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Development of a Microcontroller Based Automated Regulating System for Efficient Management of Poultry Operation

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***Abstract*—In recent times, there has been a huge demand for protein sources in a developing country such as Nigeria due to its rapidly increasing population. Poultry, from which varieties of protein sources can be derived, offers one of the major solutions to this problem. Therefore, the need for poultry farmers to put in place measures to ensure a well-controlled and conducive environment to rear birds for maximum production and efficiency arises. This work designed and developed a microcontroller-based automated regulating system to manage poultry operations effectively. The major components employed in developing the embedded system include DHT 11 sensor, Arduino UNO microcontroller with ATMEGA 328P IC chip, MQ 135 sensor, float switch, Infrared (IR) proximity sensor, buzzer, lighting (DC) bulb, 60 W AC bulb, and exhaust fans. Using relevant design models and equations, circuit designs were implemented around the Arduino UNO microcontroller, the main element of the system's control unit. A performance test was conducted on the developed system. The test results revealed that all the embedded system's key units, including power supply, lighting, sensing, display, water, and feed level control units, were fully functional, and the overall system performance was satisfactory. Apart from being suitable and efficient for small-scale farmers to rear poultry birds, the developed automated poultry regulating system could be extended to train agricultural students on the basic rudiments such as feed, water, and environmental conditions requirements in poultry bird rearing.**

***Keywords*— Bird; Nigeria; poultry farmer; poultry operation; protein source.**

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I. INTRODUCTION

The increasing global population has undoubtedly placed an enormous demand on food supply [1]–[6]. In most developing nations like Nigeria, the demand for food supply has sky-rocketed, leaving the agriculture sector with challenges of devising better and more efficient ways of mass-producing crops and livestock for human and animal consumption [7].

In the modern era of technological advancement, industrial automation has infiltrated all facets of human endeavors, including the agricultural sector, making production processes much faster and more efficient [8]–[10]. Poultry farming is one field of agriculture today where industrial automation is gaining widespread popularity and more research attention [11]. Poultry farming entails domesticating birds to extract their end-products such as meats, eggs, and others [12]–[14]. In this context, birds include guinea fowl, chicken, quail, pigeons, turkeys, ducks, geese, swans, and ostriches. Birds reared for meat and egg production are called broilers and layers, respectively [15], [16], while some are reared for dual purposes [17]. Nigeria's two major poultry production systems include commercial and subsistence or small-scale systems. In the commercial system, farmers rear poultry birds solely for profit, whereas in the subsistence system, farmers rear poultry birds for consumption and profit-making.

Poultry birds can be reared using various housing systems, including free-range and intensive schemes [18]. A free-range system entails free-roaming poultry birds around an environment, allowing them to search for food [19], [20]. On the other hand, an intensive system involves the confinement poultry birds in a house or cage throughout their rearing. There are two types of intensive systems: battery-cage and deep litter-intensive. The battery-cage intensive system involves rearing poultry birds in a cage that comprises bars in a row and column fashion, cascaded to one another with divider walls [21]. This system is generally used for layers. In the deep litter system, poultry birds are reared on a floor covered with particular types of material called bedding or litter materials in order for the birds to avoid contact with the bare floor surface [22]. This system is recommended for broilers because of their uneven body proportion (chest-to-feet ratio) caused due to their increasing weight, which will cause damage to their feet if they are in direct contact with bare floor surfaces [23].

Environmental conditions in each poultry housing system described above play a crucial role in the birds' digestive, respiratory, and behavioral changes [24], [25]. With proper atmospheric and feeding conditions, the birds can grow to their full potential and attain their expected price value in good health. Therefore, the need for a system that can assist in regulating various environmental conditions such as humidity and temperature in addition to ammonia, water, and feed levels is evident for efficient and maximum poultry production.

According to the literature, several studies have been conducted to design and develop an efficient automated poultry management system using different technologies. Zheng *et al.* [26] designed and implemented a poultry farming information management system based on a cloud database. Astill *et al.* [27] developed a smart poultry management system using smart sensors, big data, and the Internet of Things (IoT). Debauche *et al.* [28] presented the real-time monitoring of poultry using edge computing and artificial intelligence. Balachandar and Chinnaiyan [29] worked on an IoT-based real-time disease monitoring of poultry farming imagery analytics. Pereira *et al.* [30] developed an internet of thing based instrument for a poultry farm's environmental monitoring. Ayyappan *et al.* [31] designed and developed an IoT-based smart poultry farm. Choukidar and Dawande [32] developed a microcontroller-based poultry control system to effectively monitor important parameters such as water and ammonia levels, humidity and temperature. Gunawan *et al.* [33] developed a smart poultry farming using RTOS on Arduino. Thomas *et al.* [34] presented a microcontroller-based automated poultry parameter monitoring system with a conveyor mechanism.

The literature shows that the combined monitoring of poultry environmental conditions, feed, ammonia, and water levels seems unexplored. Thus, this work designed and implemented a microcontroller-based automated regulating system capable of monitoring basic poultry parameters such as temperature, humidity, ammonia, as well as feed and water levels for effective poultry production.

II. Materials and Method

A. System Overview

Fig. 1 shows the generalized block diagram of the automated poultry regulating system developed in this work. The embedded system comprises six major units: the system control unit, sensing unit, lighting unit, power supply unit, water and feed level control unit, and display unit. Arduino UNO microcontroller with ATMEGA 328P chip is the brain of the entire system, and it is responsible for decision-making and controls the activities of all other subunits. The power supply unit delivers the DC power to drive the microcontroller. This unit contains a 12 V lead-acid battery charged with the AC mains supply via an AC/DC power adapter. The sensing unit obtains the parameters such as humidity, temperature, and ammonia level from the poultry chamber and regulates these values within acceptable limits to create a more conducive environment required for efficient poultry production. The unit comprises a DHT 11 sensor for sensing temperature and humidity and MQ 135 sensor for sensing ambient ammonia levels in the poultry chamber.

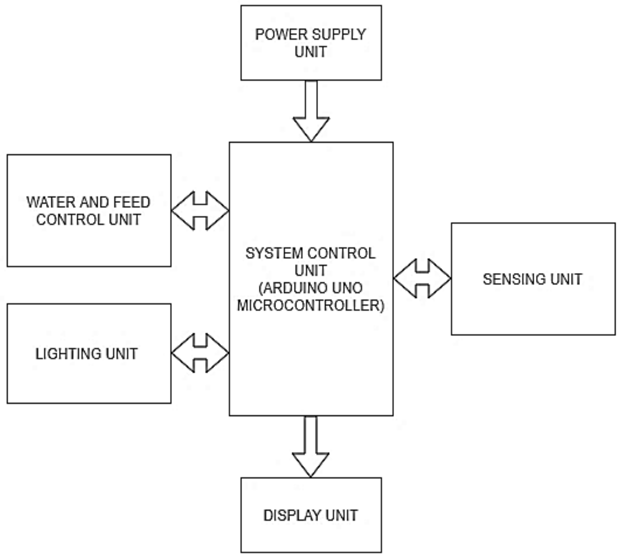

Fig. 1 Block diagram of an automated poultry regulating system

The water and feed level control unit consists of two distinct units: the water level control unit and the feed level control unit. While the water level control unit regulates the volume of water delivered to the poultry chamber from the water tank, the feed level control unit regulates the amount of feed delivered from the feed container. The water level control unit uses a float switch as its water level indicator, whereas the feed level control unit uses an infrared proximity sensor as its feed level sensor.

The lighting unit illuminates the poultry chamber at night or whenever darkness arises from conditions such as rain. It consists of a 5 V DC bulb powered by the 5 V DC output from the Arduino UNO microcontroller and a proximity sensor that detects when the door of the poultry chamber is opened and signals the control unit for further action. A Light-Dependent Resistor (LDR) monitors the light intensity of the chamber's surroundings. A LED indicator will be turned off in the presence of sunlight and turned on in the absence of sunlight.

The display unit is responsible for displaying vital information such as humidity, temperature, as well as ammonia, water, and feed levels in the poultry chamber. It consists of a 12 by 8 I2C LCD module which displays the content, a buzzer, and a LED bulb to alert the farmer when water and feed levels drop below the pre-set range.

B. Design of the Power Supply Unit

Fig. 2 shows the circuit diagram of the power supply unit.

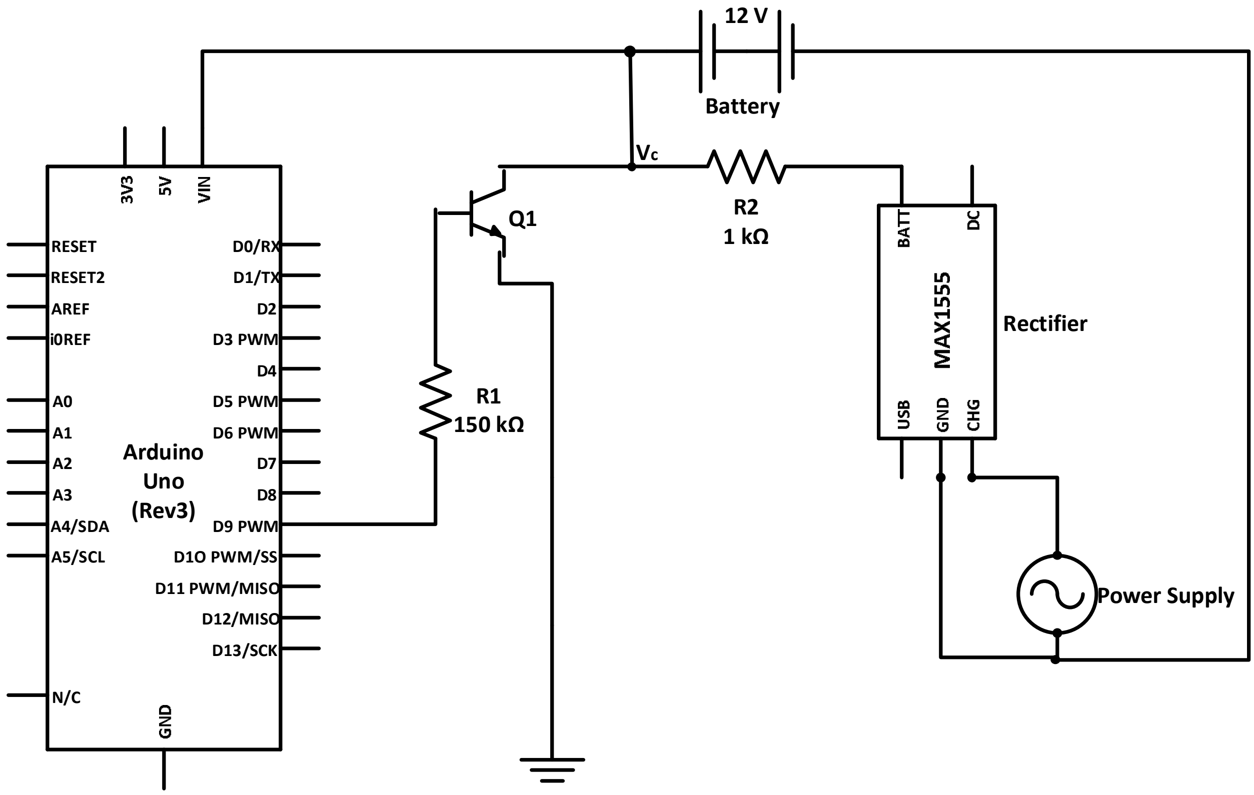

Fig. 2 Circuit diagram of the power supply unit

The battery chosen for this unit was a 12 V rechargeable sealed lead-acid battery with an amperage rating of 5 Ah. The time t in hours required to charge the battery with a 12 V/2 A power AC/DC adaptor considered was calculated using Eqs. 1 to 3 [26]:

$$\mathrm{I} = \frac{\mathrm{P}}{\mathrm{V}} \tag{1}$$

$$\mathrm{A_r} = \mathrm{It} \tag{2}$$

$$\mathrm{t} = \frac{\mathrm{A_r V}}{\mathrm{P}} \tag{3}$$

Using P, V and A_r as 60 W, 12 V, and 5 Ah respectively, t was calculated as 1 h. This implies that a wholly discharged battery would take an average of 1 h, to charge fully. A battery level monitor was also provided for the charging circuit. The base resistor R_1 and collector resistance R_2 of the transistor $Q1$ required for the battery level monitor were determined using Eqs. 4 to 6 [35]:

$$R_2 = \frac{V_{cc}}{I_{c(sat)}} \tag{4}$$

$$I_b = \frac{I_{c(sat)}}{\beta_1} \tag{5}$$

$$R_1 = \frac{V_{in} - V_{be}}{I_b} = \frac{\beta_1 (V_{in} - V_{be})}{I_{c(sat)}} \tag{6}$$

Using V_{cc} and $I_{c(sat)}$ as 12 V and 12 mA respectively, R_2 was estimated from eq. 4 as 1 kΩ. With β_1 as 250, I_b was evaluated as 48 µA from eq. 5. However, to ensure the transistor $Q1$ was well into saturation, I_b was considered as 60 µA, and this was used to determine the value of R_1 in eq. 6 as 155 kΩ with V_{in} and V_{be} respectively given as 12 and 0.7 V. Considering R_1 as 150 kΩ, eq. 6 was again used to evaluate I_b as 75.34 µA which is higher than the original computed 48 µA. Hence, R_1 was used as 150 kΩ in the circuit of Fig. 2.

C. Design of the Lighting Unit

Fig. 3 shows the circuit diagram of the smart lighting circuit for the poultry chamber. The output voltage, V_{out}, driving the analog to digital converter (ADC) section and the size of resistor R_5 for the circuit of Fig. 3 were determined using Eqs. 7 to 11.

$$V_{out} = \frac{V_{in} R_3}{R_3 + R_4} \tag{7}$$

$$\beta_2 = \frac{I_c}{I_b} \tag{8}$$

$$R_5 = \frac{V_{in}}{I_b} \tag{9}$$

$$R_5 = \frac{\beta_2 V_{in}}{I_c} \tag{10}$$

$$I_R = \frac{V}{R} \tag{11}$$

With the values of V_{in}, R_3, and R_4, considered as 5 V, 10, and 10 kΩ respectively, V_{out} was determined as 2.5 V. More so, using the transistor with β_2 of 75 at the rated I_c of 30 mA (All Transistors, 2021), R_5 was calculated as 12.5 kΩ. However, R_5 was used as 10 kΩ due to the peculiarity of the circuit of Figure 3. For the 5 V relay, the current I_R using R and V as 400 Ω and 12 V respectively was 30 mA. This is the same as I_c, which is too high for the Arduino that can only handle up to 20 mA. Therefore, a transistor was used to protect it.

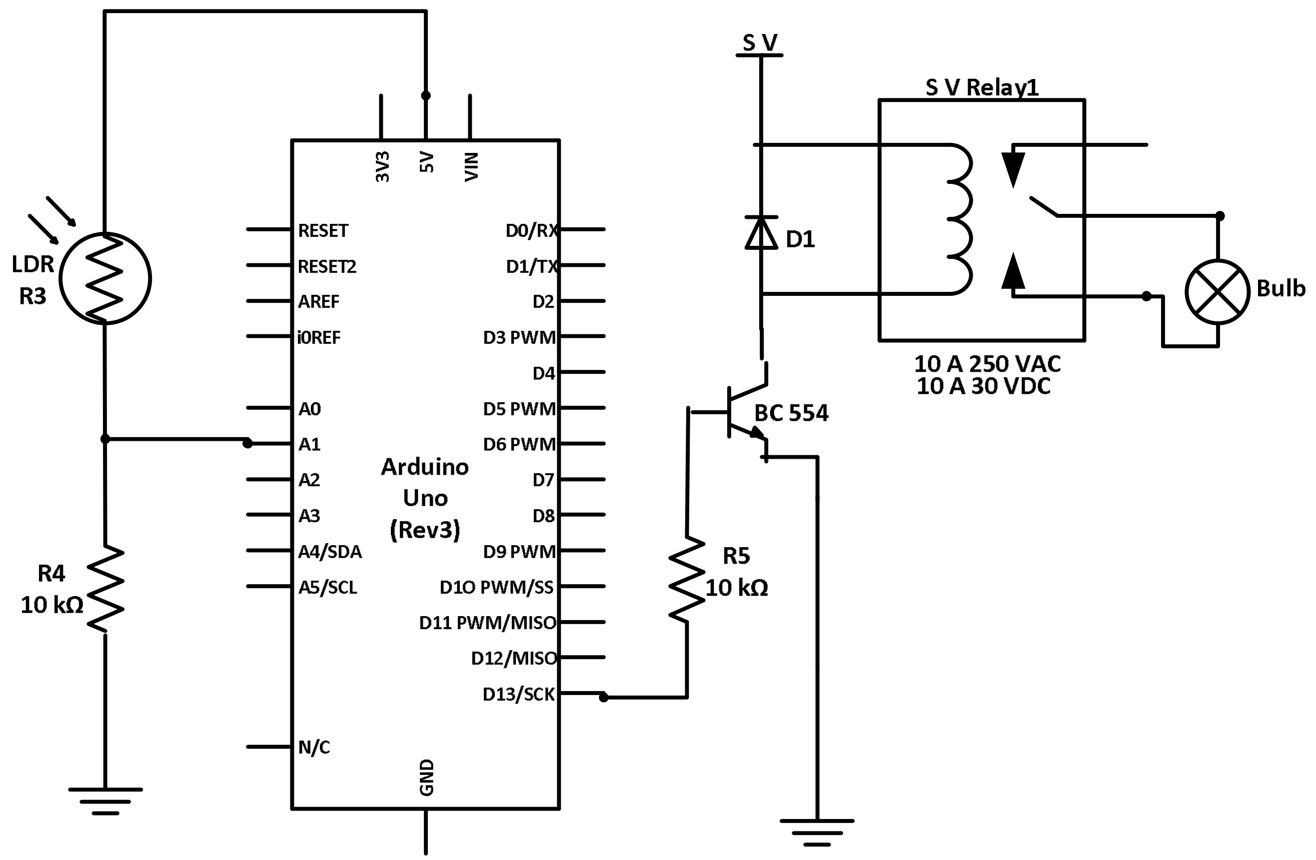

Fig. 3 Circuit diagram of the smart lighting unit

D. Design of Sensing Unit

The sensing unit is an important part of the developed system. The circuit was designed such that the sensors that read the essential parameters such as humidity, temperature, and ammonia level, among others, act as the input, and devices such as exhaust fans and heating bulb act as the output.

TABLE I
RECOMMENDED TEMPERATURE AND HUMIDITY RANGES FOR BROILERS [36]

Age	Recommended standard Temperature range for broilers (℃)	Humidity Range (%)
1st day	32-34	50-70
1st week	30-34	50-70
2nd week	26-34	50-70
3rd week	22-34	50-70
4th week	20-34	50-70

When the parameters read by the sensors are within the recommended range given in Table 1, none of the output devices are turned on, and when they are out of the recommended range, their respective outputs are activated.

According to Ezema *et al.* [36] and Idowu [37], relative humidity below 30% could lead to high agitation of the chicks and may consequently cause aggressive behavior. Excessive moisture can result in wet litter conditions coupled with high ammonia concentrations, poor air quality, diseases, and respiratory problems. Therefore, relative humidity between 50 and 70 % is recommended as ideal for chicks [36], [37]. In many countries, the recommended threshold range for the ammonia level is between 20 and 25 ppm [33], [38], [39]. However, due to colder weather, such as the winter period in some practical cases, the concentration of ammonia in broiler houses may easily exceed 30 to 70 ppm. Fig. 4 is the designed sensing circuit for the developed system.

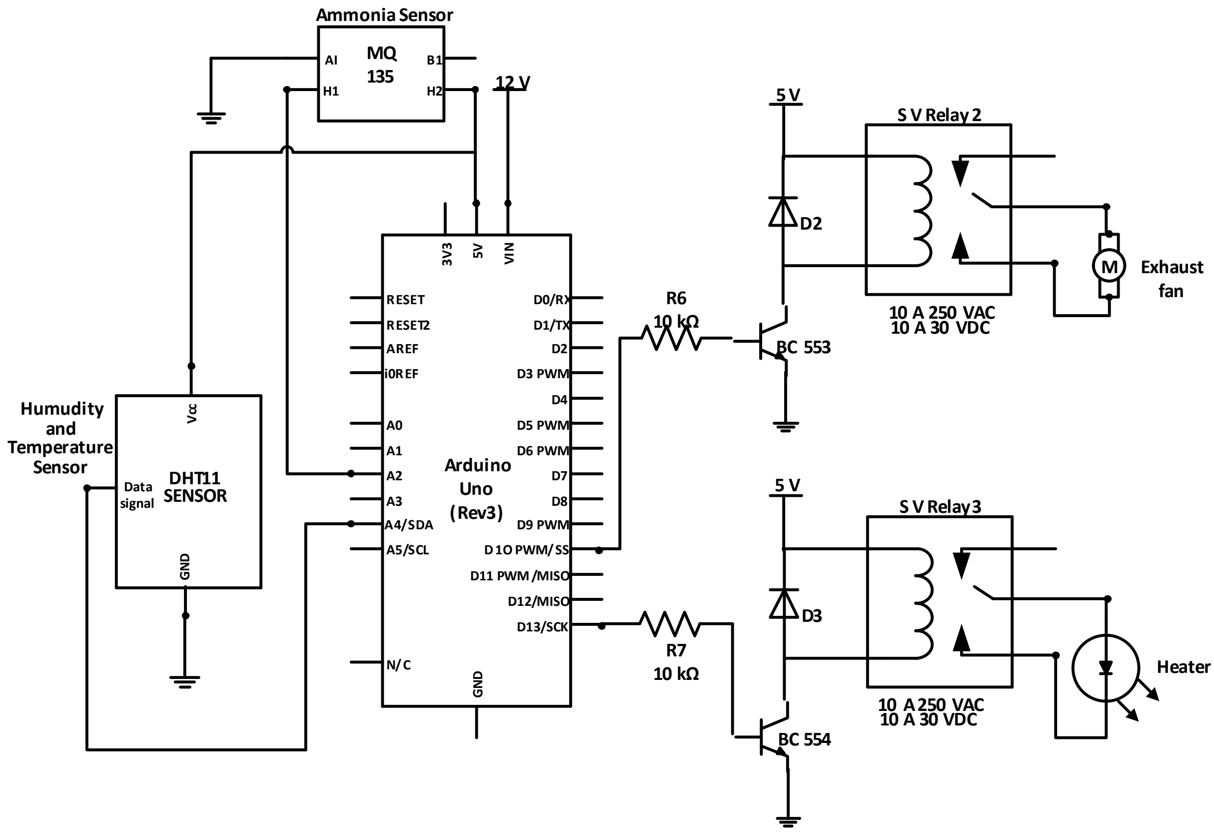

Fig. 4 Circuit diagram of the sensing unit

The resistors R_6 and $R_{7,}$ transistors BC553 and BC554, and relays 2 and 3 in Fig. 4 were configured using the same procedures employed for the lighting circuit. The flowchart describing the sensing unit's operation sequence is presented in Fig. 5.

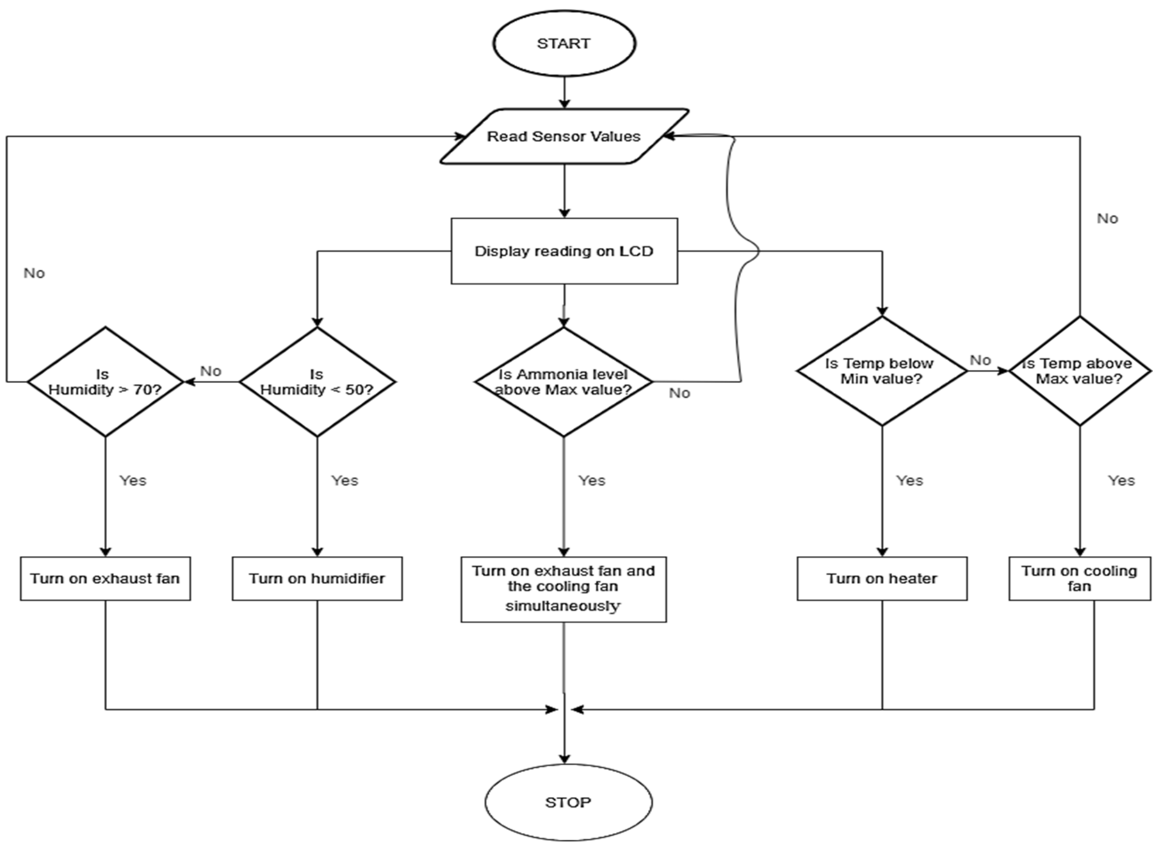

Fig. 5 Flowchart for sensing unit

E. Design of Water and Feed Control Unit

This unit is divided into water level and feed level control units. The water level control unit uses a float switch mechanism to detect the water level in the water tank, and a signal is sent to the microcontroller if the water level goes below a pre-defined threshold. Likewise, the feed level control unit employs an infrared sensor to detect the feed level in the feed tank and signals the microcontroller when the feed level is below the pre-set threshold.

The flow rate Q in cm^3s^{-1} of water and feed in their respective water and feed tank was determined using Eqs. 12 to 16 [40]:

$$V_v = \frac{Q}{t} \tag{12}$$

$$V_v = Ah \tag{13}$$

$$A = \prod r^2 \tag{14}$$

$$V_v = \prod r^2 h \tag{15}$$

$$Q = \frac{Ah}{t} = \frac{\prod r^2 h}{t} \tag{16}$$

The average velocity, u in cms^{-1}, of the fluid, when travelled through the pipe, is given by Eq. 17:

$$u = \frac{h}{t} \tag{17}$$

The use of eq.17 in eq. 16 gives the fluid flow rate Q as Eq. 18:

$$Q = Au = \prod r^2 u \tag{18}$$

For this work, the radius of the water and feed pipes used were 1.75 and 2.5 cm, respectively, while the heights were 45 and 50 cm, respectively. The circuit diagram for the water and feed control unit and the flowchart for this unit's sequence of operation is shown in Figs. 6 and 7, respectively.

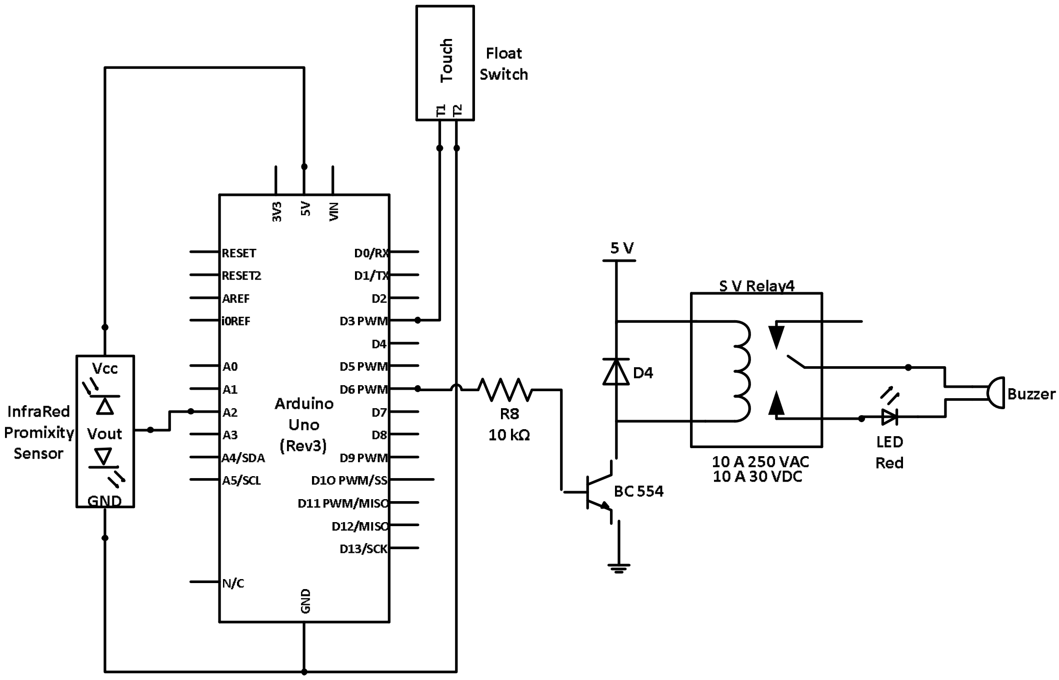

Fig. 6 Circuit diagram of the water and feed level control unit

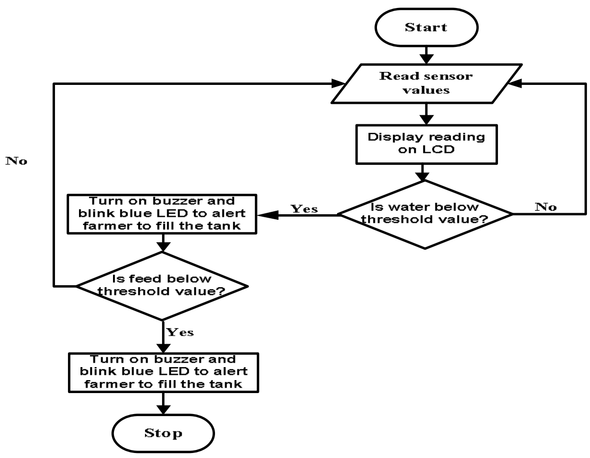

Fig. 7 Flowchart for water and feed level control unit

The resistor R_8, transistor BC549, and relay 4 in Figure 6 were configured through the same procedures used for the design of the lighting circuit.

F. Overall System Design

Fig. 8 shows the overall circuit design for the microcontroller-based automated poultry regulating system developed. The various subunits presented in Figs. 2, 3, 4, and 6 were integrated to obtain the circuit diagram of Fig. 8, which was implemented to actualize the microcontroller-based automated poultry regulating system developed. With the microcontroller as a focal point, the flowchart of Figs described the sequence of operations of the system's sensing, water and feed control units. 5 and 7.

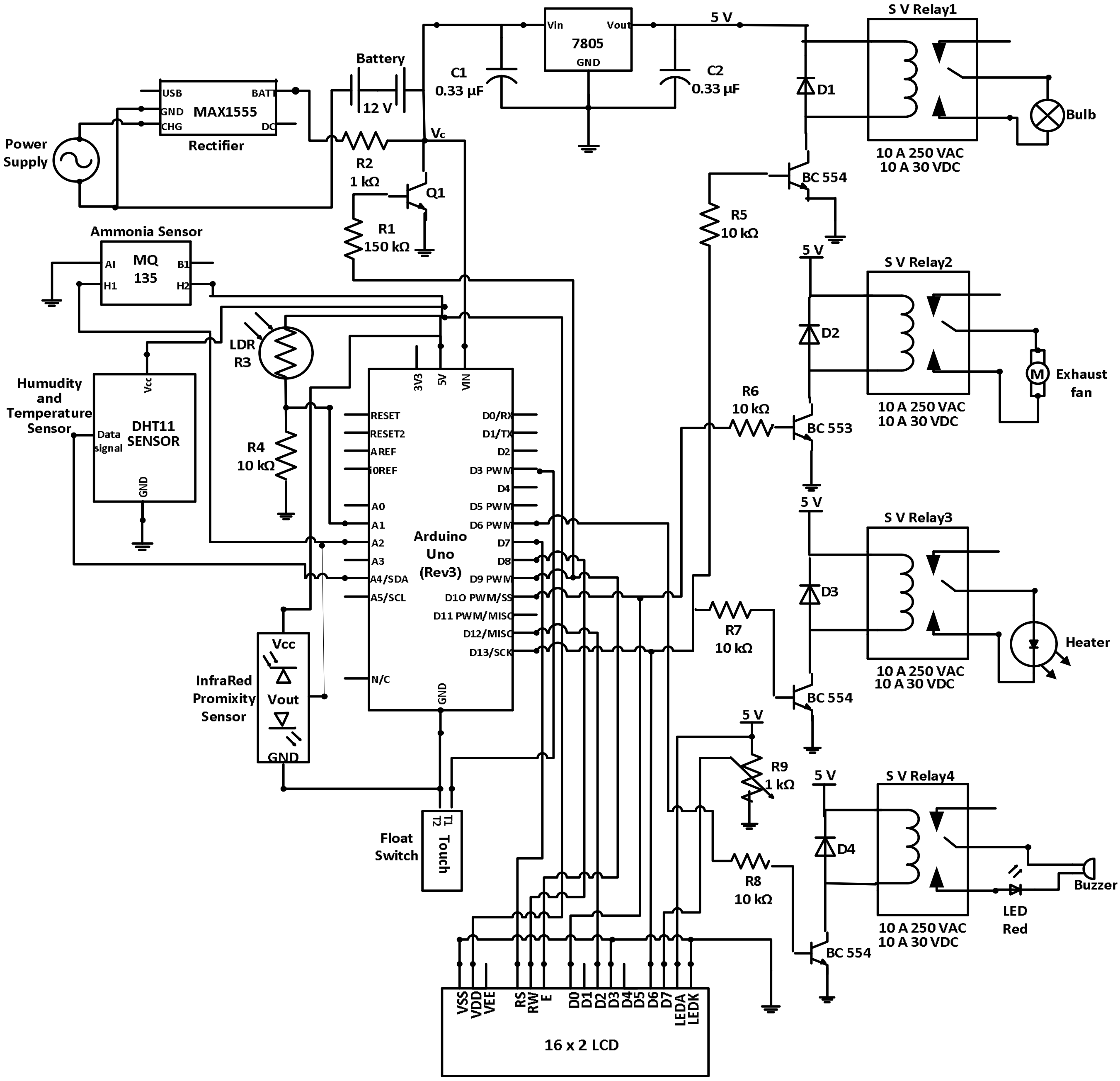

Fig. 8 Circuit diagram of the automated poultry regulating system

G. Testing of the Developed System

Having designed and implemented the microcontroller-based automated poultry regulating system, a performance test was carried out on each system subunit, including the lighting unit, water and feed level control unit, sensing unit, power supply unit, and display unit, to examine their functionality.

III. Results and Discussion

A. The Developed System

Figs. 9 to 11, respectively show the front, side, and rear views of the developed automated poultry regulating system.

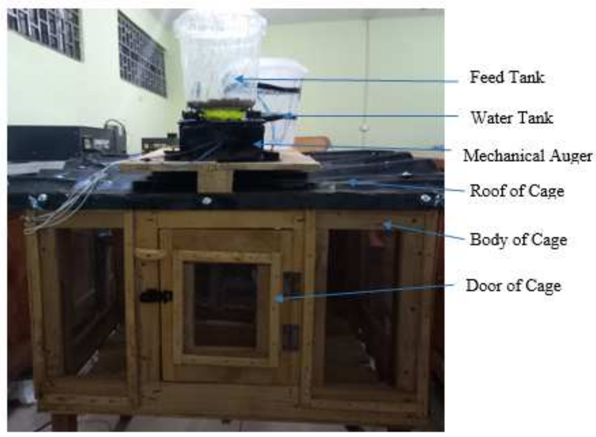

Fig. 9 Front view of the developed poultry regulating system

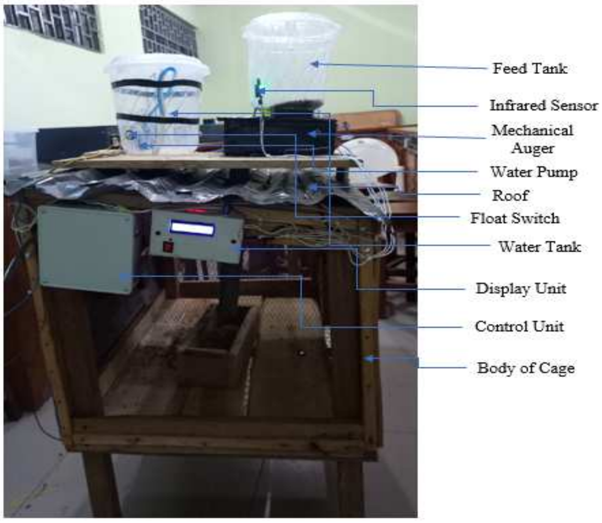

Fig. 10 Side view of the developed poultry regulating system

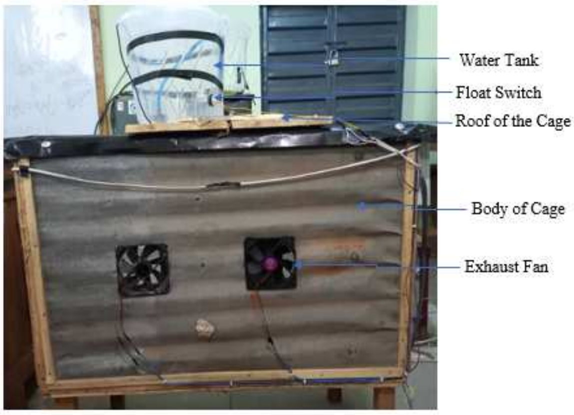

Fig. 11 Rear view of the developed poultry regulating system

Various external components employed in the system development are shown in Figs. 9 to 11. Fig. 12, on the other hand, shows the interior of the poultry regulating system with the output devices.

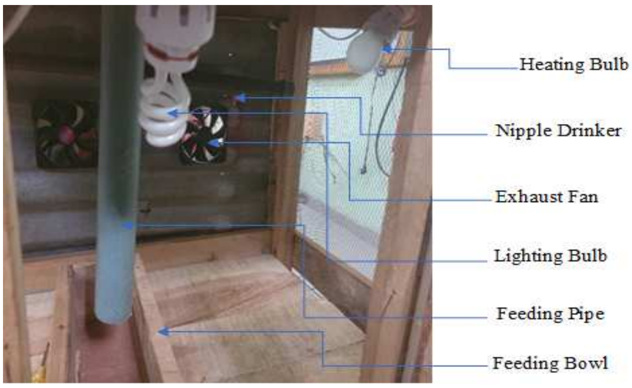

Fig. 12 Interior of the cage with output devices

B. Test Results

The results of performance tests carried out on different automated poultry regulating system units are presented in Figs. 13 to 16.

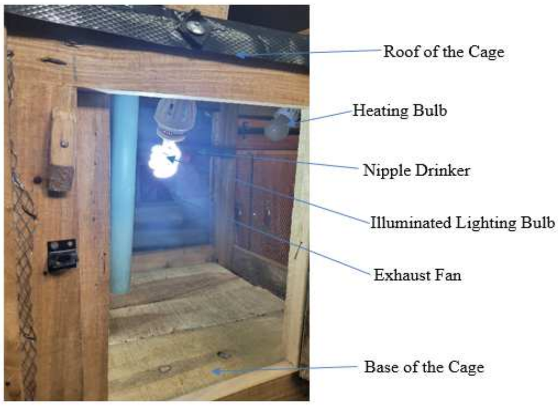

Fig. 13 Illuminated lighting bulb in the poultry chamber

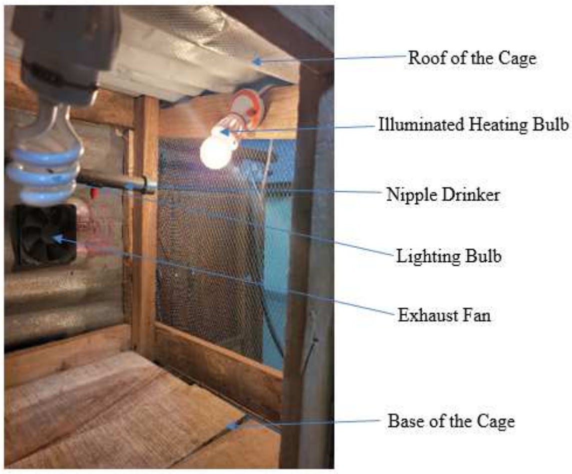

Fig. 14 Illuminated heating bulb in the poultry chamber

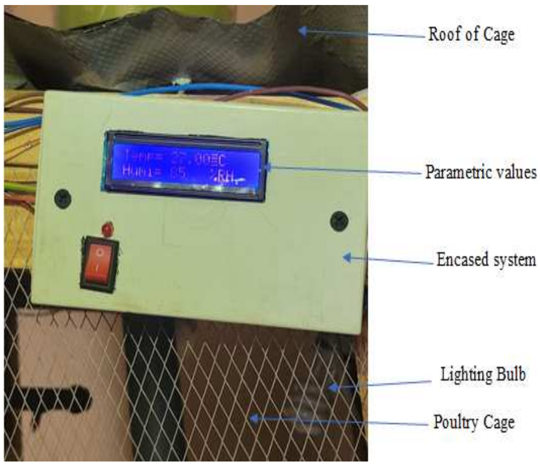

Fig. 15 Ambient temperature and humidity values on the LCD screen outside the poultry chamber

Figs. 13 to 16 together showed that the power supply unit of the developed system was fully functional since the supply source reached the various sections of the system as desired. Fig. 13 indicated that the lighting unit of the developed poultry regulating system was active when tested. The terminal voltage supplied to the lighting bulb was measured as 5 V DC; hence, the bulb performed as desired.

Fig. 16 Water level indication displayed on the LCD screen outside the poultry chamber

Also, Figs. 14 to 16 revealed that the sensing and display units of the system operated correctly during testing. As presented in Fig. 14, the heating bulb was switched on when an ice block employed to create a low-temperature condition outside the pre-set range in the poultry chamber was moved close to DHT 11 sensor located in the roof region and triggered the bulb. Figs. 15 and 16 confirmed that the system's display unit was active as temperature, humidity, and water level status within the poultry chamber was displayed on the LCD screen.

During testing, the time taken for 500 cm^3 of water and 500 cm^3 of feed to drop in their bowls within the poultry chamber from their respective containers located on the chamber's roof were 2.36 and 3.49 s, respectively. Therefore, the water and feed flow rate in their respective pipes was determined as 183.45 and 112.52 cm^3s^{-1}.

IV. Conclusion

The persistently growing global population has made industrial automation a necessity to enhance the efficiency of the agricultural sector to cope with the high demand for food supply placed on it. Therefore, this work developed a microcontroller-based automated regulating system that can assist poultry farmers in effectively managing birds for viable productions. The developed system is robust, cost-effective, and exhibited satisfactory performance when the functionality of its various subunits was tested. The system could be used for small-scale poultry farmers' indoor and outdoor applications.

For the regulating system, the water and feed level control unit were designed to deliver water and feed into their respective bowls in the poultry chamber at regular intervals, irrespective of the birds' needs. This design approach could lead to wastage if the birds are not drinking and eating as expected, and more so, the over-spilling water and feed due to their regular discharge in the chamber might mix with the birds' excreta, resulting in an untidy condition. Arising from these scenarios, to prevent wastage of water, and feed and ensure a healthy environment for the birds in the poultry chamber, the system design could incorporate a mechanism to release water and feed into the chamber on demand by birds.

Nomenclature

I	battery charging current	A
P	battery power rating	W
V	battery voltage	V
A_r	batteryamperage rating	Ah
V_{cc}	common collector voltage	V
V_{in}	input voltage	V
V_{be}	base-emitter voltage of *Q1*,	V
$I_{c(sat)}$	saturated collector current of *Q1*	A
I_b	base current	A
I_c	collector current	A
R_1	base resistor of *Q1*	Ω
R_2	collector resistance of *Q1*	Ω
R_3	variable resistance of LDR	Ω
R_4	resistance of the limiting resistor	Ω
R_5	base resistance of BC548	Ω
V_{out}	output voltage of BC548	V
I_R	relay current	A
R	relay resistance	Ω
R_6	resistance of transistor BC553	Ω
R_7	resistance of transistor BC554	Ω
Q	flow rate	cm^3s^{-1}
V_v	fluid volume	cm^3
t	time	s
A	cross-sectional area of pipe	cm^2
H	height of pipe	cm
r	radius of pipe	cm
u	average velocity of fluid	cms^{-1}
R_8	resistance of transistor BC549	Ω

Greek letters

β_1	gain of transistor *Q1*
β_2	gain of transistor *BC548*

Subscripts

r	rating
cc	common collector
in	input
be	base-emitter
b	base
c	collector
out	output
R	relay
v	volume

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