.
- iv. Actuate the relay as defined by the result of the logical comparison made between the sensed temperature and pre-set temperature.
- v. Allow user to manipulate the pre-set.
- vi. Write adjusted pre-set to non-volatile memory.
- vii. Control power to the heater

The software listing the routines used to realize the above block of control loop.

### 3.11 PROJECT BLOCK DIAGRAM

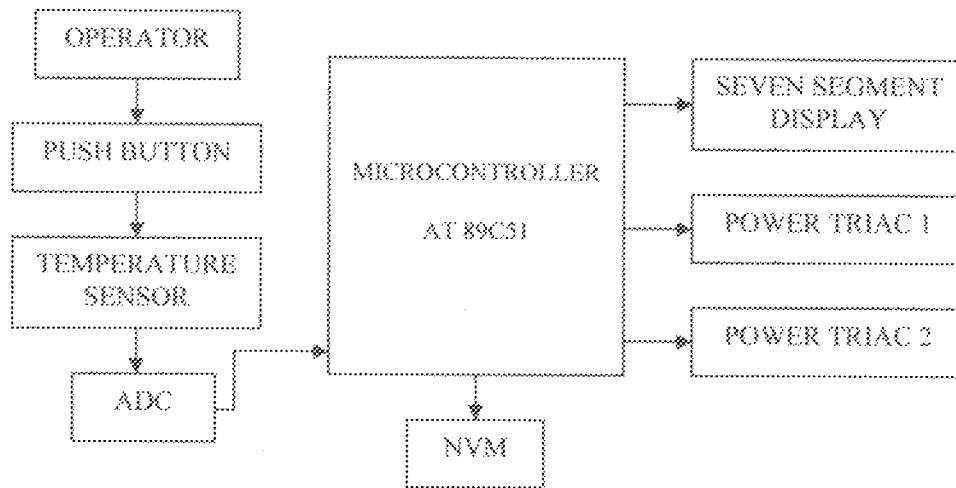


Fig. 3.11: BLOCK DIAGRAM.

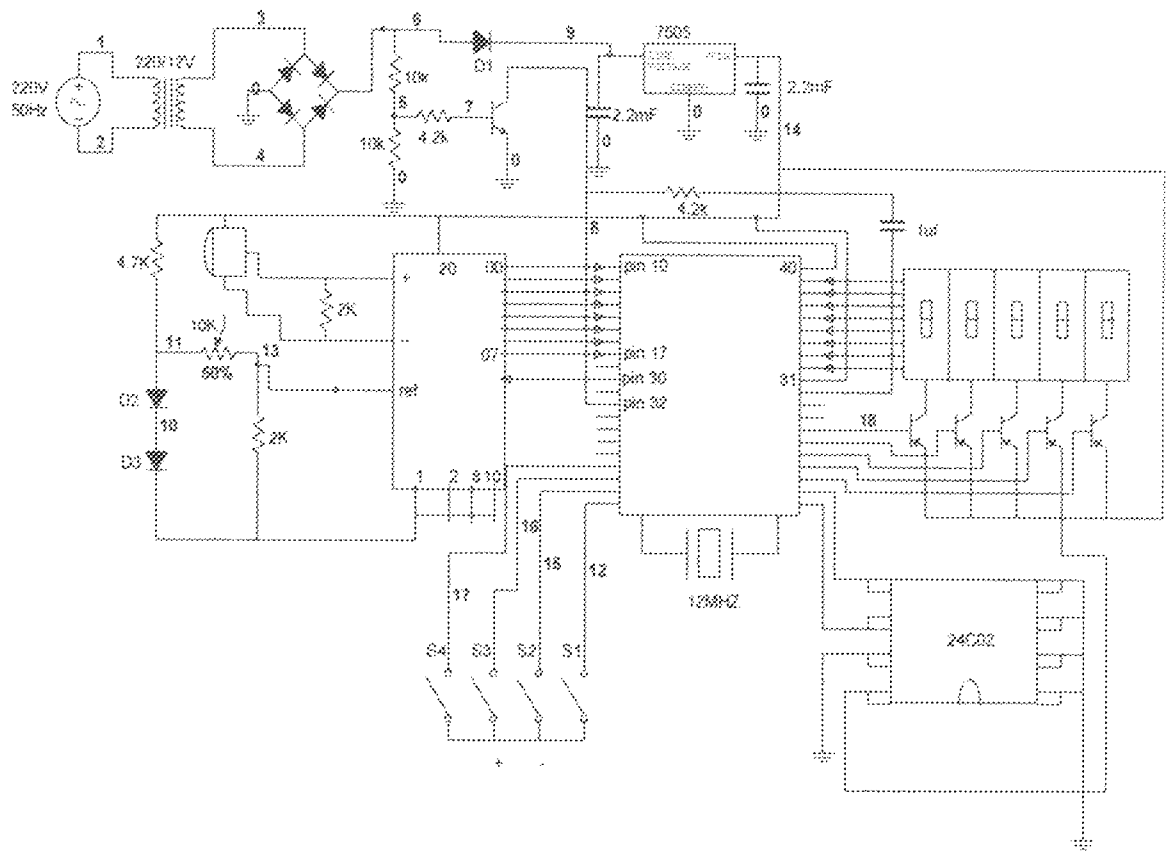


FIG 3.12 GENERAL CIRCUIT DIAGRAM.

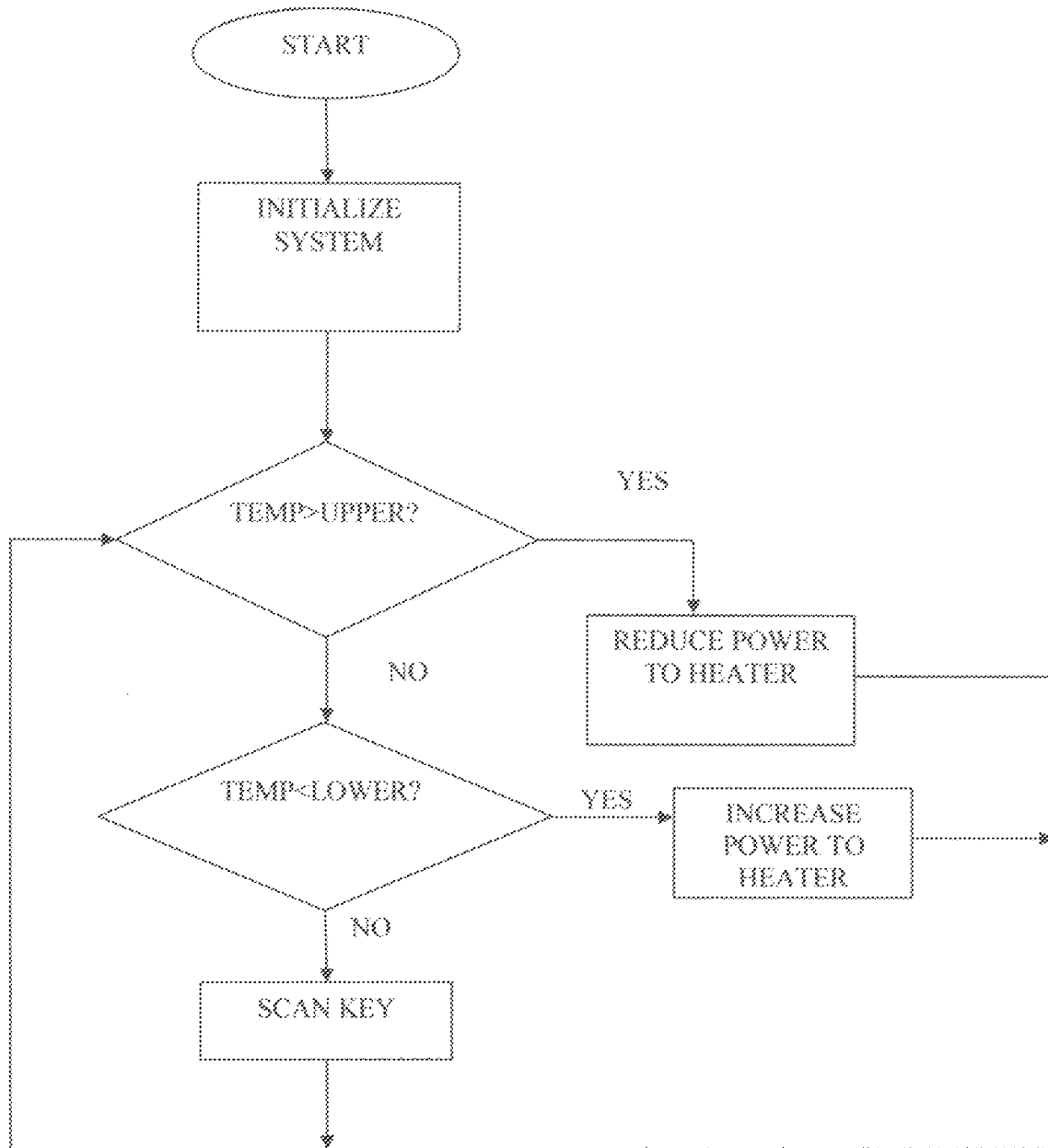


FIG 8-13 PROGRAM FLOW CHART.

**CHAPTER FOUR**  
**RESULTS AND DISCUSSION**

**4.1 PRESENTATION OF RESULTS**

The table 4.1 below shows a summary of the results obtained during the testing of the incubator.

TIME t(s)	TEMPERATURE T <sup>o</sup> C
0.00	29.6
1.68	31.5
13.61	32.0
25.75	32.4
30.91	32.9
35.20	33.4
51.93	33.8
68.19	34.3
70.12	35.2
81.94	35.9
88.81	36.2
94.26	36.7
104.79	37.1
115.67	37.6
126.59	38.1
160.55	38.5
169.90	39.0
185.65	38.6
193.50	37.0
205.60	37.4
215.30	38.0
238.70	38.0

**Table 4.1: Temperature – time table**



Below is a graph of the temperature against time from the values given in the table above.

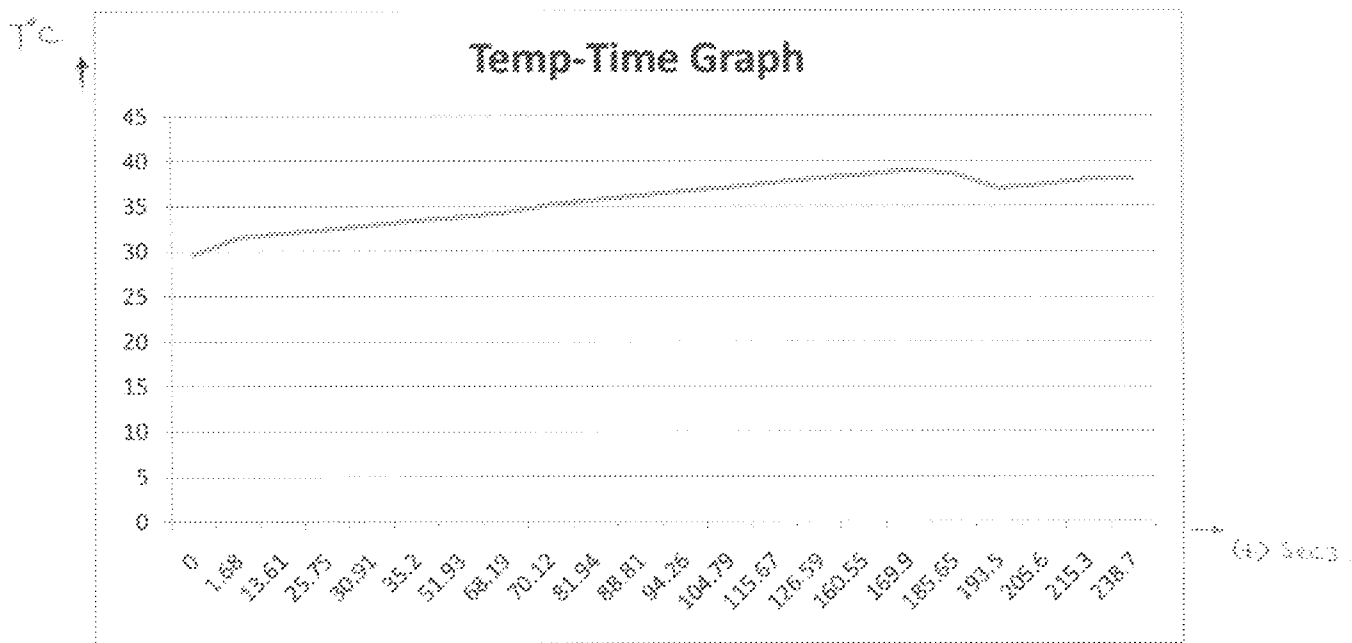


Fig 4.1 TEMPERATURE-TIME GRAPH.

#### 4.2 DISCUSSION OF RESULTS

It can be seen from the table that the average temperature of the incubator was maintained within a particular range i.e. 37°C-39°C thereby achieving the purpose of the project. It was also observed that it took 105 seconds for the temperature to reach the required minimum temperature and 170 seconds to reach the maximum temperature. The eggs were also turned after the stipulated time. It can also be observed from the temperature-time graph that the temperature of the incubator rose steadily to a maximum over time and was regulated within the required range of 37°C and 39°C.

## INCUBATION TROUBLE SHOOTING

TABLE 4.3

PROBLEM	POSSIBLE CAUSE
Chicks hatch late	Large eggs Older breeder Eggs stored for too long Inbreeding
Slow (drawn-out) hatch	Poor egg handling Hot or cold spot in incubator
Sticky chicks, smeared with albumen	Old eggs Very large eggs Poor turning
Chicks stuck in shell, dry, shell fragment stuck to feathers	Low humidity in storage Poor egg turning Cracked shell or poor shell quality
Premature hatching, bloody navels	Temperature too high
Small chicks	Small eggs Low humidity
Unhealed naval, dry, rough down feathers	Inadequate nutrition Humidity too high when hatching Temperature fluctuations
Weak chicks	Poor hatcher ventilation Contamination High hatching temperature
Chicks malpositioned	High humidity Old breeders Inadequate turning
malformations	Poor storage conditions Jarring of eggs
Crooked toes, bent legs	High or low temperature Poor nutrition
Eyes closed, down stuck to eyes	Temperature too high in hatcher Chicks remains in hatcher too long after hatching Excessive air movement in hatcher
Exploding eggs	Dirty egg from nest Water sprayed on eggs Water condensation on eggs
Haemorrhage	Contamination Nutrition deficiencies (vitamin K or vitamin E)
Swollen head and back of neck	Nutrition deficiencies
Small air cell, egg weight loss under 10%	High humidity Very thick shells

TABLE 4.3: INCUBATION TROUBLE SHOOTING

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 CONCLUSIONS

From the work carried out, a conclusion was made that the temperature of the incubator was maintained within the required range of  $37^{\circ}\text{C} - 39^{\circ}\text{C}$ . The eggs were also turned once every five hours and humidity was regulated by putting water in the basement of the incubator.

Another conclusion drawn is the fact that it took 104.79s for the temperature of the incubator to reach the minimum required temperature of  $37^{\circ}\text{C}$  and 169.90s to attain a maximum of  $39^{\circ}\text{C}$ . After attaining the maximum temperature, it took 23.60s for the temperature to fall back to the minimum. Adequate ventilation was supplied by the fan.

#### 5.2 RECOMMENDATIONS

1. The performance of the incubator can be improved upon by the addition of an automatic humidity regulatory unit which senses the relative humidity of the incubator and either absorbs or releases moisture based on comparison with a predefined humidity standard.
2. A major problem during the testing of the incubator was power supply. Another way of improving the performance of the automatic incubator is the addition of an uninterruptible power supply system in order to solve the problem of power seizure.

This can be achieved by the inclusion of a battery which will be charged when there is power supply and a relay which switches supply automatically to the battery in case of power outage. An alternate source of energy such as solar energy can also be harnessed using a solar panel.

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