DEVELOPMENT AND TEMPERATURE CONTROL OF SMART EGG INCUBATOR SYSTEM FOR VARIOUS TYPES OF EGG

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ABSTRACT

This work is aimed at modeling, designing and developing an egg incubator system that is able to incubate various types of egg within the temperature range of 35 – 40^0C. This system uses temperature and humidity sensors that can measure the condition of the incubator and automatically change to the suitable condition for the egg. Extreme variations in incubation temperature affect the embryo and ultimately, post hatch performance. In this work, electric bulbs were used to give the suitable temperature to the egg whereas water and controlling fan were used to ensure that humidity and ventilation were in good condition. LCD is used to display status condition of the incubator and an interface (Keypad) is provided to key in the appropriate temperature range for the egg. To ensure that all part of the eggs was heated by the lamp, DC motor was used to rotate iron rod at the bottom side and automatically change position of the egg. The entire element is controlled using AT89C52 Microcontroller. The temperature of the incubator is maintained at the normal temperature using PID controller implemented in microcontroller. Mathematical model of the incubator, actuator and PID controller were developed. Controller design based on the models was developed using Matlab Simulink. The models were validated through simulation and the Zeigler-Nichol tuning method was adopted as the tuning technique for varying the temperature control parameters of the PID controller in order to achieve a desirable transient response of the system when subjected to a unit step input. After several assumptions and simulations, a set of optimal parameters were obtained at the result of the third test that exhibited a commendable improvement in the overshoot, rise time, peak time and settling time thus improving the robustness and stability of the system.

Keyword: Egg Incubator System, AT89C52 Microcontroller, PID Controller, Temperature Sensor.

INTRODUCTION

Incubation is the process of keeping the fertilized eggs warm in order to allow proper development of the embryo into a chick. It may either be natural or artificial. In natural incubation, the bird provides the required conditions for the relatively few eggs she lays by sitting on the eggs intermittently until they hatch in an open space. An artificial incubator is a chamber in which temperature, humidity and ventilation are controlled for the purpose of hatching a relatively large number of eggs than a single hen can handle at a time [1]. The heat required for incubation is usually provided by coal, oil, gas or electricity.

The need for artificial incubator is to generally increase hatchability of eggs which leads to the improvement and increase in the production of chicks and eggs for human consumption and the economic market [2]. In this present age of information technology, the control and automation of devices, machines and systems are mostly achieved through mechatronic means with emphasis on soft control, this is mostly achieved by the use of programmed microcontrollers [3]. The main aim of this work is to model, design and develop an incubator system that is capable of incubating various types of egg within the temperature range of 35 –

40^0C by setting both the minimum and maximum temperature using the input interface. This can be achieved using the following embedded components such as temperature sensor (LM35) for sensing the temperature condition of the incubator, weight sensor for monitoring the development of the chicks, AT89C59 microcontroller for programming of the operation sequence of the entire system, 60watts electric bulbs for supplying of heat to the incubator, 5volts and 12volts relays, LCD, NPN-transistors, DC motor etc.

SYSTEM DESIGN

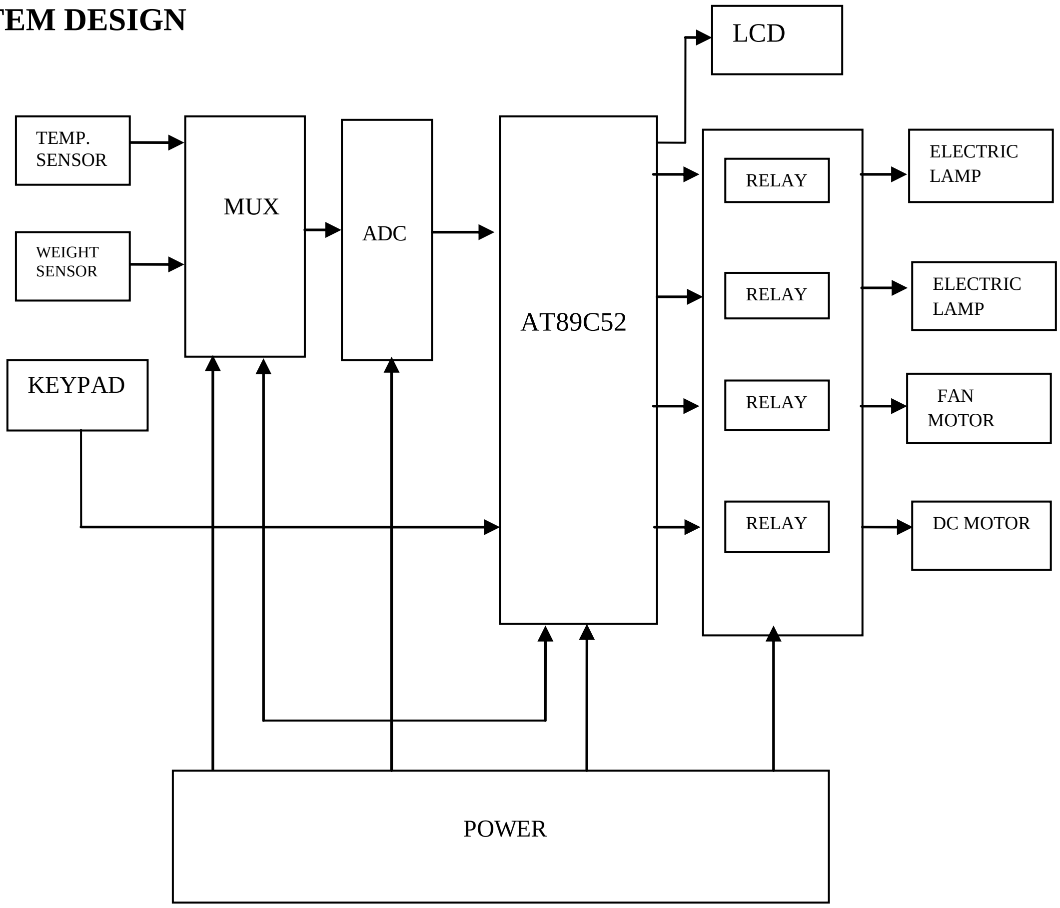

Figure 1.0: The System Block Diagram

SYSTEM OPERATION

The Sensors

The LM35 has an advantage over linear temperature sensors calibrated in ˚ Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±0.25˚C at room temperature and ±0.75˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level [4]. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry easy. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range. The sensor senses the temperature of the incubator and feeds the signal output to the 2-to-1 input time multiplexer [5].

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The Relays

The temperature control circuit consists of four relays controlled by the microcontroller. The first two relays are used for switching the incandescent lamp to a 230 V supply, the third one is used for switching a circulating fan to a 12 V supply. The last relay is used for switching the gear motor for operating the egg turning mechanism. Each of the relay is triggered using a 2N2222 NPN transistor. The base of the transistor is biased from the signal output of the microcontroller. The two 60W lamps are used for heating the air inside the incubator. The lamps are turned ON when the temperature inside the incubator is below 37° C for chick's egg and is turned OFF when it exceeds 38.5° C using a relay.

The circulating fan is also triggered using a 5Volts relay and is turned ON at the same time as the incandescent lamp. It is used for the purpose of circulating the heated air uniformly around the chamber. A gear motor is used for operating the egg turning mechanism. The gear motor is switched ON by a 5V relay and it rotates an elliptical cam connected to the egg holder. A spring is used to return the holder to its initial position. The display used is a 16x2 character LCD display with HD44780U dot-matrix liquid crystal display driver and controller. The LCD is wired in 8-bit mode.

AT89C52 Microcontroller

Since the optimum temperature for chicken egg incubation is between 37 and 38.5°C [6, 7], the microcontroller constantly check the temperature returned from the LM35 temperature sensor. For this, 1000 samples of the ADC are taken and their average is computed. The temperature is computed to two decimal places using mathematical operations and a suitable correction factor is applied to rectify an error due to the external reference voltage. If the value of temperature lies below the optimum range, a high voltage is given through the suitable pin of the microcontroller to the base of transistor T1 to trigger the relay.

The triggering of the relay turns ON the incandescent lamp through a 230V supply and the circulating fan through a 12V supply. The heat from the incandescent lamp increases the temperature of the air and this is circulated inside the incubator using the fan. This process continues till the temperature reaches above 38.5°C. Once this range is exceeded, the relay is turned off. The incandescent lamp and the fan get turned OFF till the temperature goes below the lower limit again. An LED is used for fault detection, in case the temperature goes below minimum setpoint or above maximum setpoint. An interface is provided to key in the required minimum and maximum temperature for the egg to be incubated.

Mathematical Model of the Incubation Chamber

Assume the temperature of eggs before they are placed in the incubator to be θ_1 and θ_2 be the temperature of the incubator after heat q has been transferred to the incubator causing its initial temperature to rise. LM35 sensor is used as the sensing device to take the temperature reading of the system and we want to know how long it takes the incubation chamber temperature to get to its maximum allowable temperature of 38.5°C. 38.5°C is the maximum allowable temperature for incubating chicks' egg. From the law of heat transfers which states: Temperature rise is proportional to heat added [8]

$$dq = c d\theta_1$$

(1.0)

c = heat capacity

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By dividing both sides by dt

$$\frac{dq}{dt} = \Phi = \frac{cd\theta_1}{dt}$$

(1.1)

the rate of heat transfer into the mass of egg is $\Phi = \frac{cd\theta_1}{dt}$ and the rate is governed by the thermal resistance between the air and the mass of the egg. This obeys a law similar to ohms law so:

$$\Phi = \frac{(\theta_2 - \theta_1)}{R}$$

(1.2)

Where R is the thermal resistance in Kelvin per watt

Equating for Φ we have

$$\frac{cd\theta_1}{dt} = \frac{(\theta_2 - \theta_1)}{R}$$

(1.3)

$$\frac{d\theta_1}{dt} = \frac{(\theta_2 - \theta_1)}{RC}$$

(1.4)

$$\frac{d\theta_1}{dt} + \frac{\theta_1}{RC} = \frac{\theta_2}{RC}$$

(1.5)

In all system, the product of the resistance and capacitance is the time constant τ so we have:

$$\frac{d\theta_1}{dt} + \frac{\theta_1}{\tau} = \frac{\theta_2}{\tau}$$

(1.6)

Changing from a function of time into a function of *"S"* we have

$$s\theta_1 + \frac{\theta_1}{\tau} = \frac{\theta_2}{\tau}$$

(1.7)

$$\theta_1(\tau s + 1) = \theta_2$$

(1.8)

$$\frac{\theta_1}{\theta_2}(S) = \frac{1}{(\tau s + 1)}$$

(1.9)

Where $\tau = 120$ seconds, assumed time it takes to reach maximum temperature of 38.5^0C

$$\therefore \frac{\theta_1}{\theta_2}(S) = \frac{1}{(120\,s + 1)}$$

(1.10)

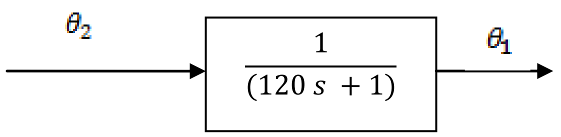

Figure 1.1: Modeled block diagram of the incubation subsystem

Mathematical Model of the Controller

The Ziegler-Nichols tuning rule was applied in the design of the parallel Proportional-Integral-Derivative controller. The PID controller was selected since it is probably the most extensively used method in industrial process control applications. The block diagram of the continuous PID controller is shown in figure 3.6, where, K_p is the proportional gain, T_i is the integral time constant, and T_d is the derivative time constant. The transfer function of the standard PID algorithm is:

$$U_{(t)} = K_p e_{(t)} + \frac{Kp}{Ti}\int_0^t e(t)dt + K_pT_d\frac{de(t)}{dt} \quad [8]$$

(1.11)

In the s-domain, the PID controller can be written as:

$$U_{(S)} = K_p [1 + \frac{1}{Ti.s} + T_d.s] E_{(s)}$$

(1.12)

The discrete form of the PID controller can be achieved by finding the Z –transform of equation above.

$$U_{(z)} = E_{(z)}K_p [1 + \frac{T}{Ti(1-z^{-1})} + T_d\frac{(1-z^{-1})}{T}]$$

(1.13)

Equation 3.14 can also be written as:

$$\frac{U(z)}{E(z)} = a + \frac{b}{1-z^{-1}} + c (1 - z^{-1})$$

(1.14)

Where

$a = K_p$, $b = \frac{K_p T}{T_i}$, $c = \frac{K_p T_d}{T}$

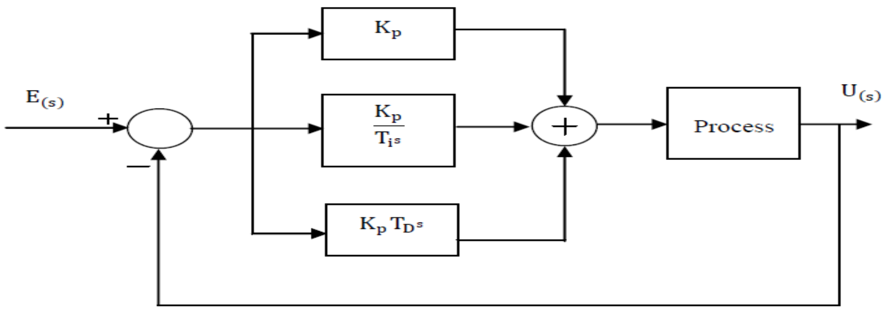

Figure 1.2: Block Diagram of a Continuous Parallel PID Controller

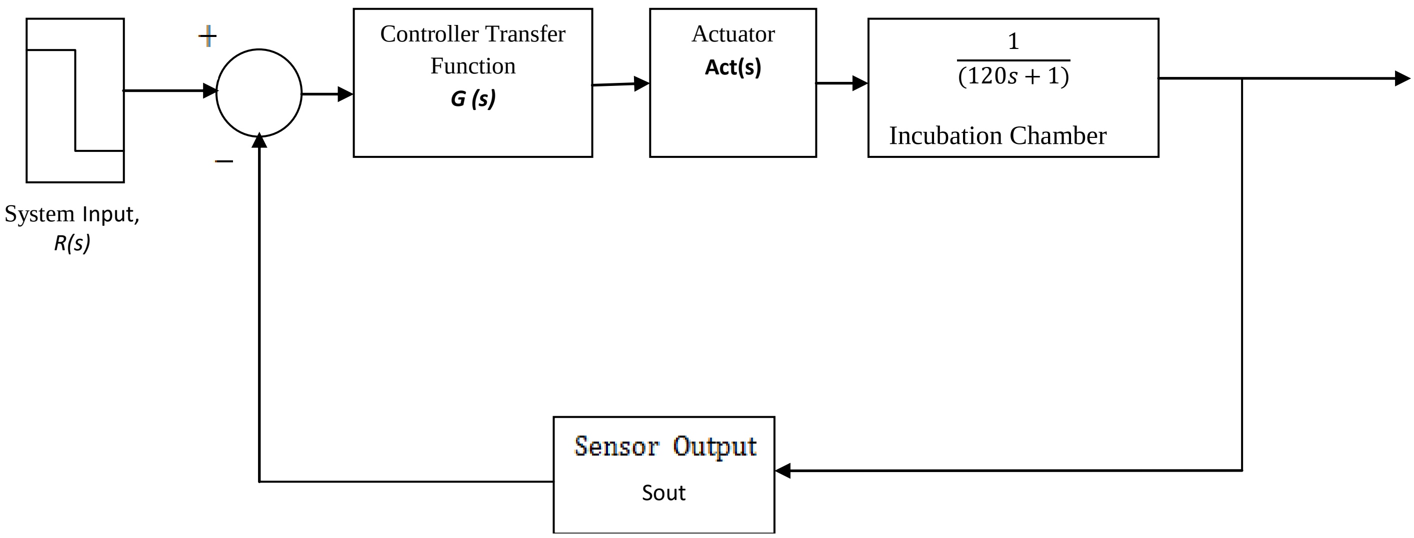

Figure 1.3: Block Diagram of the Closed Loop Incubation Temperature Control System

SIMULATION AND RESULTS

The entire system which is made up of controller, actuator, incubation chamber and sensors were modeled and validated via simulation using Matlab /Simulink. In the course of the simulation, several parameters of the PID temperature control were tuned employing Ziegler Nichol tuning method in order to ascertain the values of the parameters that gave the desired transient response of the system when subjected to a unit step input. The simulated results of the system control with PID tuning were analyzed. Figure 1.4 shows the simulink block diagram of the incubation system.

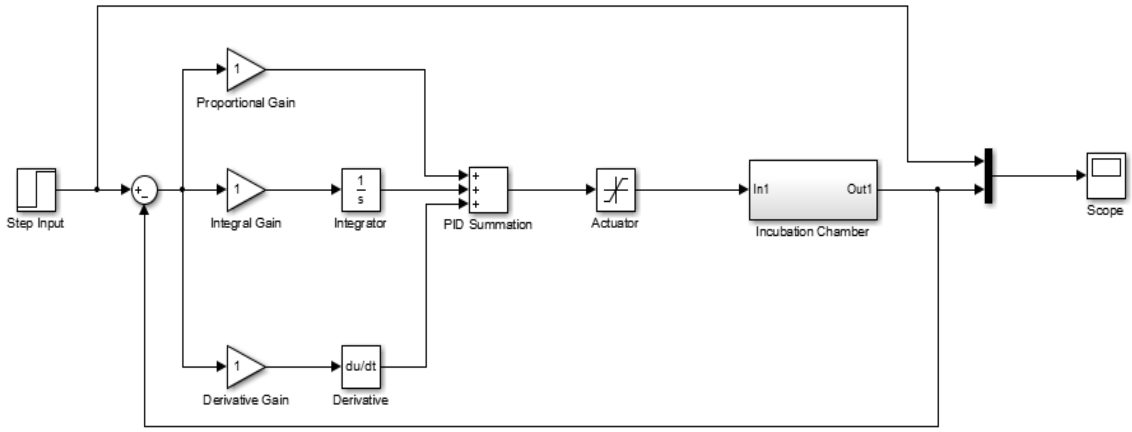

Figure 4.1: Simulink Block Diagram of the incubation temperature control system

TEST 1: Consider the following assumed values of the parameters of the PID controller and the response of the system to these values

TABLE 1.0:The first assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Values (sec)	0.2850	0.1170	0.3626

PLOT

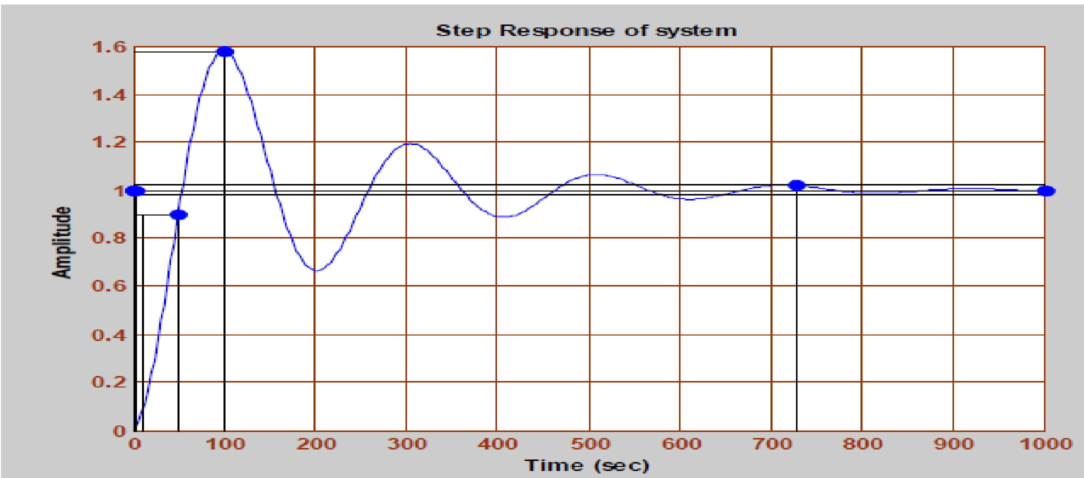

Figure 1.4: Scope of the unit step response of the system for test 1

RESULT:

TABLE 1.1: Result of test 1

parameter	T_r (sec)	T_p (sec)	T_s (sec)	Mp (%)
Values	37.8	100	728	58

TEST 2:

TABLE 1.2: The second assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Value	1.9689	0.0504	0.6300

PLOT:

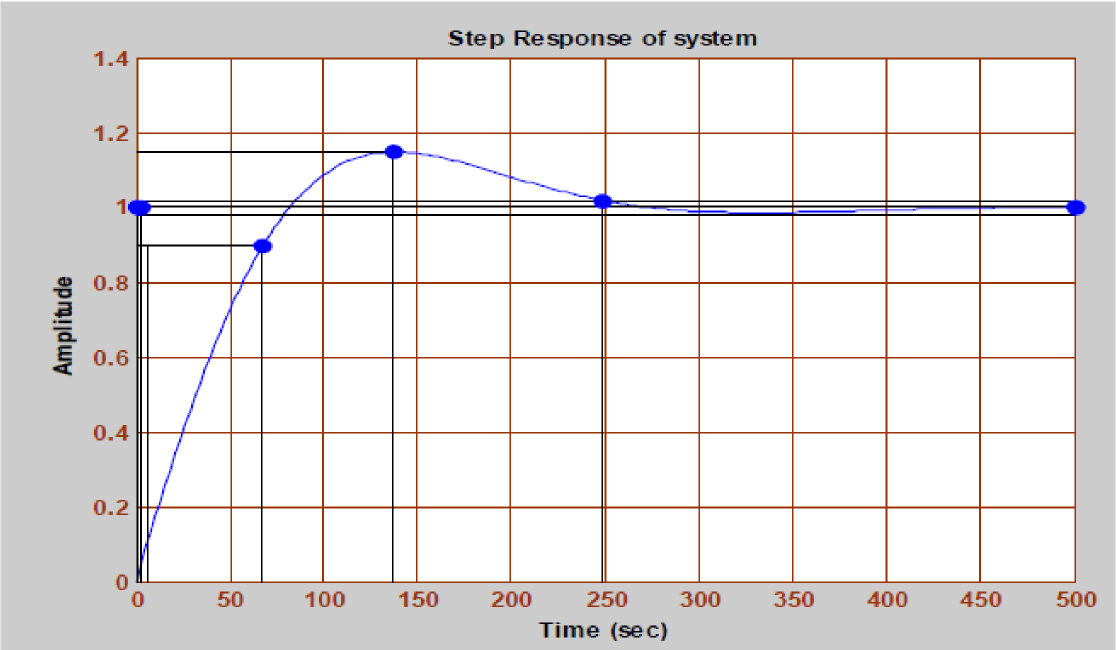

Figure 1.5: Scope of the unit step response of the system for test 2

RESULT:

TABLE 1.3: Result of test 2

Parameter	T_r (sec)	T_p (sec)	T_s (sec)	M_p (%)
Values	62.0	138	249	15.0

TEST 3:

TABLE 1.4: The third assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Values (sec)	16.374	0.1325	3.3288

PLOT:

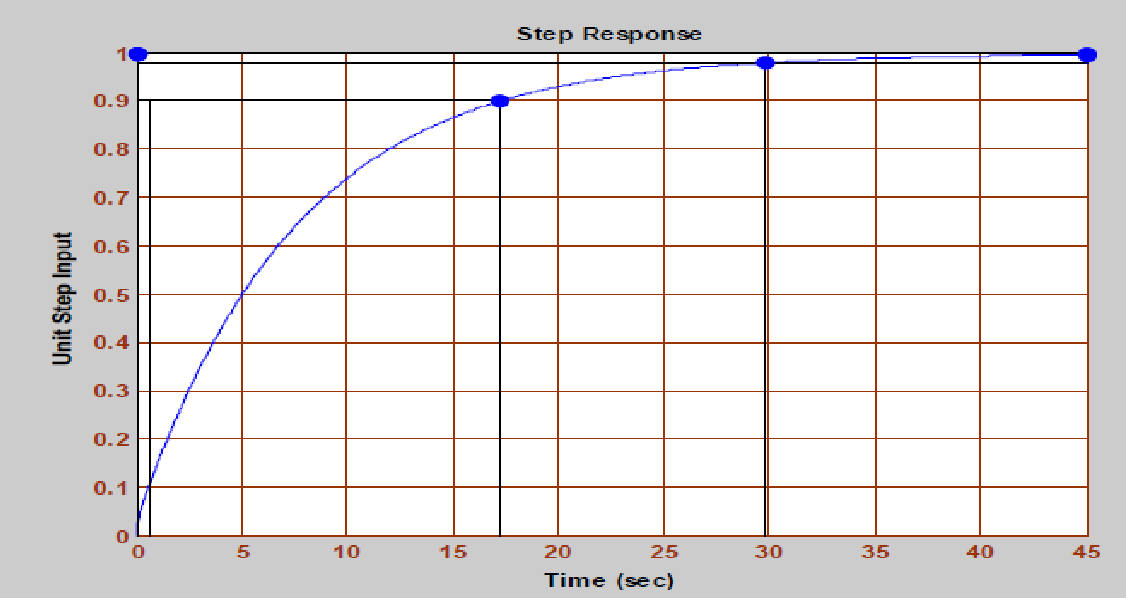

Figure 1.6: Scope of the unit step response of the system for test 3

RESULT:

TABLE 1.5: Result of test 3

Parameter	T_r (sec)	T_p (sec)	T_s (sec)	M_p (%)
Values	16.8	----	30.0	----

RESULT ANALYSIS

Using Matlab/Simulink toolbox, various parameters were tested and the best parameters were used for PID implementation on the microcontroller. The results showed the system responses to a step input with varying PID temperature control parameters based on Zeigler-Nichols tuning method. It can be inferred from the results that the optimal set of parameters that gave a more desirable transient response in terms of short rise time, low overshoot, short settling time, low steady state error were gotten from the results of test 3 where:

Proportional gain, K_p = 16.374,

Integral time, T_i = 0.1325,

Derivative time, T_d = 3.3288.

Hence, a PID algorithm implemented on a microcontroller using the set of parameters obtained from test 3 will exhibit a better control performance to changing temperature conditions in the incubation system.

CONCLUSION

This work develops a model, design and simulation of a temperature control of a smart egg incubator system for various types of egg. Keypad was incorporated in the system which allows the operator to key in the temperature value within the range of 35- 40^{o}C, depending on the type of egg to be incubated. Temperature was measured using LM35 Ic and its value displayed at the LCD. 4-relays were used for the switching of the incandescent lamps, fan motor and DC motor. Weight sensor was used to monitor the weight of egg in the incubator.

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Monitoring of weight becomes necessary in order to ensure that the embryo is properly developing.

The PID controller implemented in microcontroller control the temperature of the system. Simulation was carried out by varying the temperature parameters of the PID controller in order to obtain set of parameters that when implemented in microcontroller ensures temperature stability at the incubator.

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