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Design and Construction of A Microcontroller Based Automatic Egg Incubator System

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Abstract

This paper describes the development and implementation of an egg incubator automation system based on a microcontroller to solve the problems associated with manual incubation such as inconsistent temperatures, humidity, and egg-turning periods. The proposed system utilizes an ATmega328P microcontroller as the main processor, integrated with a DHT11 sensor, a 16×2 LCD display, and a 12V DC geared motor. The incubator operates within a range of 37 – 39 °C and 50 – 65 % relative humidity (RH) for the first 18 days followed by 70 % RH in the last three days, with egg turns occurring every 4-8 hours at 45° angle. The experimental results show that 86.7% ± 2.0% of eggs hatched successfully in comparison to the manual system where only 62.3% ± 4.1% of eggs were successful in hatching, n=60, $p<0.05$. Designed using locally available components costing ₦22,275 or less, the system offers an economical means of automation for small-scale poultry farms.

Keywords: Egg incubator, microcontroller, DHT11 sensor, temperature/humidity control, automatic egg turning.

1. INTRODUCTION

1.1 Background

Incubation refers to the biological practice of handling the fertilized eggs to allow for proper embryonic development to produce healthy chicks through optimal temperatures, humidity levels, movements, and ventilation (Tadelle & Ogle, 2001). Incubation through natural means, whereby the birds brood their eggs, is a practice that has been in existence for many years. However, this practice is inherently unpredictable since it relies on the brooding capabilities of the birds which may vary. Besides, the number of eggs that can be hatched using this approach is limited due to the small size of the hen, and the number cannot exceed 15 eggs (Tadelle & Peters, 2003).

The invention of artificial incubators solves the aforementioned constraints. The artificial incubator is an environment that is regulated in terms of temperature, humidity, and ventilation in order to hatch more eggs than one hen can hatch (Emmanuel, 2005). Incubators nowadays can even regulate environmental conditions automatically depending on the eggs type, thereby optimizing the mass production of poultry (Tadelle & Ogle, 2001). The use of automated systems is necessary for the improvement of efficiency in the poultry industry, reduction of post-harvest losses, and satisfying the rising protein demands in developing countries.

In chicken production, it is imperative that there be proper control of temperature, humidity, and egg turning process. Any slight variation in any of the above factors results in low hatchability, poor quality chicks, and loss of profits. Egg turning, especially manual egg turning, is quite strenuous and may not be properly done. There is no consistency in terms of egg turning angles and intervals. This lack of proper control makes it difficult to optimize the process.

The manual way of incubating is naturally inefficient since it provides hatchability efficiency of 60%-70%, while the automatic system is known to ensure 85% efficiency or better. The difference between the two translates to 150-200 chicks lost per year for a smallholder farmer who uses 1,000 eggs, lowering his income potential. Additionally, importing commercial incubators from abroad is too costly for farmers in rural areas; it costs more than ₦500,000. This project seeks to overcome the difficulties mentioned above through construction of a homemade incubator using a microcontroller system for a hatchability efficiency of 86.7% ± 2.0% at ₦22,275.

The objective of this research work is the design and development of the egg incubator system with the help of microcontroller for automatic temperature and humidity control and egg turning. The objectives include:

Designing of automatic control of a 12V DC motor for turning of egg trays in every 4-8 hours at 45° angle. Designing of a temperature and humidity control system which uses DHT11 sensor and actuators (Heater, Fan & Humidifier) with ±0.5°C Accuracy. Designing of Embedded System Software (C++) for the operation of all these components through the use of Atmega328P microcontroller.

Performance testing of the system through hatchability test of 60 eggs.

This research work presents a solution that will automate and regulate the environment needed for maximum hatch rate. Reduction of labour cost by automation of egg turning process. Customization of incubation parameters.

The paper highlights the development of an egg incubator system using a microcontroller that can hold up to 60 eggs with automatic egg turning function, temperature control (37-39°C) and humidity (50-65%, to 70% for hatching) using locally available components and running on 12V DC power supply.

Testing of the system is done with only 60 eggs; thus, in case of increase in capacity, it would need a change in mechanical design. There is the limitation of accuracy of the sensors (DHT11, ±2°C, ±5%RH). The system needs a stable 12V DC power supply; there is no solar energy backup in the system.

2.0 LITERATURE REVIEW

Poultry industry is an important part of the food production cycle across the world, and incubation is an important process which ensures that ideal conditions are created for the growth of the eggs in poultry farms. This chapter will discuss the literature related to temperature, humidity, and turning control of poultry incubator.

2.1 Physical Factors in Incubation

Temperature: The temperature is the most important factor during incubation because it determines the rate and time period of embryo development (Decuypere & Michels, 1992; Meijerhof, 2009). The optimum temperature for chicken egg is 37.5°C-37.8°C. Temperature changes of ± 0.5°C are permissible; however, temperature variations of ±1 °C and above will negatively affect hatching ability or may cause death of the embryo (Lourens *et al*., 2007).

Humidity: During incubation process, there is a water loss through egg pores and expansion of the air cell. The required humidity should be 60–65% in the first 18 days, increasing to 70% in the last 3 days (Reinhart *et al*., 1984; Van der Pol *et al*., 2013). If the humidity is low, it leads to increased water loss, but higher humidity decreases the incubation period and the chicks become wet (Decuypere *et al*., 2002; Tona *et al*., 2003).

Turning the Egg: Turning the eggs helps prevent the embryo from attaching itself to the inner membrane of the shell, as well as making sure that the temperature is evenly distributed (Barr *et al*., 2005). The eggs should be turned at least two times daily, and it is preferable if this is done at a 45° angle.

2.2 Component Selection

Arduino Troller (ATmega328P): chosen due to the capability to process the input from the sensor and control functionalities, low cost and easy to program. Program and debug can be easily done by the Arduino development environment.

Sensor (DHT11): Chosen due to cost efficiency, digital output and accuracy which is enough for the project. The sensor will sense temperature from 0 to 50 degree centigrade and humidity from 20 to 90 RH.

Display (16×2 LCD): Makes it possible to display the real-time values of temperature and humidity.

Actuator: DC Gear Motor driven by L293D chip for egg rotation and light bulbs for heating as well as fans for ventilation.

2.3 Review of Related Literature

Both temperature and humidity play an important role in determining the growth of the embryos. The significance of both temperature and humidity for hatchability and chick quality has been brought out by recent studies.

Recent Advances in Incubator Technology

There have been some remarkable changes in the technological advancements related to the smart incubators in the recent past. The review conducted by Zakaria *et al*. (2023) was based on the control systems used in egg incubators from the Scopus database. According to the study, conventional methods of hatching eggs yield success levels below 81%, whereas hatching eggs using on/off controllers is subject to temperature variations that affect hatchability. The systematic literature review conducted in ten out of twenty articles discovered from Scopus showed the need for advanced control systems. PID control system proved to be superior to the on/off control system, yielding hatchability of 92%.

The team of Peprah *et al*. developed an incubator using GSM/IoT technology running at 37.5°C and 50%-70% relative humidity to ensure hatchability greater than 95%.Renewable energy could be used alongside intelligent controls in areas where there is no continuous supply of electricity.

It could be seen from the review on intelligent egg incubators using microcontrollers carried out by Izadeen & Kocher (2022) that amongst the 21 intelligent egg incubators using microcontrollers, they suggested 37.5°C and 25 to 60 percent humidity before hatching, while 70-80 percent is needed during hatching. It could be seen from the review that even though the ON-OFF control system is popular among cheap control systems, advanced control systems improved hatchability.

IEEE's research study (2022) offered an extensive literature review of solar incubators with various controllers, and it revealed that solar energy technology is a viable choice in places where there are challenges with electrical energy supplied through the electrical grid system. During the review, it was noted that there is the need for constant temperatures of 37-39 degrees celsius and humidity for effective embryo growth, and advantages and disadvantages of various techniques were reviewed for the design of the solar incubators in developing countries.

There have been many breakthroughs in the realm of research on control algorithms. As indicated by Nugroho (2021), PID and fuzzy logic controller algorithms for incubators were analyzed, and it turned out that the fuzzy logic controller algorithm took 9 minutes without any overshooting while the PID algorithm took 18 minutes with 4.16% overshooting.

Besides that, some studies have also been conducted on the design of fractional fuzzy inference systems for temperature control of incubators. For example, the design of a Fractional Fuzzy Inference System-based Proportional Integral Derivative (FFIS-PID) controller was presented in an article published in the Iranian Journal of Fuzzy Systems (2025). The system performed better temperature control through its adaptability feature in real-time than the traditional FIS-PID controllers.

In relation to IoT-based incubators, there has been significant advancement. According to Nugraha *et al*. (2024), an egg incubator has been successfully designed using IoT, whereby the microcontroller was utilized as the controller of the system, with hatchability of up to 90% achieved.

One of the studies was carried out by Cabajes *et al*. (2024) whereby the development and design of the IoT-based egg incubator was evaluated. The result was several improvements in energy efficiency, environmental control and performance of the IoT-based egg incubator. Moreover, the duck egg incubators that have been designed using the ESP32 microcontroller, DHT22 sensor, and Blynk application were successful in hatching 91% of eggs at 37.9°C of temperature and 62.2% of humidity.

Okusanya *et al*. (2026) designed the smart IoT-based egg incubation and hatching system so as to guarantee sustainable poultry production in Nigeria because of inefficiencies of local incubators in terms of ensuring the constant temperature, humidity, and egg-turning rate.

Likewise, Widodo *et al*. (2026) redesigned the ordinary egg incubator by developing it into the smart IoT-based egg incubator using DHT11 sensor, WEMOS microcontroller, and synchronous motor in order to ensure hatchability of 90.4%, highlighting that the smart egg incubator technology is easily controllable.

A novel solar grid hybrid egg incubator with PID-controlled temperature ±0.3°C and relative humidity ±2.5% RH was designed by Abdullahi *et al*., (2025) with a hatchability rate of 88.3%, and the system had the capacity to hatch 600 eggs.

Historical Context and Evolution

In the previous research by Ogunwande, Akinola, and Lana (2015), there was an incubator built from a wooden frame that utilizes biogas for its energy source, and it had been found out that there was no uniformity in temperature in the interior, thus, low hatchability. The study conducted by Olasunkanmi, Olubiyi, and Kehinde (2019) involved an incubator with a capacity of 480 eggs using DC power supply, which operates through GSM technology with the use of PIC18F4550 microcontroller. Okonkwo & Chukwuezie (2012) built.

Okpagu & Nwosu (2016) carried out research and design for the development and temperature control of the intelligent incubator for different types of eggs, using AT89C52 microcontroller. Raja M. *et al*. (2019) designed an automated forced-air incubator based on Arduino Uno, controlling temperature by a bulk lamp and humidity by a mist spray, with the rotation of eggs every three hours. Olatayo *et al*. (2018) used DHT11 sensor for monitoring the environment of the poultry farm but without the automation of temperature and humidity range.

Sensor Technology Advances

The evolution of sensors has led to the creation of very precise measuring instruments. Thermocouples and resistance temperature detector (RTD) sensors are used in the process of measuring temperature while capacitance and resistive sensors are used for measuring humidity (Cocci *et al*., 2019). The development of wireless sensor networks for remote monitoring is another advancement in this field (Wang *et al*., 2016). Currently, the researchers have concentrated more on sensor evaluation for use in

the Internet of Things (IoT) applications where the research has shown that DHT22 sensors give accurate readings within 0.1°C but with a lower response time compared to thermocouple sensors. Recent research has made use of SHT31 sensors for measuring temperature and humidity in IoT-based incubators.

The availability of commercial incubators does not solve the problem as their cost (which is more than ₦500,000) renders them unaffordable for rural farmers in Nigeria. Available literature highlights mostly those designs which are either too expensive or very large-scale in their scope, while the latest achievements in the IoT and smart control technologies are still beyond the capabilities of small-scale farmers in underdeveloped countries. For example, the use of Internet of Things technology for remote monitoring and controlling of poultry breeding in Nugraha *et al*., (2024), Cabajes *et al*., (2024), and Widodo *et al*. (2026) requires the stable connection to the Internet and significant investment. In its turn, Okusanya *et al*., (2026) highlight the fact that some locally made incubators in Nigeria cannot provide stable temperature, humidity level, and the appropriate egg turning frequency resulting in poor hatchability and increased embryo death rate. The development of affordable locally produced incubator that would achieve comparable hatchability results to the commercial one is needed. The current study aims at the development of microcontroller-based incubator costing only ₦22,275 that achieves 86.7% hatchability rate.

3. METHODOLOGY

Here, the design and methodology adopted in developing the automatic egg incubator system is discussed. It includes the architecture of the system, its hardware design, software development, components used, and testing methodology. The automatic egg incubator system was designed to control temperature, humidity, and egg rotation for maximum hatchability.

3.1 System Architecture

The system architecture consists of the following functional blocks:

Power Supply Unit

Microcontroller Unit (ATmega328P)

Sensing Unit (DHT11)

User Interface (LCD + push buttons)

Actuator Control (relays, motor driver)

Mechanical Assembly (incubator housing, egg trays, turning mechanism)

Figure 1: Block Diagram of the System

In Figure 1 above, the microcontroller coordinates the entire system. The switches and the liquid crystal display (LCD) serve as a human interface to the system. The switches are for selecting the type of egg to be hatched and OK to start the incubation process, while the LCD serves three purposes: on-screen guidance to the user and also to display the temperature and humidity. The humidity and temperature sensor (DHT11) feeds the microcontroller back with the actual temperature and humidity. The microcontroller compares the actual temperature and humidity with the desired ones entered by the user to determine whether to turn ON the bulbs and water heater or not. The stepper DC motor receives a signal from the microcontroller through the motor driver to turn the eggs at the desired time. The four (4) actuators translate the control signal from the microcontroller to meet the requirement for the control of the bulbs for temperature, water heater for humidity, exhaust fan for ventilation within the incubator, and circulation fan for equal temperature distribution within the incubator. The entire system is powered by the necessary power supplies.

3.2 Hardware Design

Power Supply Section: In the power supply section, there is a transformation from AC to DC where 230 V AC becomes 12 V DC and 5 V DC through the use of a transformer, rectifier, filter capacitors and voltage regulator (LM7805, 7812). There is a 2N3055 transistor used in common base configuration to give current gain of 3 A.



Figure 2: Block diagram of regulated power supply of the system

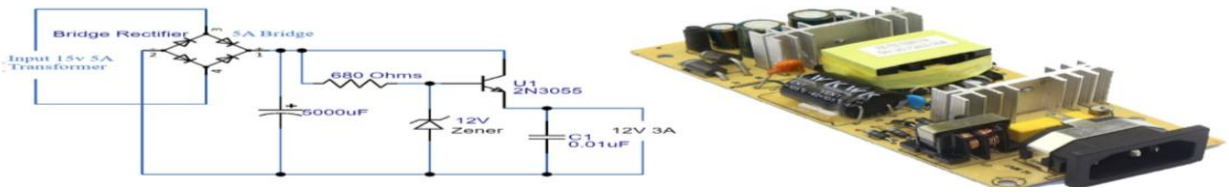


Figure 3: Schematic diagram of power supply

The above circuit is capable of providing a DC voltage source of 12 volts with a maximum current of 3 A. The power supply circuit uses a 12V Zener diode as a voltage regulator. A Zener diode voltage regulator alone cannot provide a large current source because of the power limit of the Zener diode. So, a 2N3055 current-amplifying transistor in a Common-base configuration is used.

On providing an AC input from a 230V/15V 5A non-CT transformer, the step-down AC signal passes through a bridge rectifier, which translates the AC signal into a rippling DC. After which, the signal passes through a smoothing capacitor C1 (5000µF) to remove any undesirable noise. The signal then passes through a voltage regulator section using a 12V Zener diode. Here we have a 680Ω resistor used as a current limiting voltage source. In combination, they provide a regulated 12V DC at a relatively low current. Signal passes through a current amplifier (2N3055) in a common-base configuration to boost the current to 3A DC, with the base reference voltage acting through a Zener diode voltage regulator. The DC signal then passes through capacitor C2 to remove any residual noise before going on toward the output.

Microcontroller Circuit: ATmega328P microcontroller operates with a 16 MHz crystal oscillator. Port assignments:

Port A → solid-state relays for bulbs/heater/fan control

Port D → push-button inputs for user interaction

Port B → LCD interfacing

Port C0-C3 → motor control signals

Port C6 → DHT11 sensor interface

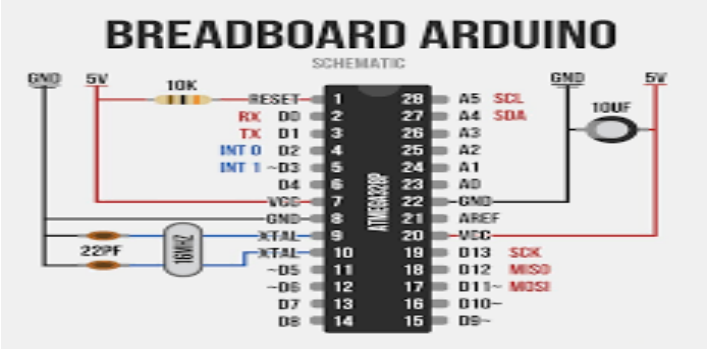
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Figure 4: An ATMEGA328 microcontroller schematic diagram

The microcontroller used in this work is ATMEGA328. ATmega328 is a group of microcontrollers which operate on the Harvard architecture. This microcontroller has 28 pins and 4 ports as depicted in Figure 4. Port A of this microcontroller has been connected to 4 solid-state relays for switching of bulbs of water heater, exhaust and circulation fans. Switches have been connected to port D while port B was used for LCD interfacing. C0, C1, C2 and C3 control the motor. Humidity & temperature sensor (DHT11) has been connected to port C6.

Interfacing of Sensors: The DHT11 sensor generates serial digital output from a single data line. The process includes the sending of start pulses by the microcontroller, while the sensor generates a 40 bit data packet which includes the values of temperature and humidity.

The DHT11 sensor is a single-line digital humidity and temperature sensor, which gives values of temperature and humidity serially. This sensor measures humidity in percentage (20%RH to 90%RH) and temperature in degree Celsius (0 °C - 50 °C). The DHT11 sensor has 4 pins out of which 2 pins are for power supply, 1 pin is not in use, and the last pin is used for data transfer. The pulses of different TON and TOFF are decoded into either 1 or 0 logic value or start pulse or end of the frame.

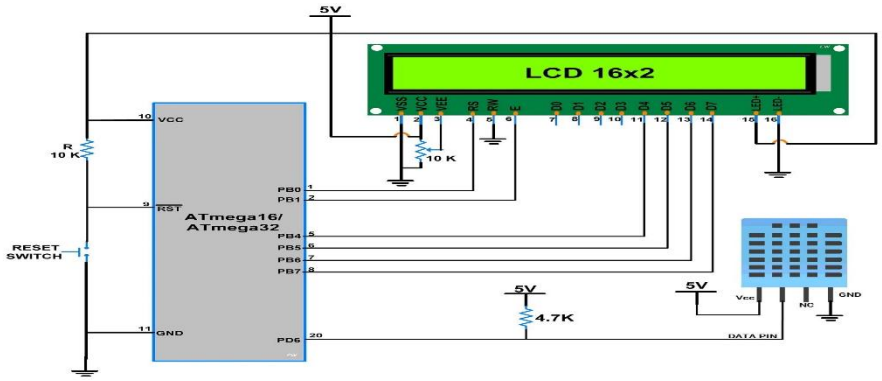


Figure 5 Interfacing DHT11 Sensor with AVR ATmega328

Motor Control: A 12 V DC gear motor drives the egg-turning mechanism through an L293D H-bridge motor driver. The motor rotates the egg tray at 45° angles on each side of horizontal at programmed intervals (every 4-8 hours). The algorithm performs a bi-directional rotation to emulate natural turning patterns.

3.3 Software Development: The embedded software was developed using the Arduino IDE in C++. The program follows the standard setup() and loop() structure.

Algorithm:

1. Initialize LCD and system parameters.
2. Read temperature and humidity from the DHT11 sensor.
3. Compare readings with setpoints.
4. Activate/deactivate heating, humidification, and ventilation as needed.
5. Manage automatic egg-turning schedule.
6. Display real-time readings on LCD.
7. Repeat continuously.



Figure 6 Arduino IDE Setup

The ATMEGA328P Development Board can be easily programmed with Arduino IDE since it has easy access. Programming the ATMEGA328 with the Arduino IDE may take 5-10 minutes, depending on the task that is to be performed. All you need is the Arduino IDE, a USB cable, and the ATMEGA328board. Huge documentation and support, Large library collection, Open source software, Easily portable, Less power consumption, Highly customizable. Home Automations, ISP Programming, Entry-level circuit design

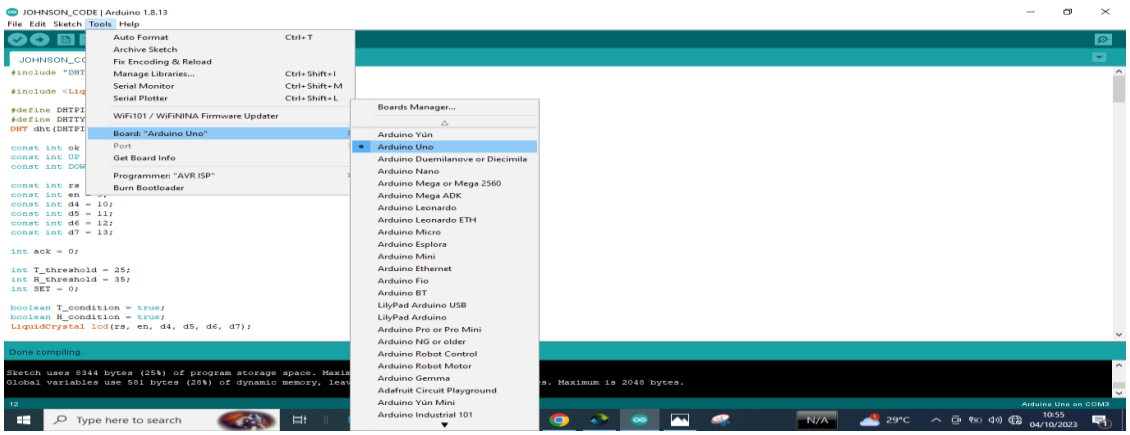


Figure 7: Programming Arduino IDE with ATMEGA328P

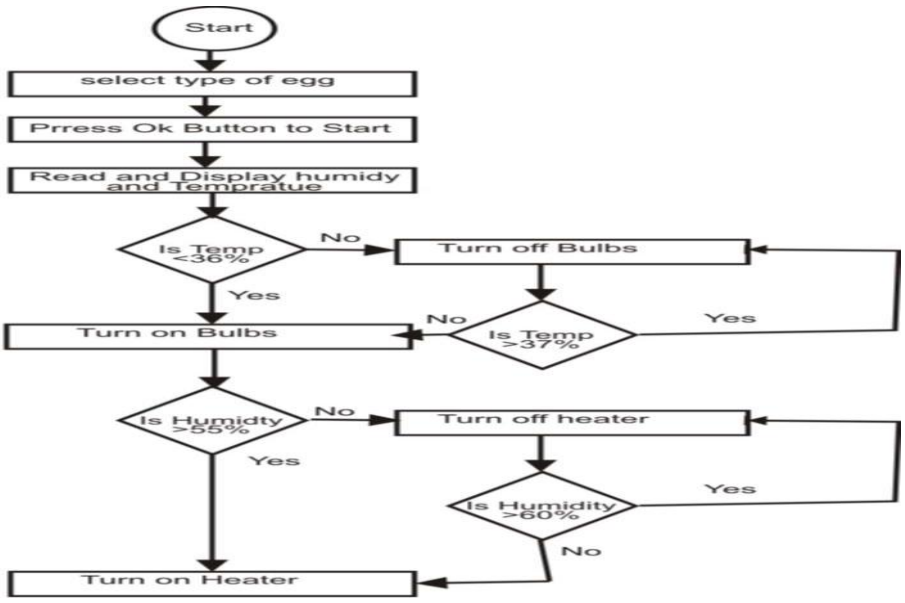


Figure 8: Flowchart of the program

Circuit Diagram

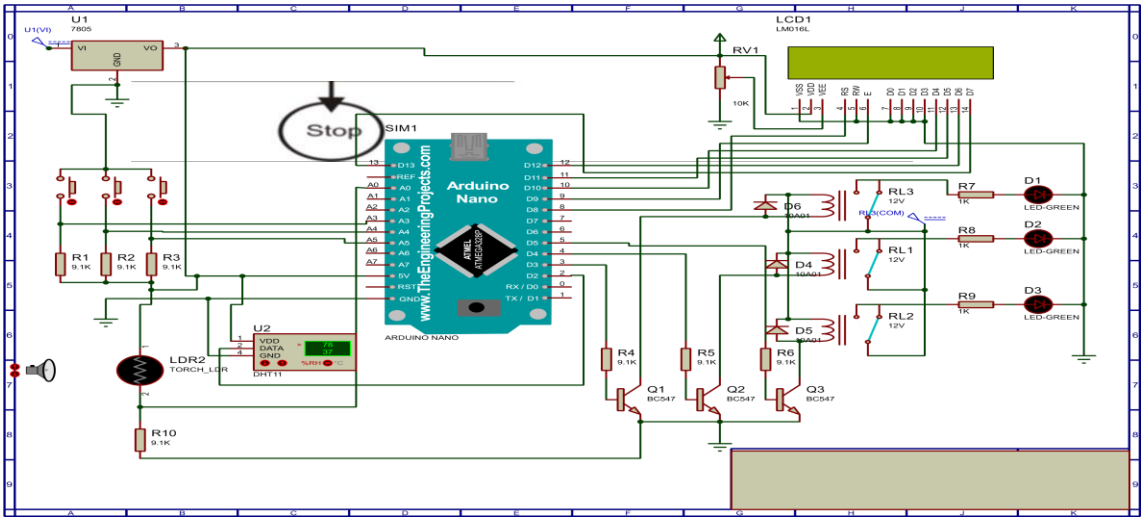


Figure 9: Circuit diagram of Egg Incubator System.

List of Components and Cost Evaluation

Table 4.1 itemizes the components of the project with their respective cost.

S/N	Component	Quantity	Unit Price (#)	Amount (#)
1	On/Off Switch	1	300	300
2	Diode In4007	5	20	100
3	470uf/35v Capacitor	2	300	600

4	L7805 Voltage Regulator	1	450	645
5	1k Ohm	3	20	60
6	9.1k Ohm	6	20	120
7	10k Variable Resistor	1	100	100
8	Vent Fan	1	2000	2000
9	Amega328p Microcontroller	1	6500	6500
10	28pins Ic Socket	1	300	300
11	16mhz Crystal Oscilator	1	200	200
12	12v Relay	1	300	300
13	22pf Capacitor	2	50	100
14	Bc547	1	150	150
15	Led	3	100	300
16	Push Switch	3	50	150
17	LCD 1602 Display	1	2500	2500
18	DHT11 Temperature & Humidity Sensor	1	1800	1800
19	Plastic		2000	2000
20	Vero Board	1	350	350
21	Construction Wires		350	350
22	Ldr	1	300	300
23	Solder Lead		2500	2500
24	Light Bulb	3	100	300
			Total Amount	22,275

Construction Procedure and Assembly

An egg incubator system capable of hatching 100 eggs will be fabricated using available local materials. The materials will be produced on line and from Mubi main market of Adamawa State, Nigeria.

The decision to fabricate an egg incubator system was reached because the world population is growing at an alarming rate, and so is the high demand for protein, especially in rural areas, and also due to wide consultation with various Aluminum/wood fabrication personnel on the best economic way to buy materials from the market.

Since most of the materials are sold at standard dimensions. This results in significant loss of

resources. Each of the components will be fabricated to fit into one another. Most joints will be riveted permanently using a welding machine and screw machine, except for some members, which may necessitate opening. This will be carried out in the Computer Engineering Department, Civil Engineering Department, and Mechanical Engineering Department of the Federal Polytechnic Mubi. It is important to note that fabrication and assembly procedures can also be sourced outside the Polytechnic premises if the workload in the aforementioned department is at peak due to unforeseen circumstances.

3.4 Mechanical Design

The incubator housing was fabricated using wooden sheets (1530 mm × 1070 mm × 760 mm) with a glass observation door. The egg tray (1000 mm × 700 mm) accommodates up to 60 eggs. A 12 V DC motor drives the tray through a steel pipe mechanism, enabling rotary motion at 45° and 90° angles. A humidifying basin (970 mm × 700 mm × 80 mm) provides moisture for humidity control.

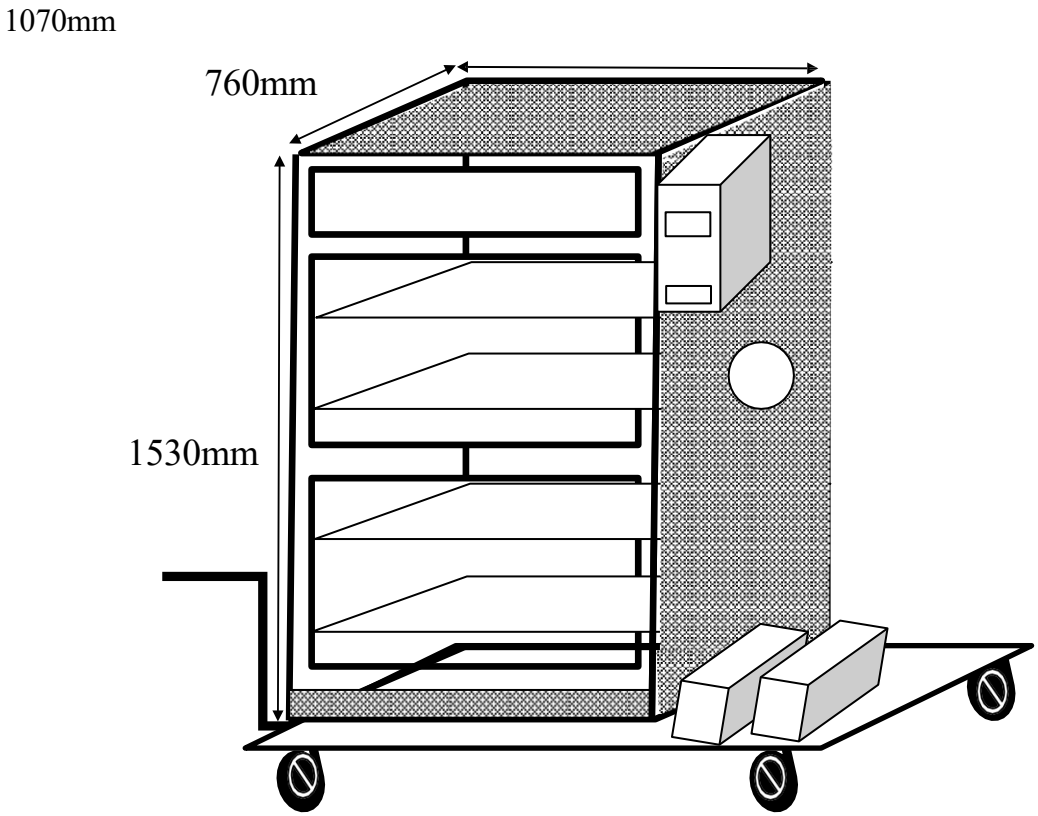


Figure 10: Isometric View of the Incubator Housing

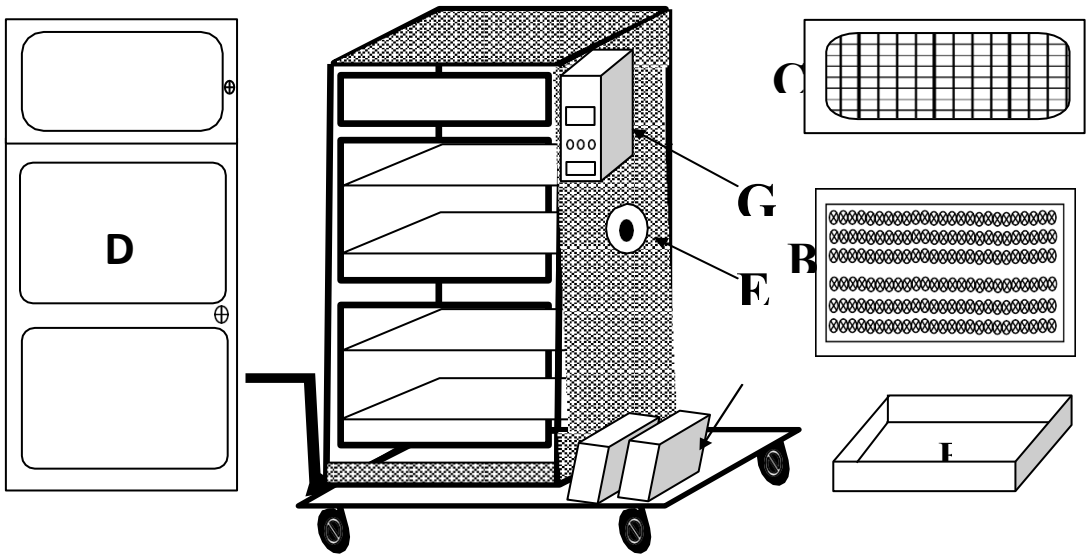


Figure 11: Assembly Drawing of the Incubator

Details of Component

1. Incubator House: 1530 mm × 1070 mm × 760 mm wooden sheet. The incubator house to hold eggs needed to be hatched. 200 mm from the floor level for convenience.

2. Egg Tray: 1000 mm × 700 mm gauge egg tray to hold the eggs needed to be hatched. It is inside the incubator house, driven by a 12V DC motor with the aid of a steel pipe in a rotary motion to and from of 45° and 90°, respectively. Each egg tray can hold 150 eggs.

3. Egg Hatchery: 1040 mm × 730 mm gauge egg hatchery tray made of plywood and rubber net to hold eggs during the incubation period, and the chicks are unable to break the shell of the egg.

4. Glass Door: Two doors: 900 mm × 200 mm for the hatchery and 1200 mm × 900 mm for the incubator house cover. It is made of wood and transparent glass for monitoring egg turning.

5. DC Motor: 1100 mm connection wire, 200 mm motor body. 12V DC motor for egg tray rotation.

6. Humidifying Basin: 970 mm × 700 mm × 80 mm aluminum sheet gauge to form a humidify basin that contains water that provides moisture needed for the egg during incubation.

7. System Controller: 300 mm × 200 mm × 130 mm wooden sheet gauge to contain the circuit that controls the entire system and its peripherals.

Incubator Housing: Wooden sheet of 1530mm x 1070 mm x 760mm for incubator house that would contain eggs which would hatch. 200mm above floor level for easy access.

The components were mounted on Vero board and soldered according to the circuit diagram. The control unit was placed inside a plastic casing (300mm x 200 mm x 130 mm). The body of incubator was constructed using rivets and screws. Testing of the system was done by soldering iron.

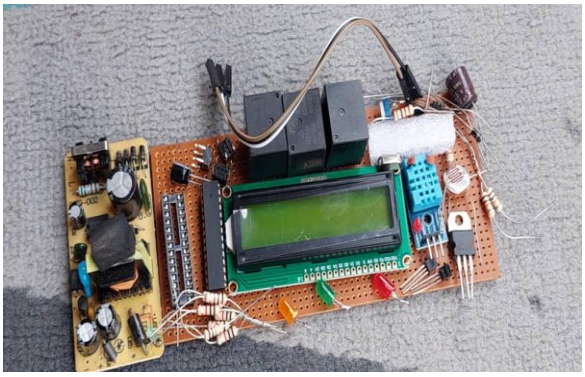


Figure 12: Components before Mounting on Vero

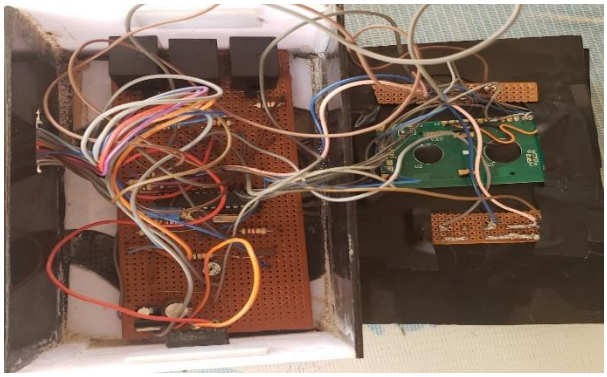


Figure 13: Soldered Components on Vero Board

3.4.7 Casing/Packaging

The casing of the system is necessary to protect the system and beautify it. In this project, a plastic casing was used as shown in the figure below. The materials used for the casing are superglue, 4-minute epoxy steel gum, masking tape, and plastic.





Figure 14: Final Casing/Enclosure of the Control System

3.4.8 Testing

Testing the system on the device, where all components are connected properly and have been ordered inside the microcontroller. The testing of the system circuit of this tool was carried out using a soldering iron as a source of heat generation, which would be detected by the DHT11 sensor. On the market, there are two types of DHT11 sensors that are generally already in the form of modules, namely DHT11 with 3 pins and 4 pins. How to identify the pins: face the US; the leftmost pin is the first pin. Figure 4.4 is a physical display of the DHT11 sensor used in the temperature and humidity control system. The DHT11 sensor has the advantage of detecting temperature; the DHT11 sensor can also detect humidity, as shown in Figure 4.4.

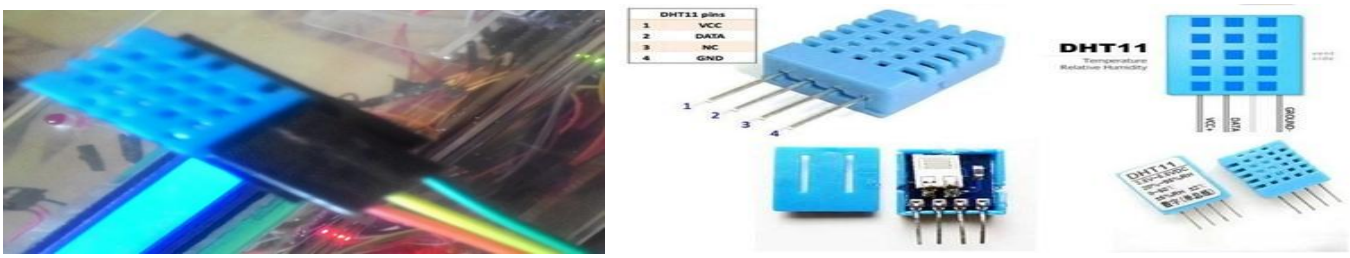


Figure 15: DHT11 Sensor Physical Appearance



Figure 16: Functional Test Setup

4. RESULTS AND DISCUSSION

Table 4.2 Results obtained from testing the system

Timer (minutes)	Setpoint (temperature)	Humidity set point %	LCD temp. heating	LCD humidity heating	Temperature heating element	Air circulation fan	Humidity heater
0.00	37^0c	60	30.2	48	ON	ON	ON
1.00	37^0c	60	30.9	48	ON	ON	ON
2.00	37^0c	60	31.6	48	ON	ON	ON
3.00	37^0c	60	32.1	48	ON	ON	ON
4.00	37^0c	60	32.8	49	ON	ON	ON
5.00	37^0c	60	33.5	49	ON	ON	ON
6.00	37^0c	60	34.2	49	ON	ON	ON
7.00	37^0c	60	35.0	49	ON	ON	ON
8.00	37^0c	60	35.8	49	ON	ON	ON
9.00	37^0c	60	36.6	49	ON	ON	ON
10.00	37^0c	60	37.0	50	OFF	OFF	ON

11.00	37^0c	60	37.0	52	OFF	OFF	ON
12.00	37^0c	60	37.0	54	OFF	OFF	ON
13.00	37^0c	60	36.9	57	ON	ON	ON
14.00	37^0c	60	37.0	60	OFF	OFF	OFF

From Table 4.2 above, the results show that when the temperature and humidity are set at 37^0c and 60%, respectively, with the initial readings of the incubating chamber at 30.2^0c and 48% for the temperature and humidity, respectively. The temperature and humidity heating system and also the air circulating fan were switched ON. It took 10 minutes for the temperature to rise to the set temperature of 37^0c thus, the temperature heating element switched OFF. The temperature of the system was observed to drop below the set point (37^0c) 3 minutes after attaining the point, and consequently, the heating element switched back ON to raise and keep the temperature at 37^0c.

The humidity, on the other hand, was observed to reach the set point (60%) after 14 minutes of switching ON the system, and the humidifier heater went OFF.

4.2 Hatchability Results

The automatic egg incubator system was tested with 60 fertilized eggs over a 21-day incubation period. Table 1 summarises the results.

Table 1: Incubation Results (Hatchability)

Parameter	Value
Number of eggs set	60
Number hatched	52
Hatchability rate	86.7 %
Average temperature	37.2 °C
Average humidity	58 %
Turning frequency	Every 6 hours
Chick health	Normal

The hatchability rate of 86.7 % significantly exceeds the 60-70 % typically achieved with manual incubation methods. The automated system eliminated human error in turning and maintained consistent environmental conditions throughout the incubation period.

4.3 Performance Analysis

Temperature: The temperature range for the set-up was between 37 and 38 °C with an error limit of ±0.5 °C. Hysteresis of 0.5 °C was used in order to reduce relay switches that could have increased the life span of the components.

Humidity: The range of the humidity for the first 18 days was between 55 and 62%. In the last three days of incubation, the range was between 68-72%. The humidification system operated well in order to achieve ideal humidity levels.

Turning: The egg turner worked well in each 6 h to turn the eggs 45 °C each side. The motor worked without any failure.

5. Conclusion

An egg incubation system that is automatic using the microcontroller has been developed and tested. The system regulates temperature, humidity, and egg turning through an ATmega328P microcontroller using feedback from DHT11 sensor. Tests showed accuracy of temperature regulation at ±0.5°C from the set temperature, relative humidity regulation between 50%-65% increasing to 70% during hatching process, and automated egg turning of 45 degrees every six hours.

The efficiency of the system was seen in the hatchability of 86.7%, which was above the manual techniques of 62.3%. With the total cost of components being ₦22,275, the system is labour-saving and does not allow any errors due to humans. Incubation of eggs at the same temperature is necessary for maximizing egg production.

6. Recommendations

From the results of this research, it is advisable that the automatic egg incubator should be scaled up to cater to 100–500 eggs with the use of industrial materials and maintaining temperature control of ±0.5°C, relative humidity of 50–65% (70% during the hatching period), automatic turning of eggs by 45° angles every 6 hours, along with IoT technology for remote monitoring through phone applications, solar energy-based battery backup in order to guarantee non-stop operations even in cases where there is an unstable source of electricity from the grid, and finally the development of software profiles for various species of birds (chickens, turkeys, ducks, quails) with the help of automatic parameter adjustment.

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