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Design of a Microcontroller Based Programmable PID Controller for Temperature Control

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Abstract—*PID algorithm enables the system in having a high temperature measuring and control accuracy. The system circuit is a simple clear structure and easy to use and understand. The controller generates the output according to error signal and derives the system in achieving the zero error. The response of the PID controller is an outcome of series of codes implied on the microcontroller. The experimental results are demonstrated in the form of graphs. It is an approach to generalize this type of system to develop a cost efficient system and is submitted to scientific community for future applications.*

Keywords*: Controls, Temperature, PID, Microcontroller.*

1. INTRODUCTION

There are many processes and places where there is a need of ambient temperature to be set all through the processes. The physical and chemical reactions prove to be very sensitive to environmental changes. It causes to disturb their physical and chemical properties. Temperature controllers need to be implied for maintaining the temperature to the set point[1, 2]. This could be possible through the use of digital computers. They have the feature of adaptability and programmability with high accuracy. With the sensor output in voltage that is converted by the microcontroller into its binary division[1]. A temperature controller with sensor output given in frequency and time interval was developed by O.I.Mohammad.et.al.

This paper describes a microcontroller based temperature controller developed using LM-35 as sensor. This proposed scheme has the advantage of a simple and easy to understand hardware that is developed by using a microcontroller and a relay for switching process. Since the sensor used is LM-35, this experimental kit has a range of -55 to 155 degree celcius.

2. PRINCIPLE OF OPERATION

The block diagram of the proposed setup is shown in Fig. 1.

From the Fig. shown, the temperature sensor LM-35 senses the temperature of the water in the electric heater. The measured temperature in terms of voltage is given to the microcontroller. The microcontroller is fed with the desired set point. The microcontroller calculates the difference in the values generated by the sensor[3].

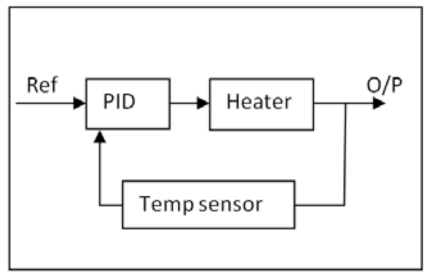

Fig. 1: Block diagram of the proposed setup

3. GENERAL DESIGN OF THE SYSTEM

3.1 Hardware Design

3.1.1 Main Controlling Unit

The microcontroller used is ATmega328. It is an open source physical computing platform and develops environment for writing software for the system. It takes inputs fro variety of switches and sensors and controls a variety of physical outputs.

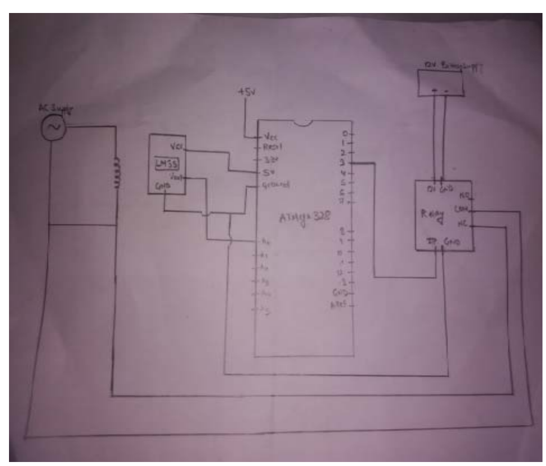

Fig. 2: Hardware design of the setup

3.1.2 Temperature sensor

The sensor used is LM-35. It is an integrated circuit sensor with a voltage output proportional to the temperature. The scale factor is 0.01V/°C. it can also be said that it has a sensitivity of 10mV/°C.

3.2 Software Design

The language used for programming is 'Embedded C'. It is a simple and has an expandable set of codes. The programs can be well understood and easy to follow.

The microcontroller has 14 digital input/output pins and 6 analog input pins. It has got a clock speed of 16MHz. The controller is provided with UART TTL (5V) serial communication which is available on pins 0 and 1. It also supports 12C(TWI) and SPI communication.

4. MATHEMATICAL EQUATION OF HEAT TRANSFER SYSTEM

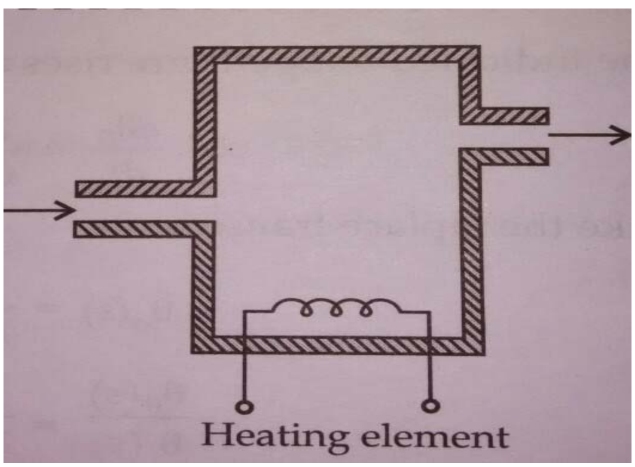

Fig.3: Block diagram of a thermal system

Suppose, there is no heat store in the system and water having uniform temperature, the equation developed is

$$Q = C(d\theta_0/dt) + \theta_0/R \qquad \ldots\ldots (1)$$

Where Q = rate of heat flow from the heating element. θ_0 = temperature of water. R = thermal resistance[2, 3].

With reference to equation(1), it can be said that the time constant of the electric heater is RC.

So in the setup taken for the experimental values, the heater has the operating power of 700W. so the resistance of the heater is ought to be 46Ω.

The setup developed is firstly observed under normal conditions with no control system applied. The heater takes 4minutes 15 seconds to heat the water at 50°C at room temperature.

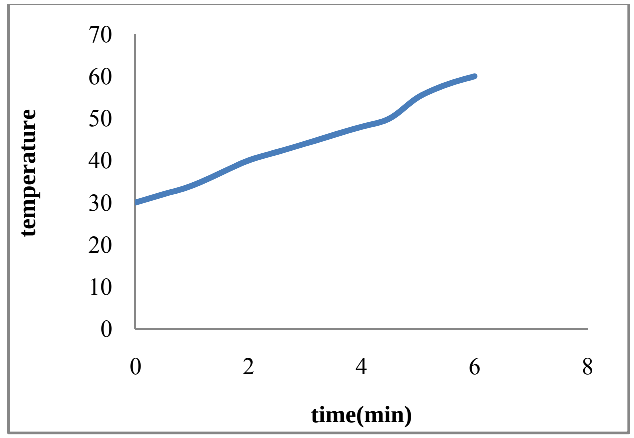

Fig. 4" Time response of the heater with no control system applied.(Open loop system)

5. WHAT IS PID?

A Proportional-Integral-Derivative controller is a feedback system. It calculates the error value as the difference between a measured process and a desired set point. There are three parameters of PID for tuning a system to the desired set point. Adjusting these values will change the way the output is adjusted.

5.1 P only' Controller

'P only' Controller stands for Proportional only Controller. Proportional is termed under the present error defined with the desired set point[2, 5].

Our desired set point of the system is 50°C. so, the error in the output before or after reaching 50°C is calculated and accordingly the relay is set to switch on/off in the system.

Implication of Proportional Controller increases the rise time of the system and eventually tries to improve the time constant in reaching to 50°C.

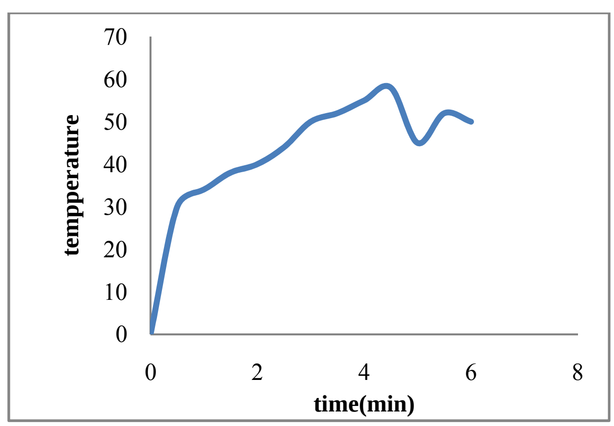

Fig. 5: Time Response of P only controller for the system.

From the response shown in Fig. 5, it can be seen that the response rises very speedily to 50ºC. It can also be seen that the response rises to some higher extent as well. After some time it decreases to a lower value of 48ºC and then rises back to 50ºC. So, we require reducing the steep rise and even cutting short the deviations in the response.

5.2 PI Controller

A Proportional – Integral Controller is a combination of Present errors and cumulations of past errors of the system[5].

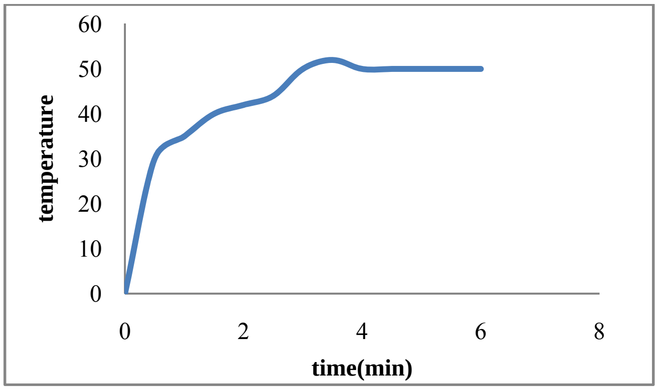

Fig. 6: Time response of the PI controller for the system

From the response shown in the fig,6, it can be seen that the overshoot that has been generated due to proportional control has reduces from 55ºC to 52ºC. The response also settles down to 50ºC in 4 minutes.

The time response improves to a commendable value but it can be given a last shot to improve the response to a better position. So, a differential controller is added to the PI Controller.

5.3 PID Controller

The Proportional-Integral-Derivative Controller is a combination of all the present errors, past errors and estimation of future errors. All the errors determined eventually lead to the system perform in an error free condition[5].

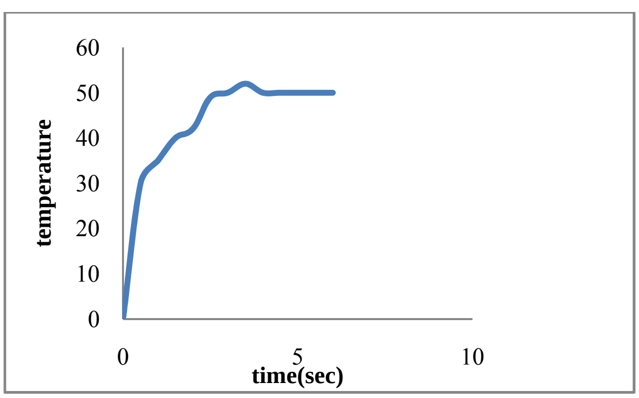

Fig. 7: Time Response of PID controller

6. CONCLUSIONS

1) The performance of the electric heater has been studied and parameters of the PID controls are obtained.
2) The manual control of the system gives factors needed for improvement through feedback response.
3) The P, PI, PID Controllers give the stepwise rectifications in the optimization of the results as desired.
4) The PID Controller added to the system can estimate the error and control the input of the system preventing from delay and wastage simultaneously.
5) The P, I & D parameters set for a system can be said to be unique. They can be different for different systems.
6) It is observed that for any system to be stable, PID can be a good solution, and the parameters resulting in a perfect solution is an important step which may require a number of iterations.

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