ENGINEERING

ISSN (Print): 24490954
ISSN (Online): 26364972

AUTOMATIC TEMPERATURE CONTROL SYSTEM

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Manuscript Received:20/05/2018 Accepted: 30/06/2018 Published: September, 2018

ABSTRACT

The main thrust of this research is the development of an automatic temperature control system. Temperature is a measure of degree of hotness or coldness of a body or an environment. There are many activities of man where regulation of temperature is not only required but necessary. Typical example of such is the operation of egg incubation unit which requires among others a steady operational temperature. In the present research design, the device operates in such a way that when the temperature is higher than 29°C, a fan is switched on to cool down the environment while at a temperature less than 25°C, a means of raising the temperature is triggered on. In the design, LM35 is employed as temperature sensor and LCD is used to display the ambient temperature while the device has at its heart a PIC18F4550 microcontroller. The developed device can be deployed in the bird's egg incubation unit for enhanced productivity.

Keywords: *temperature control,sensor, microcontroller*

INTRODUCTION

Temperature control or ambient conditioning is common with diverse methods in existence for its realization. In an industrial setting or production units, the need for the control of temperature is enormous as it has far reaching impacts on the overall production output. For example, smelting, welding and the likes operations require a working environment that is maintained at correct temperatures for the realization of the desired output. Ample accounts exist in the literature describing any efforts towards efficient and effective regulation of temperature of an area. In the list, one can identify those that are based on application of fuzzy logic control (Singhala *et al.,* 2014, Wei, 2016; Isizoh *et al.,* 2012), based microcontroller unit (Zilog, 2008; Levarda and Budaciu, 2010; Nwankwo *et al.,* 2014; Alyousif *et al.,* 2017; Okpagu and Nwosu, 2016), based on application of simple ON-OFF control model and pulse width modulator (Tisa *et al.,* 2012).

Singhala *et al.,* (2014) developed a temperature control system around fuzzy logic which has the capability of holding the temperature at a preset value in an insured manner. The problem of slow response and low accuracy of automatic system for control of temperature in industrial setting was considered by Wei (2016). The proposed system is based on a programmable logic control with the box temperature control realized via the use of the fan and the heating plate. In addition, the control algorithm is obtained as a hybrid of PID and Fuzzy Logic controls. In another development, Isizoh *et al.,* (2012) proposed a temperature control system where fuzzy logic control algorithm is loaded into a microcontroller to realize a controlled temperature output function. Other components include temperature sensor, operational amplifier, analog-to digital converter and display unit among others.

Application of Zilog's Real-Time Kernel (RTK) was demonstrated for the control of temperature of an environment. The control system is able to determine whether and when to put fan or bulb ON or OFF using the input signal from temperature sensor. The device displays both the preset temperature limit and the instant temperature of the environment (Zilog, 2008). Levarda and Budaciu (2010) proposed a low cost device for effective control of temperature using PIC18F4620 microcontroller. Effective monitoring and control of temperature in a greenhouse is the subject of discussion of Alyousif *et al.,* (2017) while modelling and development of an egg incubator system that works within the temperature range of 35^0C-40^0C was presented by Okpagu and Nwosu (2016). In that work, electric bulbs are used as heat source while water and fan are used to regulate humidity and ventilation respectively. Other components used include DC motor, iron rod, AT89C52 microcontroller implementing PID controller.

Egg incubator is an invention that enables hatching of birds eggs without having the real birds for brooding. Incubators mimic the conditions and experiences of a brooding bird for fertilized eggs. Foremost among these conditions is appropriate temperature, humidity and ventilation levels. Okpagu and Nwosu (2016) submitted that poor results are recorded when temperature, humidity, ventilation, egg turning and sanitation are not properly controlled. Humidity is easily regulated via provision of water pan of sufficient surface area in the hatchery. The major task lies with the control of temperature and ventilation. Consequently, successful operation of an egg incubator is heavily dependent on maintaining the temperature at appropriate level throughout the incubation period. When the temperature is too high or too low for sufficient time interval, the growth and development of the embryo is interfered with. Thus, effective method of temperature control in hatcheries is not only desirable but also a worthy investment. Hence this work is aimed at development of a temperature control system that is suitable for deployment in a poultry incubating unit.

MATERIALS AND METHODS

DESIGN CONSIDERATIONS

The design process is divided into two phases: the hardware and software phases. The former comprises of six subunits which are power supply unit, display unit, control unit, temperature sensor, actuating unit, temperature conditioner. The software phase is concerned with the writing and loading of the firmware of the microcontroller.

Hardware Phase

Fig. 1 depicts the subunits of the hardware involved in the developed temperature control system and their inter-connections.

Power supply unit- power requirement of the developed system is made available at two Direct Current (DC) voltage levels: +12V and +5V. The former is required to power the fan while the latter is needed by the microcontroller and other solid state electronics components employed. The power supply unit is built around main supply from the utility. A 220V/12V step-down transformer is used, output of which is fed into a bridge rectifier that is made of four IN4007diodes. The DC voltage after rectification is obtained using:

$$V_{DC} = V_{\max} - V_{hc} \qquad \text{....................................(1)}$$

where V_{DC} is the DC voltage after rectification, $V_{\max}$ is the effective voltage at the secondary terminal of the transformer, and V_{hc} is the voltage drop per half-cycle in the rectifier, which is twice the voltage across a diode V_d .

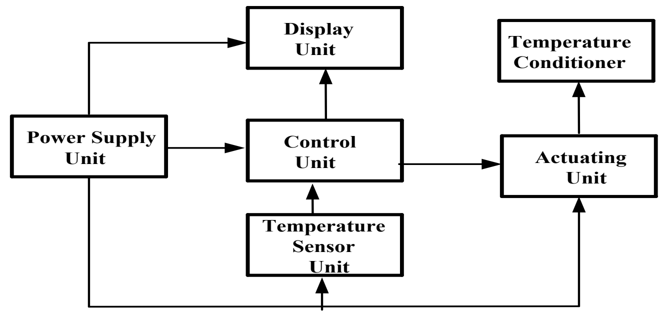


Fig. 1: Block diagram of the developed temperature control system

With $V_{max} = 12\sqrt{2}V$, $V_d = 0.6V$, the value of V_{DC} is found to be 15.77V DC. Ripples existing in the rectifier output are filtered out via the use of capacitor. The value of filtering capacitor is determined using (Theraja and Theraja, 2008):

$$C = \frac{I_{DC}}{8\sqrt{3}\gamma f V_{DC}} \qquad \text{.............................(2)}$$

where $I_{DC} = 2I_{\max}/\pi$ is the current after rectification, $I_{\max} = \sqrt{2}I_{rms}$ is the effective current and γ is the ripple factor.
Assuming a ripple factor of 10% when the root mean square (rms) value of the current from the secondary side of the transformer is 0.5A, the filtering capacitor is found to be $412\mu F$. For this work, a capacitor having capacitance value of $450\mu F$ is utilized.
In order to get the required +5V by the microcontroller, voltage regulation is carried out post filtering of ripples using LM7805.

Temperature sensor unit- LM35, which is a three pin modular temperature sensor, is utilized in this work. Its selection is informed by its wide temperature sensing range capability. A typical LM35 works over a temperature range between -55^0C and 150^0C. It does not require any external calibration or trimming to provide typical accuracies of $\pm0.25^0C$ at room temperature and $\pm25^0C$ over a full -55^0C to 150^0C temperature range. The low-output impedance, linear output and precise inherent calibration of the LM35 device makes its interfacing to readout or control circuitry very easy. LM35 draws only $60\mu A$ from the supply; it has very low self-heating of less than 0.1^0C in still air.

Control unit- PIC18F4550 microcontroller is employed in the control unit of the developed temperature control system. It occupies the heart of the device and coordinates the control of ambient temperature of the environment based on the information received from LM35. PIC18F4550 is chosen because of its specifications which include low power requirement, large RAM size of 2048kB, 32kB flash memory and data size of 256 bytes.
The microcontroller requires an external clock. A 16MHz crystal oscillator is utilized for clocking signal generation. Two equal capacitors C_1 and C_2 are employed as smoothen capacitance for the crystal oscillator. Values of C_1 and C_2 are obtained from

$$C_L = \frac{C_1C_2}{C_1 + C_2} + C_s \qquad \text{......................... (3)}$$

wh $C_L = 16pF$ (datasheet) is the load capacitance of the crystal, C_s is the stray capacitance having values between $2-5pF$. A choice of $5pF$ is made for C_s in this work, which results to $C_1 = C_2 = 22pF$.

Display unit- Liquid crystal display module having 16×2 matrix operating on +5V DC supply is used to give visual information of the ambient temperature. It displays the value of the temperature based on the output of LM35 as processed by the PIC18F4550.
Actuating unit- The output pins of the PIC18F4550 are +5V DC which is not enough to drive each of the fan and the heat source. In this work, the control signal from PIC18F4550 is fed into BC107, an NPN transistor switch with its collector terminal feeding a relay (CK0-D1-1240) to trigger ON/OFF either of the fan or heat source, based on the input received from LM 35 by the PIC18F4550 microcontroller.

Temperature conditioner unit- This unit comprises the fan and the heat source. Either the fan or source of heat is activated based on the input signal to PIC18F4550 from LM 35. When the temperature is lower than the preset value, the heat source is activated to raise the temperature. However, when the temperature is higher than the preset value, the fan is triggered on to drive down the temperature.

Software Phase

The software design flow is illustrated in Fig. 2. This phase is concerned with the programming of the PIC18F4550 microcontroller to enable it function as expected in line with the design specifications. The firmware of PIC18F4550 is written in assembly language. Writing the control program for the microcontroller requires a specialized program in the windows environment. Any text editor can be used for this purpose. The program is written in assembly language. The bone of contention here is to write all instructions in such an order that they would be executed sequentially by the microcontroller; observing the rules of assembly language programming and writing instructions exactly as they are defined. When using custom software, there are numerous tools which are also installed to aid in the development process. One such tool is the simulator. This enables the user to simulate or test the code prior to burning it to the microcontroller unit. To enable the assembly language compiler to successfully run the program, the source file must have the extension, .asmin its name, for example: Program.asm.

Since the microcontroller does not understand assembly language, hence, it is necessary to translate the program into machine language. This is made easier using a custom program because a translator is built into it and it is just a click away. MPLAB assembler is used to generate the machine language code with a .hex ("hex code") extension. The machine code is then compiled and from PC to the microcontroller using USB communication cable to connect the programmer having the microcontroller in place. The steps are simple: Insert the microcontroller onto the "*programmer*" device and connect the device to the PC, then load or open the "hex code" document; set a few parameters on the burning software such as the type of the microcontroller, frequency and clock oscillator etc., and click on the "WRITE" icon for burning,. After a while, a sequence of 0's and 1's are burned onto the microcontroller through the USB connection cable and the "*programmer*" hardware.
It worths mentioning that two temperature thresholds are preset in the software to guide the operation of the PIC18F4550. The low temperature threshold T_L and high threshold T_H. When the ambient temperature T is lower than T_L, a heater or source of heat is switched ON while in a situation when $T > T_H$, the fan is activated to drive down the temperature. The entire process is a feedback control system that ends only when the system is powered OFF.

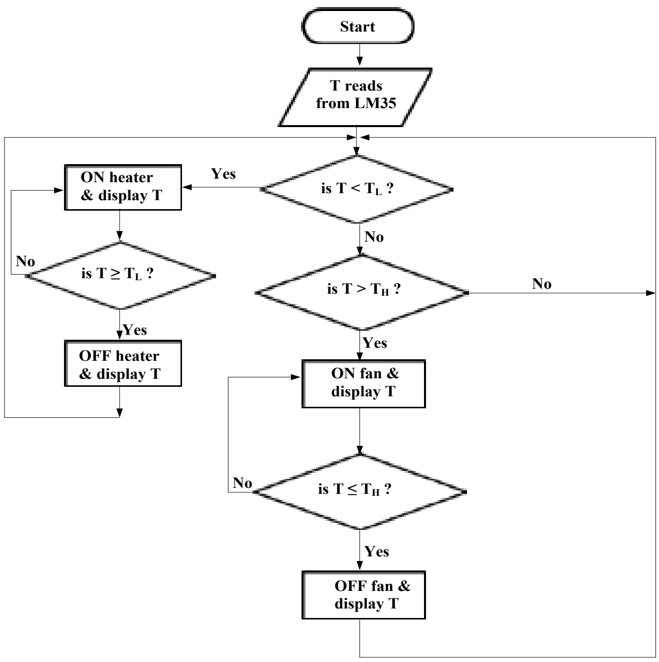


Fig. 2: Software design flow for PIC18F4550 microcontroller

IMPLEMENTATION

The complete circuit diagram of the developed temperature control system is shown in Fig. 3. Prior implementation, the circuit is simulated using Proteus software to ascertain the workability of the design. After the simulation, required components, based on the design considerations, are sourced for the implementation of the circuit shown in Fig. 3. It is pertinent to state here that in the firmware of the PIC18F4550 used for implementation, T_L and T_H are preset at 25^0C and 29^0C, respectively. Furthermore a small DC fan requiring 12V DC and 2A is utilized while a 30W tungsten lamp is used as the heat source. Fig. 4 shows snapshots of the constructed temperature control system for the demonstration of the workability of the design.

RESULTS AND DISCUSSION

After the construction exercise, the developed system was put to test to ascertain its level of conformity with the design specifications, especially with respect to the two preset temperature thresholds. The range of the preset temperature in the constructed temperature control system is 25ºC – 29ºC. If the temperature is below 25ºC, the heater is expected to switch ON and if the temperature is above 29ºC, the fan is switched ON. The designed and built system is tested to determine if it conforms to these design specifications. In order to carry out the test, ice block is placed inside the cabinet representing the environment whose temperature is to be controlled, to induce reduction in the ambient temperature. For temperature increase, a cup containing hot water is placed inside the cabinet to cause temperature increase. In each case, LM35 sensor responds appropriately, indicating visually on display unit the value of the temperature inside the cabinet. In place of heater, a single incandescent 30W bulb is used to generate the needed heat to raise the temperature. When neither the ice block nor the cup of hot water is placed inside the cabinet, neither the fans nor the bulb is activated. This shows that the ambient temperature is within the preset temperature range. The results are presented in Table 1. In addition, Figs. 5-7 show plates indicating responses of the constructed system with respect to temperature changes during the test.

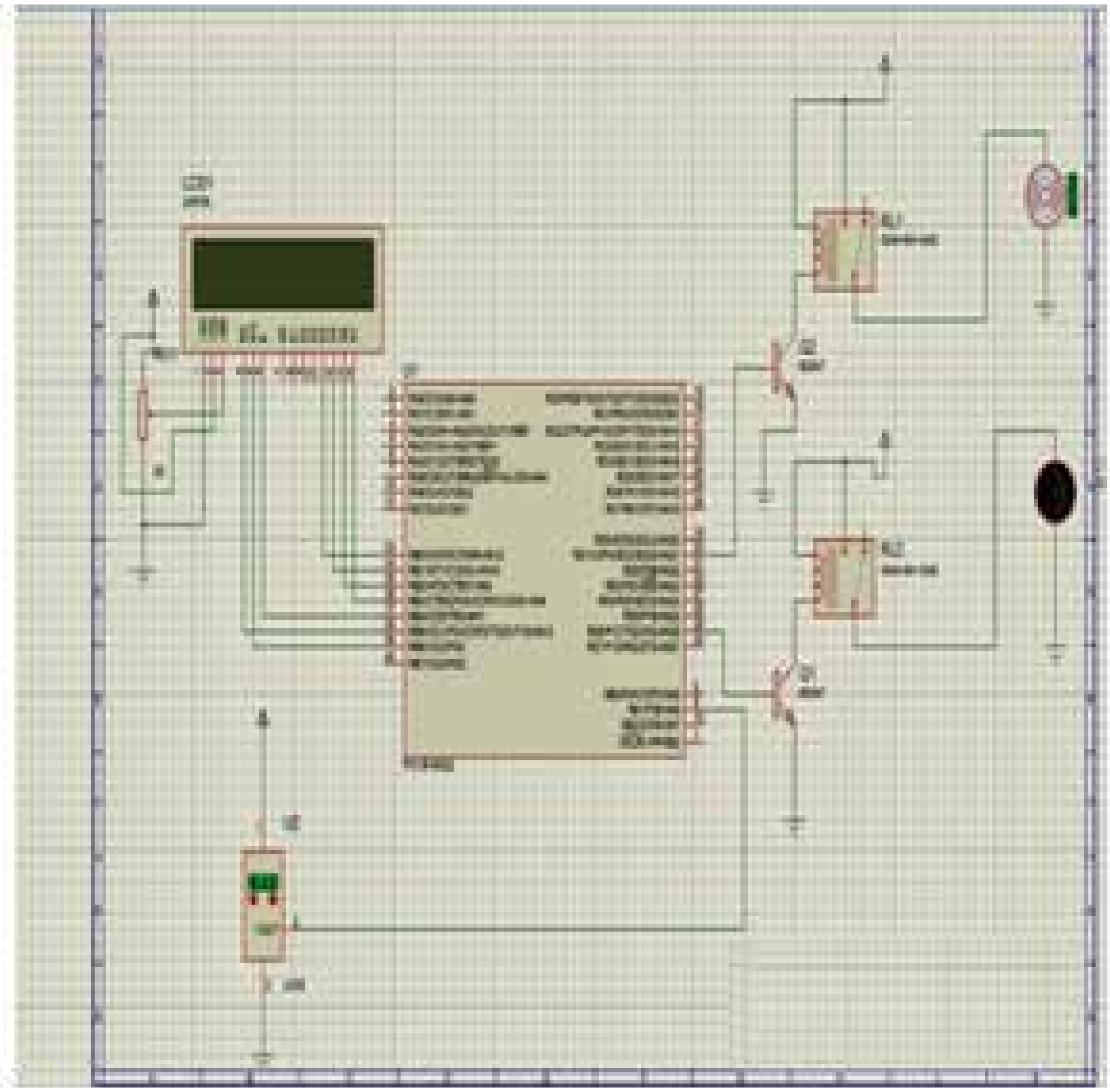
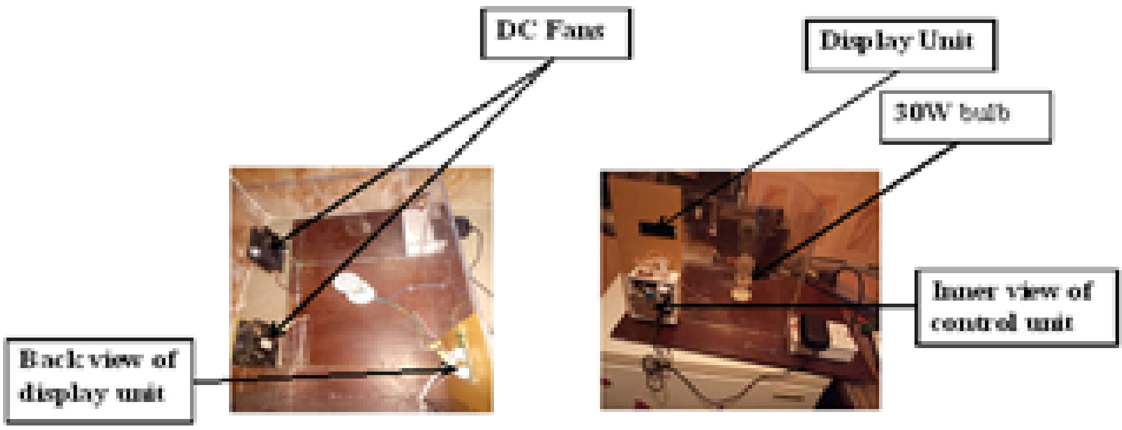


Fig. 3: Circuit diagram of the developed temperature control system



(a) (b)

Fig. 4: Plates showing different views of the constructed temperature control system (a) inner view (b) outer view with the control unit opened

Table 1: Test of the constructed device

Status of temperature inside the Cabinet	**Expected action**	**Action observed during test**
Temperature below 25^0C	Activation of source of heat	The bulb is switched ON
Temperature above 29^0C	Activation of fans	Fans are switched ON
Temperature between 25^0C and 29^0C	Neither fans nor source of heat is activated	Fans and the bulb are OFF

Fig. 5:Plate showing response of the constructed device to change in temperature when the temperature is (a) 18.1^{0}C (below 25^{0}C)

Fig. 5:Plate showing response of the constructed device to change in temperature when the temperature is temperature is 28.8^{0}C (between 25^{0}C and 29^{0}C)

Fig. 7: Plate showing response of the constructed device to change in temperature when the temperature is 29.3^{0}C (above 29^{0}C)

CONCLUSION

A temperature control system is developed from this research using PIC18F4550 microcontroller at its heart for coordination. LM35 is employed as temperature sensor, output of which is utilized by the PIC18F4550 to trigger ON/OFF fan or heat source based on the ambient temperature of the environment. Deployment of the developed device in this work will ease the task of people working in the hatchery and incubator unit greatly via reduction in the stress of regulating the ambient temperature required to be maintained. The cost of implementing the developed device is reasonable and all the components are readily available in the local market. The design was implemented, tested and found satisfactory with respect to specifications.

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