INTERNATIONAL JOUNAL OF: ENGINEERING RESEARCH AND TECHNOLOGY

TIMBOU-AFRICA ACADEMIC PUBLICATIONS
INTERNATIONAL JOURNAL, MAY, 2022 EDITIONS
VOL. 9 NO. 5 ISSN: 2707-5654

# HYBRID INCUBATION SYSTEM: DESIGN AND CONSTRUCTION

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## ABSTRACT

*The Hybrid GSM-based egg incubator system was designed to reduce the risk of damage and abnormal egg incubation caused by uncertain environmental conditions. The principle of operation of the system is based on temperature and humidity manipulation where a sensor is employed in the system. The*

## Introduction

The hybrid GSM-based egg incubator designed to improve the hatchability of eggs. It works principally with a feedback control system. Feedback controls are employed as the basic mechanisms by which devices, networks, systems, whether mechanical, electrical, or biological, maintain their equilibrium. The basic feedback parameters in this system are humidity and temperature. The digital temperature and humidity (DHT) sensor serve the function of

*system consists of a motor which rotates the eggs at specified period of time to prevent the embryo from sticking to the shell and the measured temperature and humidity will be processed by the microprocessor. The microprocessor is the main controller that controls the overall system. The system was also equipped with a unique feature to alert the user on the system performance by sending an SMS when the need arises. The system has the capability of not only hatching chicken eggs but that of Guinea Fowl and Turkey. A keypad is provided to select the type of Egg to hatch and the system automatically selects the features of such Egg selected. As a backup to the system, a solar and an inverter as subsystems are also incorporated to provide an uninterruptible power supply to the system. The system was found to have performed as expected with improved performance which is attributed to the presence of the solar and inverter system. The best hatching results was attained within the normal oxygen level in the atmosphere.*

***Keywords:*** *GSM Module, Inverter, DHT Sensor, Incubation, Solar system.*

sensing both temperature and humidity, thereby serving as the feedback element.

The system intends to solve the issues related to loss of energy as a result of interruptible power supply, energy leakages, low hatchability and improper monitoring. The system monitors humidity and temperature using the DHT sensor, display the duration of incubation, real time and date and as well alert the user of complete hatching by sending short service message (SMS) to the user. Unstable temperature and humidity are also sent to the user using the GSM system. This is done for proper monitoring and control.

The microcontroller automatically controls temperature and humidity according of the environment (incubator) and other parameters given by the user.

Low hatchability is one of the major problems of poultry farmers recently. Proper and more efficient way is really a solution to the matter. This is to enhance and improve mass production and to save time by producing chicks in large quantity.

## LITERATURE REVIEW

Adetola et al., (2019) worked on a Kerosene Powered Multi Bird-Egg Incubator. Heat generated by the combustion of kerosene was transferred into the incubator chamber by conduction and circulated by means of a 12 V D.C fan powered by a 12volt battery. LM35 temperature sensor was used as the temperature sensing device. Both the turning of eggs and heat generated from heat source were controlled by mechanically incorporated driver motors. The LM35 temperature sensor and the two stepper motors were controlled by a PIC16F877 microcontroller. Insulation of the incubator chamber was achieved by lining the inner portion of the incubator with fiber materials. The incubator was designed and constructed using locally available material to reduce cost with little or no dependence on electricity and more user friendly. The incubator was tested with 90 eggs each for the three birds (i.e Chicken, Quail and Turkey). The result obtained shows that quail has the highest hatchability of 93% followed by Chicken with 84.4% and lastly turkey with 70%.

Nazif et. al., (2021) designed and constructed a GSM based incubation system that incubates only chicken egg. The use of a digital temperature and humidity sensor was made and a DC motor that will rotate the eggs. SMS feedback was used to alert the user


TIJERAT
ISSN: 2707-5654

of an emergency situation or if a hatch is complete. The system works on only main supply without a backup and hence the limitation.

Bamikefa et. al., (n.d) worked on Smart Egg Incubator System with GSM Based Remote Access. The system is designed to incubate different types of eggs, having a user-friendly interface to set the temperature range for its operation. The temperature is monitored by a digital thermometer DS1820 and controlled by a microcontroller AT89S52 embedded with a software program which toggles it between high and low temperature. The GSM module provides the system with remote access, whereby the user can monitor the temperature as well switch the system on and off. The egg roller is a mechanical part needed to roll the eggs at intervals, to ensure proper development of embryos in the eggs. The prototype incubator constructed has been able to achieve the aims and objectives of the research albeit with modifications.

Ogbeh et al., (2018) designed an automatic fixed factor egg incubator. LM 35 is used as the temperature sensor which is coupled to Analogue to Digital Converter (ADC), senses the surrounding temperature and send it to ADC which converts it to microcontroller language for regulation of a constant temperature. As the process continue, the fan is ON when the temperature exceeds the threshold temperature and OFF for the heater to ON when the temperature is low.

## MATERIALS AND METHODS

The materials used to implement this work are the electric motor, the DHT sensor, the LCD, ATMEGA328 microcontroller and other basic electronic components. The methodology of design and implementation follows the following flow chart.



TIJERAT
ISSN: 2707-5654

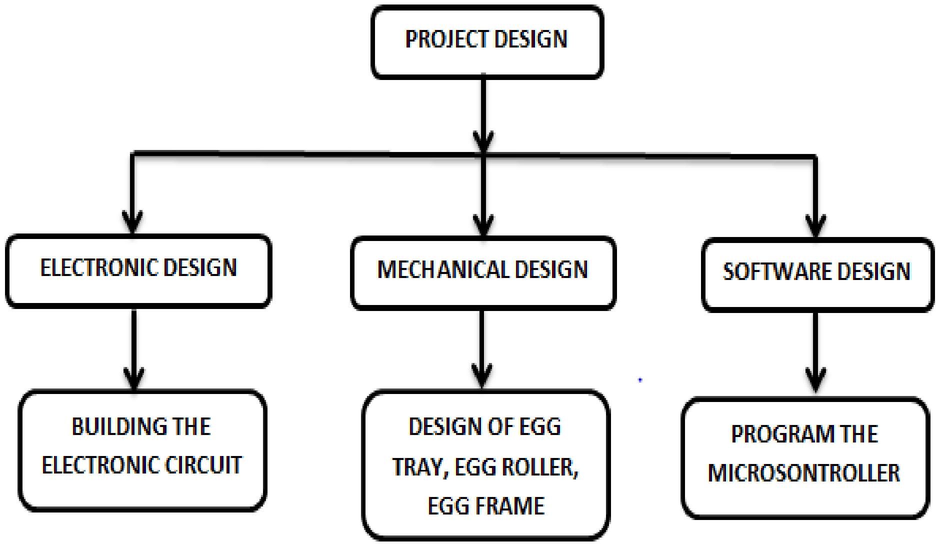


Figure 1: Flowchart of the project development

From figure 1 above, the project development was divided into three main sections. There are mechanical design, electronic design and software design. These parts will combine together to form the GSM based Egg Incubator System.

## MECHANICAL DESIGN

The project development begun with the mechanical design. It consists of the development of incubator casing, egg frame and egg crate.

### Incubator Casing

To build the egg's incubator system involves lots of concern in terms of the temperature, humidity and movement in order to care for the health of the egg. One important thing to be known is how to change the position of the egg during the period of incubation. It should get along with a mechanical egg-shifting system. The eggs in the incubator need to be shifted slowly and smoothly, since jostling would disturb the development of the chicks. By using the DC motor, the microcontroller is programmed in order to control the speed of the motor.

The construction of the incubator will begin with building the casing of the incubator. A good quality material was chosen because it has proper insulation that will contain the temperature and humidity for some time even when there is power outage. The casing was chosen to be Deep Freezer. Dimensional measurement of the freezer is given in the figure below.

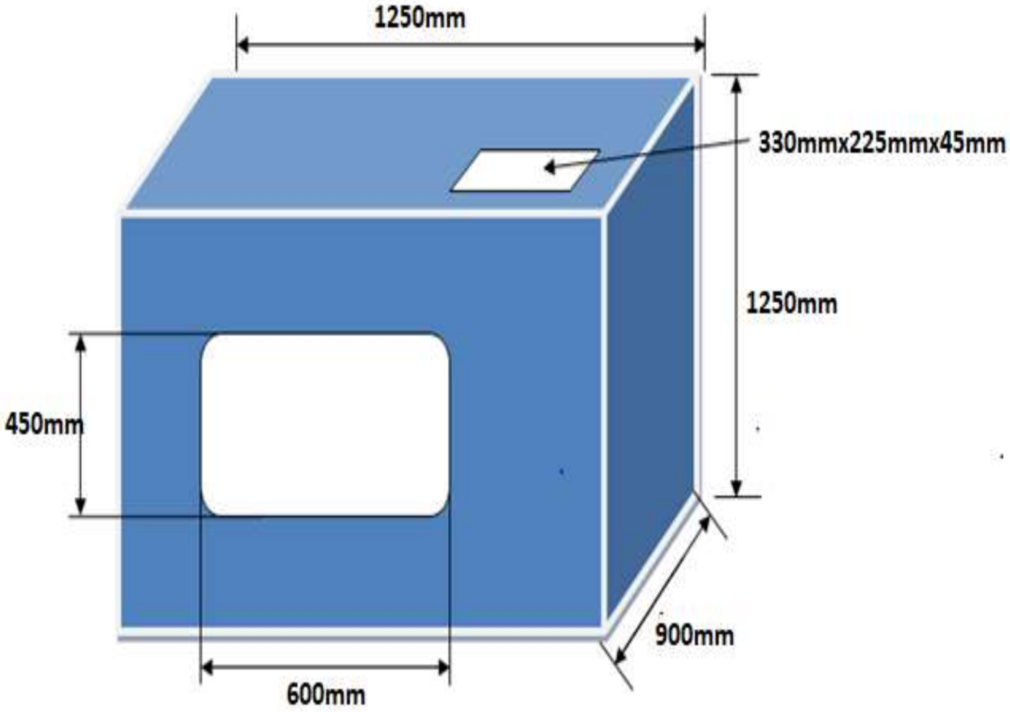


Figure 2: Casing of incubator

A blower was placed around the wall inside of the incubator. The blower will provide both the required temperature and humidity to the egg.

## Egg Frame

The egg frame contains the egg crates arranged in steps, one after the other each containing the egg. The egg frame is place inside the incubator. It can also be removed any time if desired. The DC motor is also situated on the right side of the egg frame. The dimensional measurement of the egg frame is as illustrated in figure 4 below.

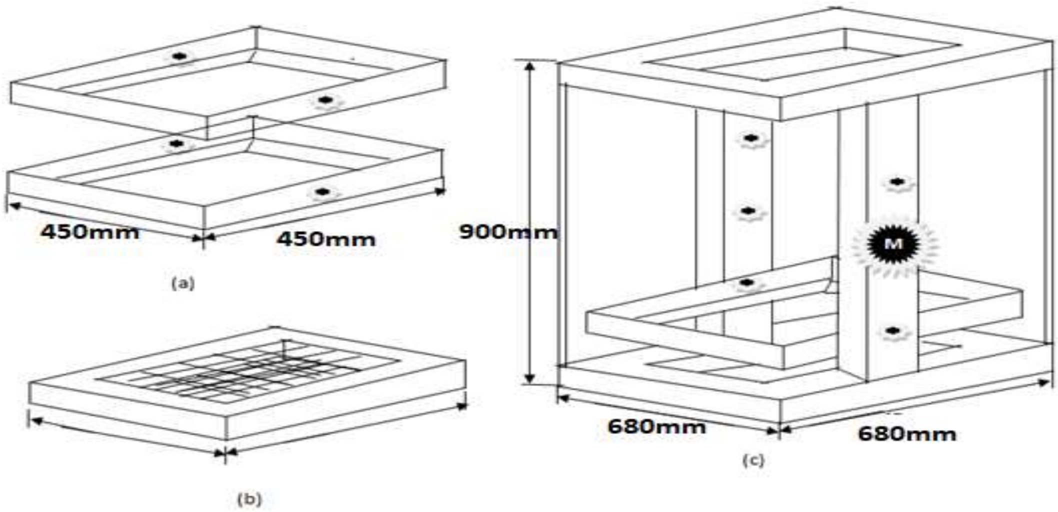


Figure 3: Shows the design of the (a) Egg Tray, (b) Egg Crate and (c) Egg Frame

**Egg Crate**

The egg crate contains the eggs that will be hatched. There are three stages for the incubator where the eggs are placed. Each stage can carry 270 eggs for the chicken, 180 for the Duck and 225 for the Guinea fowl. The total number of eggs the incubator can carry for each species is given in Table 1 as shown below.

Table 1: Number of eggs for each species in the incubator.

| S/No | Specie/Type of Bird | Quantity of Egg |
|---|---|---|
| **1.** | Chicken | 270 |
| **2.** | Duck | 180 |
| **3.** | Guinea Fowl | 225 |

The egg crate is illustrated in figure 3(b) above. The egg crate is placed inside the egg tray as in the figure 3(a) above. This incubator becomes user friendly because it can be moved to other places. A transparent glass was used at the front of the casing so that the content of the incubator will be seen.

**Egg Tray**

The egg tray contains the egg crate and the combination is placed inside the incubator frame as shown in figure 3(c) above.

**DC Motor**

The DC motor is very important in order to change the position of eggs. The position of egg must be change 2-3 times (at least) every day until the 18th day of incubation, after that the eggs must not be turned until hatching. The DC motor chosen is the car glass whiner DC motor.

Torque generated by electric motor

$$T_m = \frac{\text{power}}{\text{angular velocity}} \quad \text{-----1.0}$$

$$\text{I.e. } T_m = \frac{60 \text{ x power}}{2\pi N}$$

Where N = Speed in rpm

**Design of Ventilation Holes**

Ventilation is basically the volume of mass flow in and out of the incubator, so the volume flow rate is given as;

Volume flow rate = Cross sectional area x Velocity -----1.1

Where;

Cross sectional area = $\pi r^2$ -----1.2

Assume number of holes = 20 holes

Assume diameter of holes = 0.80cm

Volume flow rate through one hole is given as;

Volume flow rate = cross section area × velocity

Velocity = $2\pi N$

Cross sectional area = $\pi r^2 = \pi(0.004)^2 = 5.03x10^{-5}cm^2$

Motor feed = speed of fan = 0.25rev/sec

Volume flow rate = speed of fan x volume ----1.3

Volume flow rate = 0.25 × $5.03x10^{-5}$

Volume flow rate = $1.2575x10^{-5}cm^3$/s

## Electronic Design

The electronic design consists of five (5) major parts. There are master controller circuit, slave controller circuit, switching controller circuit, power supply circuit and the Inverter system. The master controller circuit was interface to the temperature and humidity sensor (DHT), Liquid Crystal Display (LCD), Keypad and the blower. For the slave controller circuit, it interfaces with DC motor circuit that turns the egg crate/tray.

The Block diagram shown in figure 4 below shows the connection of all parts of the system. These consists of the input, CPU and output. The inputs of the system are keypad, temperature and humidity sensor and also power supply. The ATMEGA328 will operate as a CPU which is the main controlling system. For the output element consist of LCD screen display, DC motor and the blower.

The block diagram below shows the operation of the GSM based Egg incubator system.

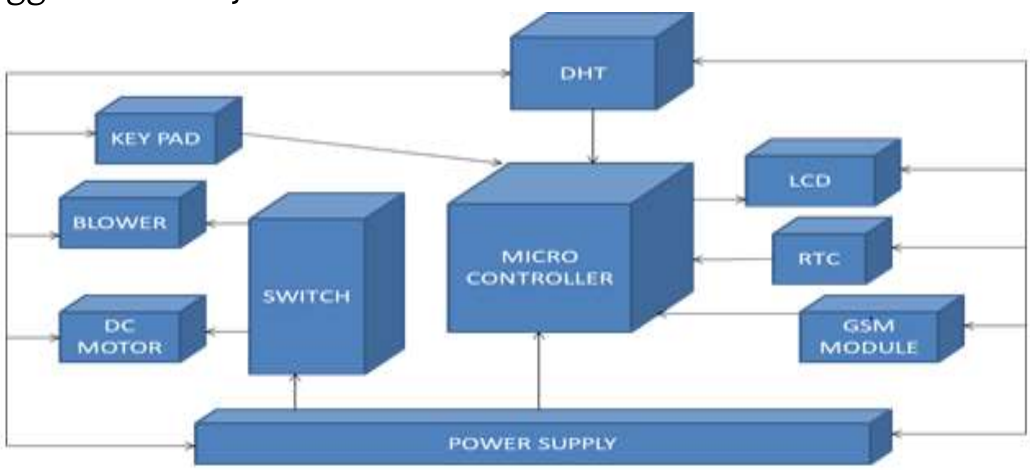


Figure 4: Block diagram of the hardware design

The operation of the system starts as the user selects the type of egg by pressing the code on the keypad. After that the controller which is ATMEGGA328 will set up the range of the temperature and humidity of the incubator. If there is any change in the ventilation of the incubator, the temperature and humidity sensor will measure and send data to the controller as feedback. LCD board will display any changes that might occur. The controller will control the speed of fan, light and flow of water until the ventilation of the incubator is back to the condition needed. The controller also controls the shift rotation of the DC motor. This allows the egg change their position to take care of the growth of the embryo.
This system will run until the egg is hatched. To make sure the system always runs, a battery source is needed. The battery as a backup power supply will supply the voltage whiles the system works. The system may fail if main power supply out.

**Master Controller Circuit**

The master controller circuit schematic is shown in the figure 5 above. The function of Master circuit is to control the input data from keypad and display on the LCD screen. It also reads the input data from temperature and humidity sensor and store in variable before display on the LCD screen. The master circuit also controls the output fan. When the CPU detects the value of temperature is high than suitable value, heater will off and when the CPU detect the value of humidity is high than suitable value, the fan will on. It can make the suitable condition in good status for egg incubation process. The microcontroller used in this work is the ATMEGA328, which is popular, cheap and available.
Liquid crystal display (LCD) screen displays the current value of temperature, humidity and duration of incubation. A real-time clock (RTC) is a computer clock (most often in the form of an integrated circuit) that keeps track of the current time. GSM/GPRS module is used to

establish communication between a computer and a GSM-GPRS system. Digital temperature and humidity sensor is a digital signal output that has been calibrated. It is a temperature and humidity composite transmission Sensor.

**Power Supply Unit**

The power supply unit consists of transformer, rectifiers, filters and a voltage regulator and is designed by taking the following steps;
This type of power supply uses is a full wave rectified power supply. The use of a regulation IC to give a steady output of 12V and 5V is employed.
The 220v ac is stepped down to 15v ac using a transformer of 15v, 1A, 50Hz.

$$V_{peak} = \sqrt{2} \times V_{rms} \quad \text{-----1.4}$$

$$= \sqrt{2} \times 15v = 21.21v$$

Consider the equation the below; this is usually referred to as the basic transformer equation.

$$V = 4FfaBN \text{ X } 10^{-8} \quad \text{-----1.5}$$

Where:

V = the r.m.s voltage across a considered winding in volts.

F = form factor (normally 1.11 for sine wave)

f = input frequency in Hertz (50Hz)

B = flux density in lines per metre square

N = number of turns on a considered winding

a = core area in per metre square

A conservative value for B is 75000 lines per square meter of core area.

$$V = 4 \text{ x } 1.11 \text{ x } 50 \text{ x } a \text{ x } 75\text{x}10^{3} \text{ x } N \text{ x } 10^{-8}$$

$$V = 16650 \text{ x } 10^{-5} \text{ x } N \text{ x } a$$



TIJERAT
ISSN: 2707-5654

N/V=6/a

The term N/V is known as the turns per volt figure for a transformer that is to say, the number of turns on the winding for each volt across them. This ratio is the same for each winding on a transformer.

The rectifier circuit is needed for ac signal rectification. A full wave bridge rectifier is the most commonly used rectifier circuit. Its arrangement is shown in figure 6 below.

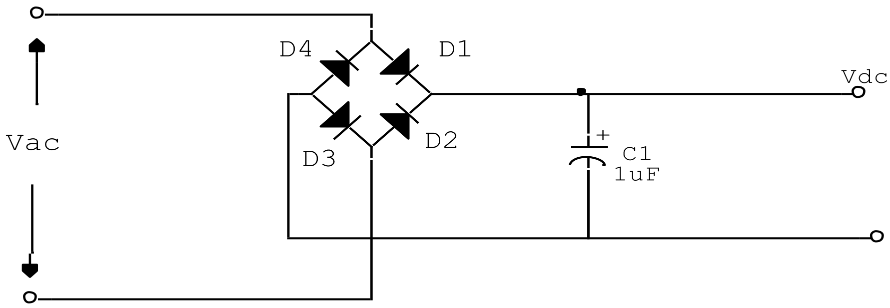


Figure 5: Full wave bridge rectifier. (Arbor, n.d.)

The bridge rectifier consists of four diodes. The operation of the circuit is that two diodes conduct during any of the half cycle of the ac input voltage. AC is converted to DC with the aid of the rectifier section/circuit.

A circuit that converts a pulsating output signal of a rectifier into a smooth dc voltage is known as a filter. To achieve this, a capacitor is used in parallel with the load. This type of filter is known as capacitor input filter. The filtering action of this filter wave is shown in figure below.

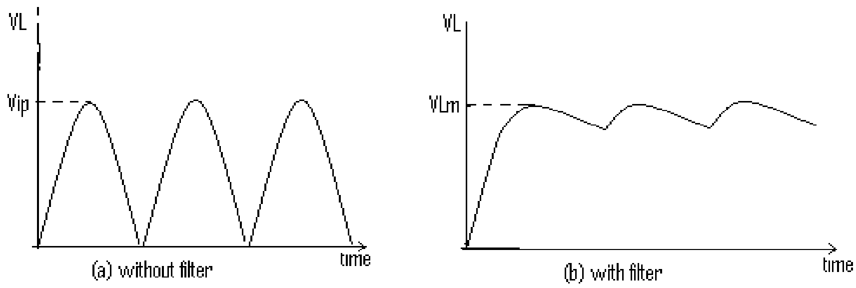


Figure 6: Filtering action of a capacitor filter. (Arbor, n.d.)

The value of the shunt capacitor is given by

$$C = \frac{1}{4\sqrt{3} f \gamma R_2}$$

-----1.6

Where f = frequency at the main voltage

γ = Ripple factor

$R_2$ = load resistance.

Since these voltages are peak voltages therefore their root mean square (r.m.s) value will be:

$$V_{r.m.s} = V_{peak\,(dc)}$$

-----1.7

$$15/\sqrt{2} = 10.61 \text{ Volts}$$

The conversion from r.m.s value to peak value is practically done using smoothening capacitors.

Since the r.m.s value is pulsating and supplied by a bridge rectifier then the r.m.s voltage will be transformer r.m.s voltage (ac) less two diode drops since for each half-cycle at the ac voltage two out of the four diodes of a bridge rectifier conduct.

Transformer r.m.s voltage $T_{rms}$ is given by:

Trms = 10.51 + 1.4 = 11.91v (ac)

Recall, the turn per voltage ratio is N/V= 6/a

Where:

N = number of turns on a considered winding

V = voltage across a considered winding in Volts

a = core area in meter square which has been chosen to be 18 $m^2$ for the primary winding.

V = 4.444fΦNP

Φ = BA

----1.8

Where B = 1.2T

A = 4.0 x 4.5cm = 18 x $10^{-4}$m



TIJERAT
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$$N_P / V_P = 1/222\Phi$$

$$N_P / V_P = 2.085$$

$N_P$= 2.085 x 220 = 458.8

∴ Primary turns = 459 turns

For the secondary winding

$V_s$ = 11.91v

$$N_S / V_S = 2.085$$

$N_s$ = 2.085 x11.91 = 24.83

∴ Secondary turns = 25 turns

The function of the filter is to smooth the pulsations present in the output voltage supplied by the rectifier. In practice, no filter gives output voltage that is as ripple-free as that of a battery, but it considerably reduces the ripple to certain extent. A capacitor is used to achieve the filtering as shown below:

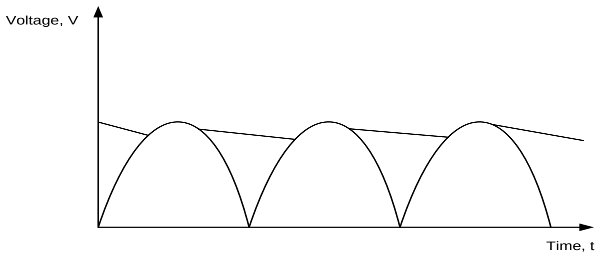


Figure 7: Rectified and Filtered Output. (Arbor, n.d.)

$$V_{dc} = \frac{V_s}{1 + \frac{I_{dc}}{4fCV_s}}$$

----1.9

Equation above refers to the relationship between the filter capacitor and other supply parameters.

Where,

$V_{dc}$ = Expected DC output from the regulator

$f$ = Supply frequency



TIJERAT
ISSN: 2707-5654

$I_{dc}$ = Output current of regulator

$V_s$ = Transformer Secondary Voltage

$C$ = Capacitance of the filter capacitor

It is preferable to choose a filtering capacitor that will hold the peak-to-peak ripples at approximately 10% of the peak voltage. Therefore;

$V_{ripple} = 0.1V_{peak}$ ----1.10

$V_{ripple} = 0.1 \times 11.91 = 1.191v$

But also

$V_{ripple} = I/2FC$ for full wave ----1.11

Where;

I = current taken by the load

F = frequency of supply

C = filtering capacitor

$C = I/2FV_{ripple}$

$= 0.17/(2 \times 50 \times 1.191)$

$C = 1427.37\mu F$

From this calculation, a capacitor of 2200µF was chosen.

**Circuit Diagram**

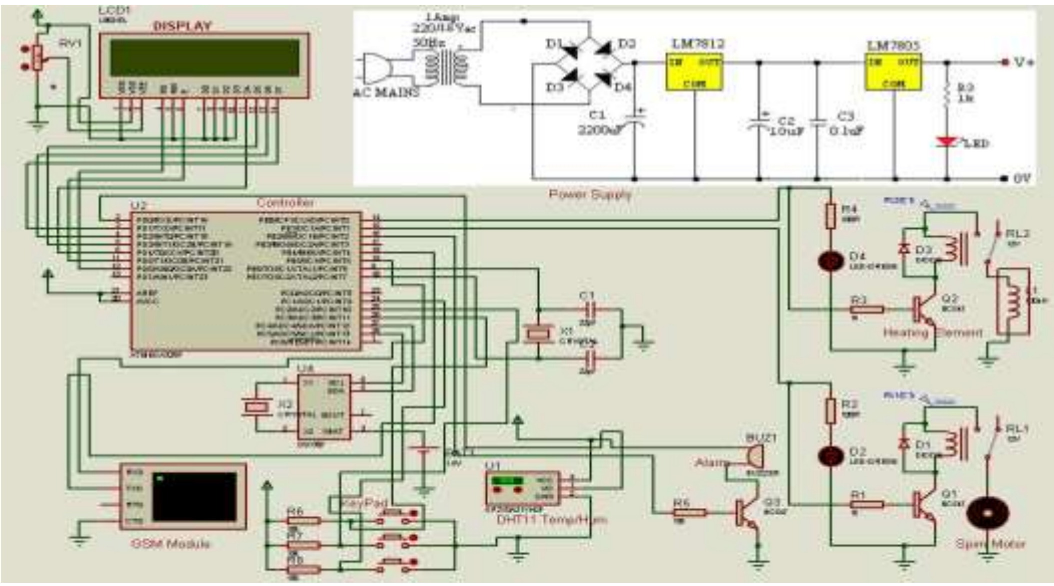


Figure 8: GSM based Egg Incubator System.



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## Software Design

The software design has to do with the program flow chart and the program/code. The program is written in C++ and is intended to compare the reference values of temperature with the incubator environment and thereby control the heater and fan. It keeps track of time and count the number of days of incubation and lastly, send SMS whenever an egg is hatched or there is an abnormality.

## Inverter Section

The inverter unit is incorporated with a PV system to provide an alternative power supply to the system. This functions in a situation of power interruption. The capacity of the inverter used was 1.5kVA, which powers the DC motor enabling it to turn the eggs based on the program stored in the microcontroller. It also powers the RTC to keep track of the real time and the count of number of days of incubation. The inverter takes care of powering the entire system in case of power failure to prevent interruption of its operation.

## RESULTS AND DISCUSSION:

The various components and stages were tested to ascertain proper functioning of the system accordingly. The result of the transformer testing and the voltage regulators is shown in the table below.

Table 2: Results of Transformer testing

| | | Before rectification | | After rectification | | Resistance | |
|---|---|---|---|---|---|---|---|
| S/NO | **Component** | **Input Voltage (v)** | **Output Voltage (v)** | **Without Filter** | **With Filter** | **Input Resistance (Ω)** | **Output Resistance (Ω)** |
| **1.** | Transformer | 240.50 | 16.95 | 16.20 | 23.13 | 113.50 | 1.20 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2. | 7812 | - | - | 12.02 | - | - | - |
| 3. | 7805 | - | - | 5.01 | - | - | - |

For a good design, the results obtained are most often very close to the theoretical values, exceptions may be used in certain circuits due to some impractical assumptions. The performance of the system was observed to have improved as a result of incorporation of an inverter system. The objectives of the project were achieved using materials that were readily available in the local market with the aim to increase the rate of chicks' production among small scale farmers in developing countries.

From the design results, the values obtain from the transformer, 7812 and 7805 were very close to the theoretical values. Also, the output voltage of the DHT does not change with temperature change and hence the design fell within a reasonable range.

## CONCLUSION

The design was implemented from easily available, moderately cheap and readily available, weather resistant materials. The design also makes the construction simple which also makes the question of assembly and maintenance a matter to be solved without resort to any highly specialized skills or technology. The incubator can compete economically with other conventional poultry egg incubators i.e. electric egg incubators and the running cost is minimal once the initial cost of purchase has been settled. The incubator will certainly find application in areas where the population is inaccessible to electricity. Incorporation of IOT technology can be further considered in order to improve the performance efficiency of the system.

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