NAU Journal of Civil Engineering (NAUJCVE) August/September/October 2023
Nnamdi Azikiwe University Journal of Civil Engineering (NAUJCVE)

Volume-1, Issue-3, pp-120-130
www.naujcve.com
Research Paper Open Access

Experimental Design of a Microcontroller-Based Temperature Monitoring and Control System for Broiler Brooder

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Abstract: *Temperature measurement and monitoring is an integral part of any control system operating in a temperature sensitive environment. To achieve the purpose of managing temperature, embedded system becomes a special actor. An embedded system is comprised of a microcontroller, control software and actuators. A temperature monitoring system is an integrated device used in monitoring, controlling and regulating the temperature of a particular environment. In this project, the experimental design of a microcontroller-based temperature monitoring and control system for broiler brooder was done using ATMega328 microcontroller as the heart of the circuit, National Semiconductor's LM35 temperature sensor for sensing the temperature of the brooder, LCD for displaying of the current temperature and relays that regulates the heater and the fan. The system is pre-set with the temperature range of 32^{o}C maximum to 21^{o}C minimum which is adequate for a broiler brooding condition for a period of 21 days. A timer is set such that after 24hrs, it will decrease the value of the maximum temperature range by 1/2^{o}C. It compares the sensor data with the new temperature value for that day. If the sensor value is above the preset value, the system turns off the heater and turns on the fan but if the sensor value is below preset value, the system turns off the fan and turns on the heat. This project presents the experimental design of a Microcontroller-based temperature monitoring and control system for chicken brooding house.*

***KEYWORDS*:** *Temperature; Microcontroller; Sensors; Broiler Brooding; Regulator; Monitoring.*

Date of Submission: 16-10-2023 Date of acceptance: 22-10-2023

I INTRODUCTION

Among the most common measurements and monitored parameter across a broad variety of industries, home and the entire environment is the temperature. Hence, temperature monitoring and control becomes inevitable to mankind.

In broiler production, temperature is one of the major parameters to be controlled, most importantly during brooding stage. According to (North et al, 2004; Shaheen et al, (2019) brooding is the most critical segment of commercial poultry among the disciplines of management, especially where the foundation has been laid for a healthy flock. The authority further explained brooding as a process of providing an environment especially temperature in the poultry house where the chicks can feel comfortable in initial phase of life.

A good brooding house must provide and maintain a certain range of temperature for the period of the brooding. According to (Penderson, 1971; Charlse 2007), the starting temperature of a brooder should not be below 30^{o}C and gradually be reduced at the rate of 1/2^{o}C per day. In conformity to this figure, (North et al, 2004; Shaheen et al, 2019) agreed that brooding temperature can be decreased 2.8°C/week to a limit, approximately 1/2°C per day. Consequently, (Fairchild, 2012) noted that any failure in the provision of adequate environmental conditions especially in the form of heat during this phase may hamper the growth performance.

Therefore, monitoring the temperature of a brooding room is a critical task to ensure that the performance of the birds is not hampered. Nevertheless, a system that is capable of regulating the heater and the fan to avoid over heating or under heating of the room will be very useful.

The temperature measurement and monitoring is an integral part of any control system operating in a temperature sensitive environment. To achieve this purpose of managing temperature, embedded system becomes a special actor. An embedded system is comprised of a microcontroller, control software and actuator.

A. Microcontroller

Microcontroller is a single-chip special-purpose computer dedicated to specific application. Like a general-purpose computer, microcontroller consists of small sized memories (RAM, ROM, and Flash), I/O peripherals, and processor core. However, a microcontroller's processor core is not as fast as in general purpose-computer.

All embedded systems such as, home appliances, vehicles and toys utilize the capabilities of the microcontroller. In the market today, several microcontroller products are available, most common among them are Intel's MCS-51 (8051 family), Microchip PIC, and Atmel's Advanced RISC Architecture (AVR).

B. Sensor

This is a device that detects the change in the environment responds to some it by generating a corresponding output for interpretations. According to (Jon, 2004), sensors perform a vital function by providing an interface to the real world. Without sensors, most electronic applications would not exist.

C. Microcontroller Based Temperature Monitoring System

This is a system that utilizes temperature sensing component and the microcontroller in monitoring the temperature of a given thing. According to (Tun, 2018), microcontroller based temperature control system controls the temperature of any device according to its requirement for any industrial application.

In past, many researchers have designed and implemented temperature monitoring systems using the microcontroller and the temperature sensors. Some of them achieved this either by using the National Semiconductor LM5 temperature sensor or the thermocouple type of temperature sensor. The idea of using either of the sensor type is being determined by the type of environment where the temperature is to be measured.

Baruah, Zaman and Islam, (2014) designed and developed a cost-effective temperature monitoring and controlling system using microcontroller and LCD. Their work was modular in nature where they have the first module as the temperature monitoring and the second module as the temperature controlling. The user's temperature requirement is given in the form of a set-point and the microcontroller then compares the temperature of the surrounding environment against this set-point. If the temperature goes above the set-point then the cooler goes on and if the temperature goes below the set-point then the heater is switched on.

Tun (2018), designed a microcontroller based automatic temperature control system using the PIC 16F887A microcontroller at the heart of the circuit to control all its functions and thermocouple as the temperature sensor for sensing the temperature of environment. This temperature is compared with the value stored by the user and if the temperature goes beyond the preset temperature then heater will switch off and if temperature goes below to preset value then heater will switch on. The system displays the temperature on a seven -segment display in the range of 0℃ to 750℃.

Wellem and Setiama (2012) in their work designed and implemented a microcontroller based room temperature monitoring system. In contrary to (Tun, 2018) work above, Wellem et al (2012) used the Atmel ATmega8535 microcontroller at the heart of the circuit and National Semiconductor's LM35 as the temperature sensor. The system is equipped with a Wavecom GSM modem to send and receive text message (SMS) and relay board to control electronic equipment. While Tun (2018) work switches off and on the heater in response to external stimuli and displays result using seven-segment display, Wellem et al (2012) system raises an alarm and sends an alert message to administrator when the room temperature is above threshold, which is preset to 28°C.

Zhu and Bai, (2009) proposed a system for monitoring the temperature of electric cable interface in power transmission. The system consists of Atmel AT89C51 microcontroller just like others but uses Maxim's

DS18B20, 1-wire digital thermometer to sense the temperature. This new feature of this work entails using decoders for interfacing purpose.

In taking their work further, the deployed the capabilities of PC which served as the central machine, host control machines, and temperature collectors. They formed a sensor network which is connected to a host control machine through RS-485 communication network which limited by cable length (1200 meters). Each temperature collector saves the temperature in SRAM and sends the temperature information back to the host control machine when requested. The host control machine also stores this temperature data in its memory (SRAM) and sends it back to the central PC machine when requested. The host control machine also communicates and exchanges data with the central PC machine using General Packet Radio Service (GPRS) connection.

Some researchers went further in monitoring other parameters and incorporate them in the temperature monitoring systems. This feature was seen in Eigenberg, Nainaber, Brown-Brandl and Hahn (2002) work. They developed a system for Rugged Environmental Monitoring Units for Temperature and Humidity. It was designed with additional complexity of construction and calibration for certain applications that involve harsh environments but lacked the hardware control unit to meet specific conditions.

Similarly in Pande, Chauhan and Parihar (2013) work, a temperature and light monitoring system was done. The work consists of LCD, two sensors, PIC microcontroller and an ADC 0809 for analog to digital conversion. While (Baruah et al, 2014)uses potentiometer to setthedesired temperature value, Pande et al (2013) set the temperature value and light value with the help of provided keypad.

Another work that encompasses the duo of temperature and light monitoring was done by Goswami, Bezboruah and Sarma (2009). They proposed an Embedded System for Monitoring and Controlling Temperature and Light. In their work, ADC 0809 was used in temperature measurement and light intensity while AT 89S52 microcontroller was used as the control of the system.

Some works were based on telemetry where by the result of the measurements are sent to a remote location. Such work include the work of (Loup, Torres, Milian and Ambrosio, 2011). Their server room monitoring system was embedded with a Bluetooth. When the room temperature is above threshold, the system sends a message to each server via Bluetooth to shut down the server.

In similar work, Bing and Wenyao, (2010) designed a wireless temperature monitoring and control system for communication room where Jennic's JN5121 Zigbee wireless microcontroller was used in communicating the results of measurement and Sensirion's SHT11was used as the temperature sensor.

Some temperature monitoring system has the ability to store temperature values for future use. Such systems are applied in the areas like hospital to manage the temperature of a patient that is possibly critically ill, monitor the operations of other hospital operations such as preservation of food, drugs or at weather stations etc. (Saidu, Momoh and Mindaudu, 2013) designed a Temperature Monitoring and Logging System suitable for use in Hospitals. At the heart of their system is the ATMega16 microcontroller. The system is capable of sending GSM Text Messages.

This project presents the experimental design of a Microcontroller-based temperature monitoring and control system for chicken brooding house.

This experiment was carried out within the boundaries of Federal Polytechnic Nekede Owerri Imo State. According to (Iwuchukwu, Asoegwu & Okereke, 2018), the Mean Values of the raw data for the climate properties in Imo State is given at table 2 at the result and conclusion. It were under these climatic conditions that the experiment was carried out.

II. MATERIALS AND METHODS

A. Materials

i. Panel Box Enclosure

This is the enclosure in which the construction works are done on, it is 400mm in height and 350mm in width, it contains an earth linkage point which helps to control any earth leakage fault which may occur in the circuitry. It is always strong enough to be able to condone the weight of the components that will be mounted on its base.

Fig. 3.1: Panel Box Enclosure

ii. ATMega328 microcontroller

The ATmega 328microcontroller is the current top of the line in the 28-pin ATmega x8 series. It has 32kB flash memory, 2kB RAM, and 1kB EEPROM. It can be considered a step up from the ATmega8. It runs at 3.3V with a 16MHz crystal. It has 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator and five software selectable power saving modes. The device operates between 1.8-5.5 volts. Its maximum operating frequency is 20MHz.

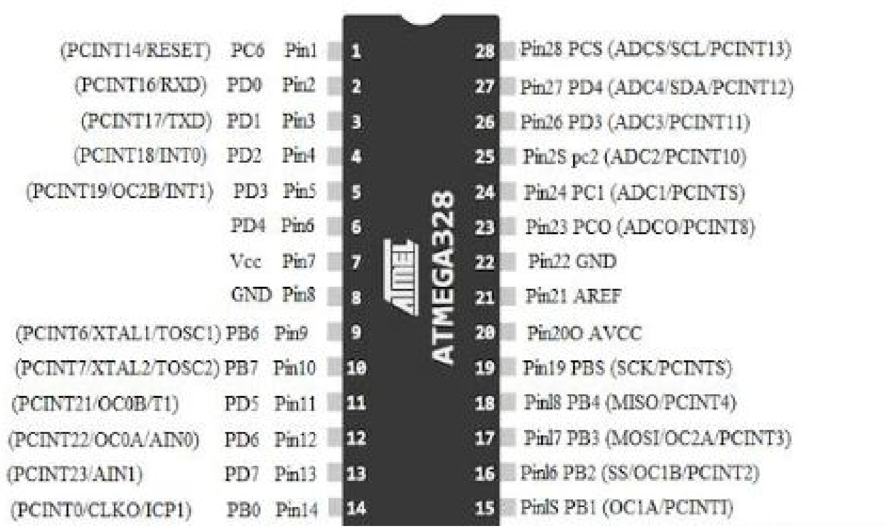

Fig. 3.2: ATMega328 microcontroller

iii. Relays

Relays are switches that open and close circuits electromechanically or electronically. Theycontrol one electrical circuit by opening and closing contacts in another circuit. Majorly they are used in switch starting heating elements and other devices.

Fig. 3.3:Relays

iv. Temperature Sensor (LM35)

The LM35 is a temperature sensor whose output voltage is linearly proportional to the Celsius temperature. This sensor has linear output and low output impedance which makes it easy for connecting it to the readout circuitry. Three pins, +Vs, GND, and Vout are defined for the sensor. When used as a basic temperature sensor with range of (2°C to 150°C), any change in temperature by 1°C will be converted to 10mV or the output voltage (Vout) = 0mV +10mV/°C.

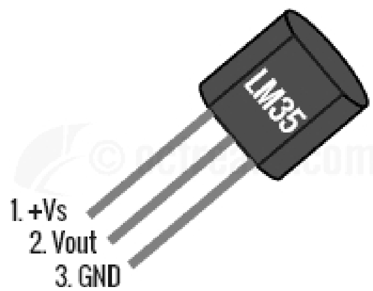

Fig. 3.4: Temperature Sensor

v. Halogen Heater

Halogen heater uses radiant heat from tubed containing halogen to heat up the environment. It is usually equiped with an intetnal blower that helps push the heat out s to warm up the environment evenly

Fig. 3.5: Electric Heater

vi. Ventilator Fan

Ventilator fan is a device used in regulating the intetnal temperature of the broodet. It equally removes carbon dioxide and other gasses like ammonia. It also removes moisture from the brooder.

Fig. 3.6: Ventilator Fan

B. Methods

There are two methods by which temperature can be sensed and processed. The first method is the ON-OFF method and the second one is the Continuous method.

In ON-OFF method, the sensor senses the temperature and sends it to the MCU that compares it with set value. If it is greater, then it switches off the heater and switches on the cooler but if it is less, then it switches on the heater and switches off the cooler.

In Continuous method, temperature is sensed and compared with set value. If it is greater, the MCU then control the heater by decreasing its supply current. If is it less, it increases its supply current.

In this project, the ON -OFF was adopted. The set value for temperature was pre-determined in the control software during coding. The actual temperature is sensed by LM35 analog temperature sensor and sent to ATMega 328 microcontroller. ATMega 328 has an inbuilt ADC that is used to convert the analog output voltage of the LM35 to a proportional 10-bit digital value suitable for the microcontroller. The microcontroller accepts the output of ADC and performs necessary manipulations on it and displays it numerically on an LCD display. It compares the set value and the sensed value. If the sensed value exceeds the set value, the heater is turned off while the fan is turned on. When temperature falls below the specified limit again, heater is turned on while the fan is turned off. Below is the block diagram of the system

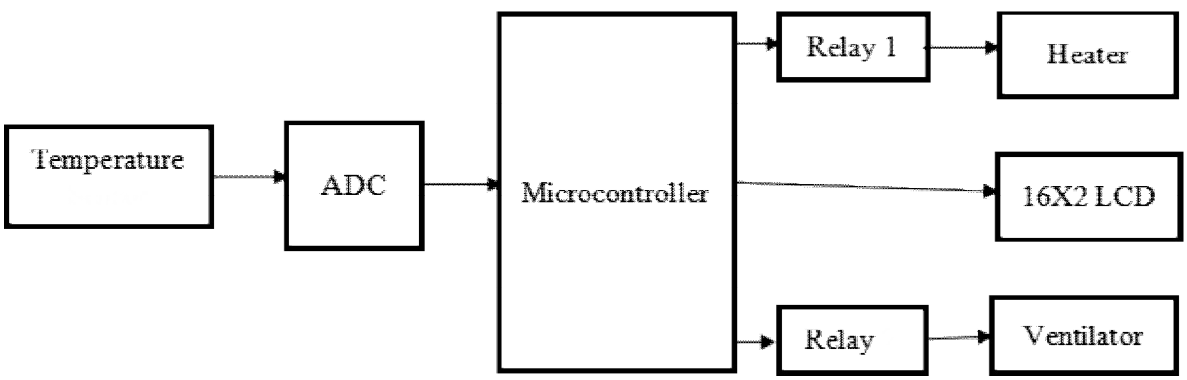

Fig. 3.5: Block Diagram of the System

a. Construction

In the construction of the work, the output of the LM35 is connected to the analog input pin (pin 23) of the microcontroller. Data lines are Pins 4, 6, 11, 17 and 18 of the microcontroller which are the digital inputs D2, D3, D4, D5, D11 and D12 respectively. These Pins are interfaced with the LCD as:-

LCD RS pin to digital pin 12

LCD Enable pin to digital pin 11

LCD D4 pin to digital pin 5

LCD D5 pin to digital pin 4

LCD D6 pin to digital pin 3

LCD D7 pin to digital pin 2

LCD R/W pin to ground

10K resistor ends to +5V and ground, wiper to LCD Vo pin (pin 3) for contrast adjustment of the LCD. The reset switch is connected to pin 1 of the microcontroller through a 10k resistor. A crystal oscillator is connected between pins 9 and 10 of the microcontroller through two 22pF capacitors. The control signals for the two relays are taken from pin 13(digital 7) and pin19 (digital 13) for driving the heater and the cooler respectively. Some of the components are describe below.

i. Power Supply Module

This module is basically designed to achieve 5V regulated power supply for the circuit typically for the microcontroller and operation of the relays. It mainly consists of a transformer which is used to step down the AC voltage, IN4007 diodes used to form a full wave bridge rectifier to convert AC to DC, 1000µF capacitor used as a filter circuit and 7805 regulator IC to obtain 5V at the output of the regulator.

ii. LM35 Temperature Sensor

National semiconductor's LM35 IC was used for sensing the temperature. It is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^{o}C). The temperature can be measured with it more accurately than using a thermistor or thermocouple. The sensor circuitry provides accurately linear and directly proportional output signal in millivolts over the temperature range of 0C to 155C. It develops an output voltage of 10 mV per degree centigrade change in the ambient temperature. Therefore the output voltage varies from 0 mV at 00C to 1V at 100 0C and any voltage measurement circuit connected across the output pins can read the temperature directly. Its accuracy is 0.50C.

iii. Signal Conversion

Since the signal from the temperature sensor is analog and Atmega 328 has an inbuilt ADC and was programmed to read data from LM35. The first thing in software program is a routine that enables the ADC to read and write data and convert the analog sensor values to digital values.

iv. Microcontroller ATMega328

It is used to form the MCU for reading the temperature and holding the monitoring and the controlling program. It receives the analog voltage signal coming from the sensor. After the conversion into digital signal, it checks whether the sensed value is in the set value. If the data does not come under the set parameter, then the microcontroller starts its controlling action.

b. Implementations

i. Hardware implementation

During the hardware implementation of the work, a project board is used to for the prototyping and testing. So, it was easy to change connections and replace components. The project board has many strips of metal (copper usually) which run underneath the board .These strips connect the holes on the top of the board. This makes it easy to connect components together to build circuits. To use the project board, the legs of the components are placed in the holes like sockets. The holes are made so that they will hold the components in place. Each hole is connected to one of the metal strips running underneath the board. Each wire forms a node. A node is a point in a circuit where two components are connected. Connections between different components are formed by putting their legs in a common node. On the breadboard, a node is the row of holes that are connected by strip of metal underneath. The long top and bottom row of holes are generally used for power supply connections. After testing implementing the work on a project board, the system was certified reliable. Finally, the required components are assembled and soldered in a general purpose printed circuit board and the connections are made accordingly.

ii. Software Testing and Implementation

During the software testing and implementation, the assembly program for measuring temperature and controlling it according to the user's requirements (switching on and off the heater and the fan) and displaying the temperature in LCD module was developed. The software program includes the reading of ambient temperature from sensor, converting analog value to digital values, displaying the temperature in the 16X2 LCD display and the program for controlling action. The assembly level programming is done on Arduino IDE software. The Arduino IDE combines project management, make facilities, source code editing, program debugging, and complete simulation in one powerful environment. It supports Windows, Mac OS X and also Linux. The Arduino platform is easy -to-use and helps one to quickly create embedded programs that work. The Arduino editor and debugger are integrated in a single application that provides a seamless embedded project development environment. The developed program is programmed in the ATMega328 microcontroller. The circuit diagram was drawn using Diptrace software.

III. RESULTS AND DISCUSSION

The experiment was carried out on July 2023 and the average minimum temperature was 22.959 degree Celsius and a maximum of 29.375 degree Celsius as seen on **table 1.** The corresponding relative humidity was 87.059%. Inside the brooder, the increased relative humidity prevented the evaporation of water and reduced the dehydration, therefore the ability of the bird to cool it selves by evaporation were limited, and there was no incident of dehydration. Though, the brooder was overheated above the ambient temperature.

Table 1 shows the temperature readings of the brooder for the 21 days of brooding. Because of the high relative humidity, most of the operation of the system was to cool down the brooder using the fan.

Table 1: Temperature Levels at The Brooder.

Period (days)	Tem (^oC)	
	Day	Night
1	30	25
2	30	28
3	29	23
4	35	29
5	36	30
6	33	30
7	31	29
8	35	31
9	33	30
10	31	29
11	30	29
12	29	25
13	29	27
14	25	22
15	25	21
16	23	21
17	22	22
18	24	22
19	24	22
20	25	23
21	25	24

From the table above, it will be noted that the brooder temperature were lower than the preset temperature hence there was little heating. Afterwards, the brooder temperature became higher and lasted till the end of the brooding period. So, most of the operations of the system was to cool the brooder temperature to the preset level.

Table 2: The Mean Values of the Raw Data for the Climate Properties in Imo State

Month	R.H	Min. Tempt.	Max. Tempt.	Rainfall	Sunshine Hours	Wind speed	Vapour Pressure
Jan.	66.882	22.894	33.835	34.0000	4.9824	3.7118	24.0353
Feb.	71.529	24.294	35.071	42.8235	4.9647	3.6000	27.9059
Mar.	76.882	24.382	34.012	118.853	4.6588	3.6647	30.2118
Apr.	78.177	24.247	33.247	192.794	4.9059	3.9235	30.7529
May.	79.588	23.735	32.194	285.924	5.2529	3.5353	30.2941
June	83.706	23.406	30.888	363.294	4.1118	3.7294	29.5588
July	87.059	22.959	29.335	359.270	3.0353	3.3235	28.8353
Aug.	86.882	22.924	29.482	343.694	3.0235	3.5882	28.7294
Sept.	84.706	23.129	30.365	369.812	3.2000	3.4059	29.1529
Oct.	82.235	23.135	31.177	215.088	3.8647	3.1588	29.5412
Nov.	76.1765	23.5882	32.9824	73.5941	5.3176	2.9118	29.2882
Dec.	70.8235	22.5824	33.6000	17.6625	5.3765	3.2765	26.5529

IV. CONCLUSION

Temperature measurement and monitoring for sensitive environment like brooder can be done using an embedded system. This system used National Semiconductor's LM35 temperature sensor for sensing the temperature of the brooder, LCD for displaying of the current temperature and relays that regulates the heater and the fan. The system is pre-set with the temperature range of 32^{o}C maximum to 21^{o}C minimum which is adequate for a broiler brooding condition for a period of 21 days will decrease the temperature by 1/2^{o}C. If the brooder is above the daily temperature, the system turns off the heater and turns on the fan but if the temperature of the brooder is low, it turns off the fan and turns on the heat. From this work, the season of the year determines how the system operates. The system will depend on the relative humidity of the environment and the ambient temperature. During the period of this research which was on July, the relative humidity was high and likewise the ambient temperature. This led to the system predominantly occupied cooling the brooder. This have also indicated that such period of the year will be more cost effective to brood birds as cooling is more inexpensive than generating heat.

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APPENDIX: Circuit diagram