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Design and Implementation of a Microcontroller Based Roasting Machine Using Software Based PID Controller

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Abstract :*this research work was devoted to design and implementation of a microcontroller based temperature control for roasting machine, the study of programmable controller and PID controller. The principle of microcontroller was demonstrated in the temperature control of a roasting machine. The system was built around AT89S52 microcontroller and utilize keyboard /display interface, ADC, Solid state relay as helper chips. The PID software based was developed using AT89S52 instruction set. Experimental test was conducted for both the open loop and the closed loop. The results show that PID controller was able to track the temperature set point with minimal steady state error.*

KeywordS–*Microcontroller, Oven, PID Controller, Roasting Machine, Temperature Control*

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I. Introduction

Electrical appliances such as ovens, incubators, roasting machine and so on need their inferior temperature to be controlled accurately within a desired range[1]. These devices have been playing significant roles in our houses, hospital, food processing industries etc. oven is an enclosed compartment for hearting, baking or drying[2].they are widely used in hospitals for sterilization of medical equipment, in our homes for baking, cooking and Roasting. In food processing industries controlling temperature is very important for culturing bacteria and other microorganism [3]. For best results the interior temperature of such devices need to be controlled as desired by any category of users.

Conventionally, such controls have been achieved in electrical appliances with the aid of thermostat or electronically via relay. Relays, being electromechanically actuators are characterized by terminal ganging as a result of the sparks generated during switching, leading to system failures. Thermostat on the other hand utilized the principles of bi-metallic strip which depends on the coefficient of linear expansivity of the materials used. These have been used in appliance such as electric irons, ovens, and so on. Unfortunately, the coefficient of linear expansivity of materials changes with time and this affects the precision of the thermostats[4]. Today, ovens are not only required to maintain fixed interior temperature but should also be capable of following a temperature profile faithfully and with better user friendliness. For example, in supermarket, the profile could be such that, the oven starts at high temperature to roast some pieces of meat and thereafter, adjust its temperature automatically to maintain it content warm.

Additionally, oven distribution of heat around the contents is now a necessary function of such systems. These requirements create more control challenges that cannot be met with conventional control devices such as the thermostats or relays. To achieve these requirements therefore, it is very necessary to develop a more drastic control system that could offer better accuracy, reliability, flexibility and user friendliness. One way to achieves this is to use the top-down approach, which requires that each of the functionalities be implemented separately, then the units can be inter connected to provide the overall system functionality. This research work Focus on the design and implementation a microcontroller based PID controller for the temperature control of a roasting machine. The proportional controller is to speedup error convergence. The integral part ensures zero steady state error while the derivative acts as a damper to minimize temperature overshot[5].

II. System Description

The system comprises of microcontroller keyboard, display Unit, a heater, actuators, and analog to digital converter (ADC). The system is built around AT89S52microcontroller. When the system is powered, the heater is triggered on by microcontroller through a solid state relay. The temperature in the oven is sensed by the sensor (LM35) which is a physical quality. This temperature is being converted to voltage with the help of a transducer. Since the amount of the voltage sensed is not reasonable enough for the ADC to use, the amplifier

LM4558 was used to amplified the voltage and give out the amplified voltage to the (ADC) analog to digital converter. The analog to digital converter convert the analog voltage into a digital one which the microcontroller read the actual voltage and them compares it with the desired. If the actual temperature (voltage) sensed by the sensor is less than that of the desired. The microcontroller sends a control signal to solid state relay. the solid state relay increases the energy of the heater, thereby increases the peak voltage and so the temperature in the oven is risen. On the other hand, if the actual voltage in the oven is greater than that of the desired, the microcontroller also sends a control appropriate signal to the solid state relay and so the temperature in the oven decrease by the decrease in the peak voltage. At any point in time when the temperature is inputted through the keyboard, both the desired and the actual will be display liquid Crystal Display (LCD).

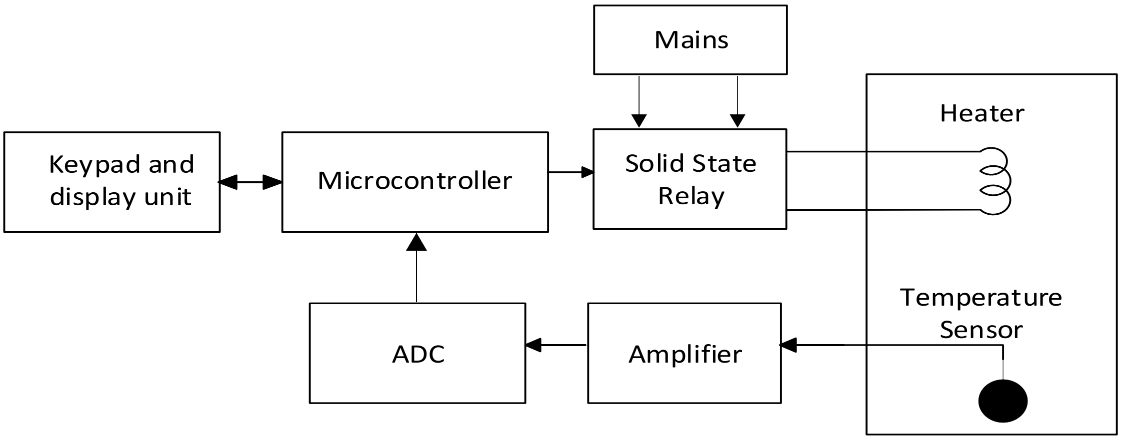

Fig 2: Complete System Block Diagram

III. Design Procedure

The implementation of this research work was carried out in two major phases; - Hardware and Software The hardware aspect involves the design of the various modules making up the system; this is followed immediately by the implementation of each block. The software algorithm was developed using assembling language.

3.1 Power Supply Unit

The unit generates 5v dc power supply using LM317 voltage regulator. From the block diagram shown below, a step down transformer is used to step the 220V ac for the mains to 15V ac. The voltage is rectified that is; converted to dc and then filtered. The regulation stage regulates the voltage to give the desired output.

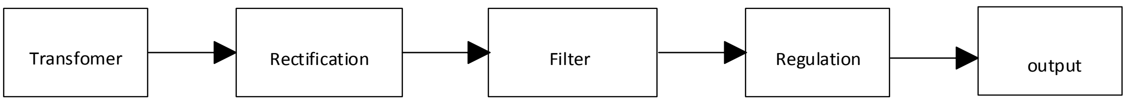

Fig 3: Block diagram of power supply unit

3.2 Solid State Relay and Microcontroller Unit

This unit controls the heater energy via Pin 3.6 of the microcontroller. The heater is turn off if a ‘0’ is sent to the port and turn on if a ‘1’ is sent to the port. The resistor at the base of the NPN transistor is used to bias the transistor which is use for switching the solid state relay. The AT89S52 is a low power, high performance CMOS 8- bit microcontroller with 8 kilobytes of in – system programmable flash memory [8]. The device manufactured using Atmel’s high density nonvolatile memory technology and is compatible with industry standard 80C51 instruction set and pin out.

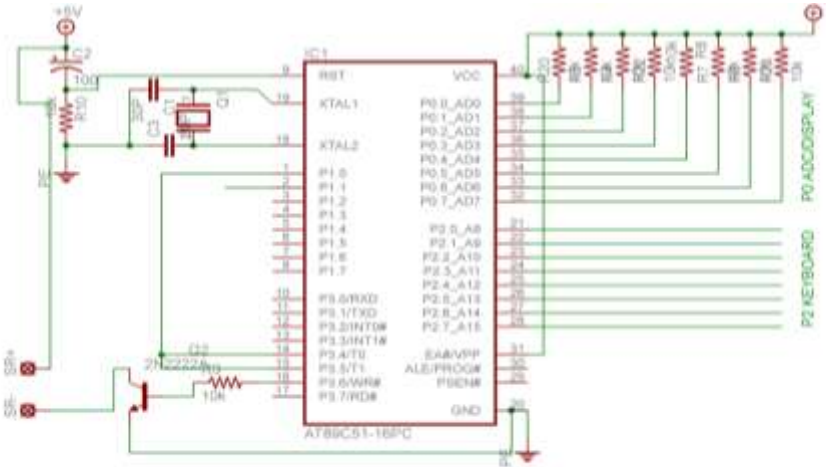

Fig 4: Microcontroller Schematic Diagram with Solid State Relay

3.3 The ADC Unit

The Analog to digital converter (ADC0804) is designed using only reference resistor, clock capacitors for its operation. All value of external resistors used are suggested by the chip manufacturer. Thermistor, which senses the temperature in the oven, is connected to the ADC via a 5KΩ variable resistor. The ADC receives the temperature in form of voltage and then converts it to digital form (0_s and 1_s) that can only be understood by the microcontroller. The voltage converted is sent to the microcontroller via port zero.

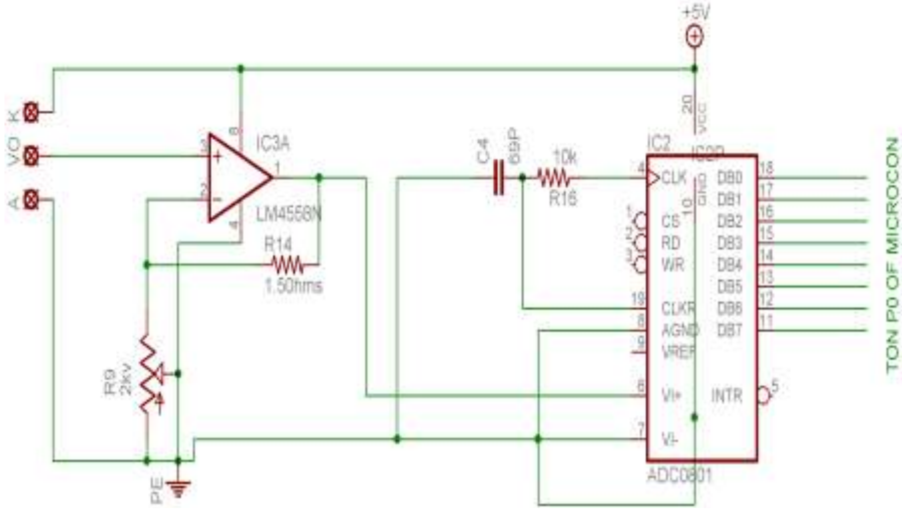

Fig 5: Analog to Digital Converter in cooperated with an Amplifier

IV. Process Model

The experimentally obtained step – response is shown in Figure 6: the process has a dead time and it is damped. Therefore, the step – response can be fitted into a simple first order model with dead time:

$$G(s)=\frac{K\ell^{-\theta s}}{\tau s+1} \qquad (1)$$

Where K is the process gain

θ is the death time

τ Is the time constant

Referring to the graph in figure 6:

$$K=\frac{(270-25)^{o}C}{3500W}$$

$K=0.07^{o}C/W$

τ = 1090s

θ = 17s

Therefore:

$$G(s)=\frac{0.07\ell^{-17s}}{1090s+1} \quad (2)$$

V. Software Based PID Control Algorithm

The transfer function of the PID controller is given as[6]:

$$G(s)=K_p+\frac{K_i}{S}+K_dS \quad (3)$$

From Ziegler and Nichols PID controller is given as:

$$K_p=\frac{1.2\tau}{K\theta} \quad (4)$$

$$K_i=\frac{1}{2\theta} \quad (5)$$

$$K_d=0.5\theta \quad (6)$$

Using the above data's obtained from the graph. K_p, K_i and K_d become;

$K_p=1099.15$, $K_i=0.03$ and $K_d=8.5$

By experimental tuning the values of the PID above become:

$K_p=200$, $K_i=0.25$ and $K_d=50$

In digital mode PID controller becomes

$$D_z=\frac{U_z}{E_z}=K_p+\frac{K_iTs}{2}\left(\frac{z+1}{z-1}\right)E_z+\frac{K_d}{Ts}\left(\frac{z-1}{z}\right) \quad (7)$$

$$U_z=K_pE_z+\frac{K_iTs}{2}\left(\frac{z+1}{z-1}\right)E_z+\frac{K_d}{Ts}\left(\frac{z-1}{z}\right)E_z \quad (8)$$

$$U_z=(z-1)U_z+K_pE_z-K_p(z-1)E_z+\frac{K_iTs}{2}E_z+\frac{K_iTs}{2}(z-1)E_z+\frac{K_d}{Ts}E_z-\frac{K_d}{Ts}(z-1)E_z+\frac{K_d}{Ts}(z-2)E_z \quad (9)$$

Take the inverse z-transform of the equation above, we have the following:

$$U(k)=U(k-1)+K_pE(k)-K_pE(k-1)+\frac{K_iTs}{2}E(k)+\frac{K_iTs}{2}E(k-1)+\frac{K_d}{Ts}E(z)-\frac{2K_d}{Ts}E(k-1)+\frac{K_d}{Ts}E(k-2) \quad (10)$$

Substituting the values of PID in the equation.

$$U(k)=U(k-1)+200E(k)-200E(k-1)+\frac{0.25\times10}{2}E(k)+\frac{0.25\times10}{2}E(k-1)+\frac{50}{10}E(k)-\frac{2\times50}{10}E(k-1)+\frac{50}{10}E(k-2) \quad (11)$$

$$U(k)=U(k-1)+206E(k)-209E(k-1)+5E(k-2) \quad (12)$$

The control equation can be re-written in Hexadecimal as:

$$UH=U(k-1)H+(CE)HE(k)-(DI)HE(k-1)+5E(k-2) \quad (13)$$

Data to be loaded into the microcontroller is calculated as follow:

Data loaded (in decimal) = $DL=\frac{Ts}{\frac{V^2}{R}}\left(\frac{10000}{10}\right)U$ (14)

Where:

$Ts=10s$ sampling time

$\frac{V^2}{R}=3500W$ power of the heater

$$DL=\frac{10}{3500}\left(\frac{10000}{10}\right)U \quad (15)$$

$$DL=3H\times UH \quad (16)$$

VI. Experimental Results

6.1 Open loop Test

A digital millimeter (mas – 34x) with a PC interface was used to obtain the oven temperature. The meter was set so as to measure the temperature for about 30minits at every 10seconds interval. The data obtained for the temperature against time of the oven without the control system was plotted as shown in figure 6

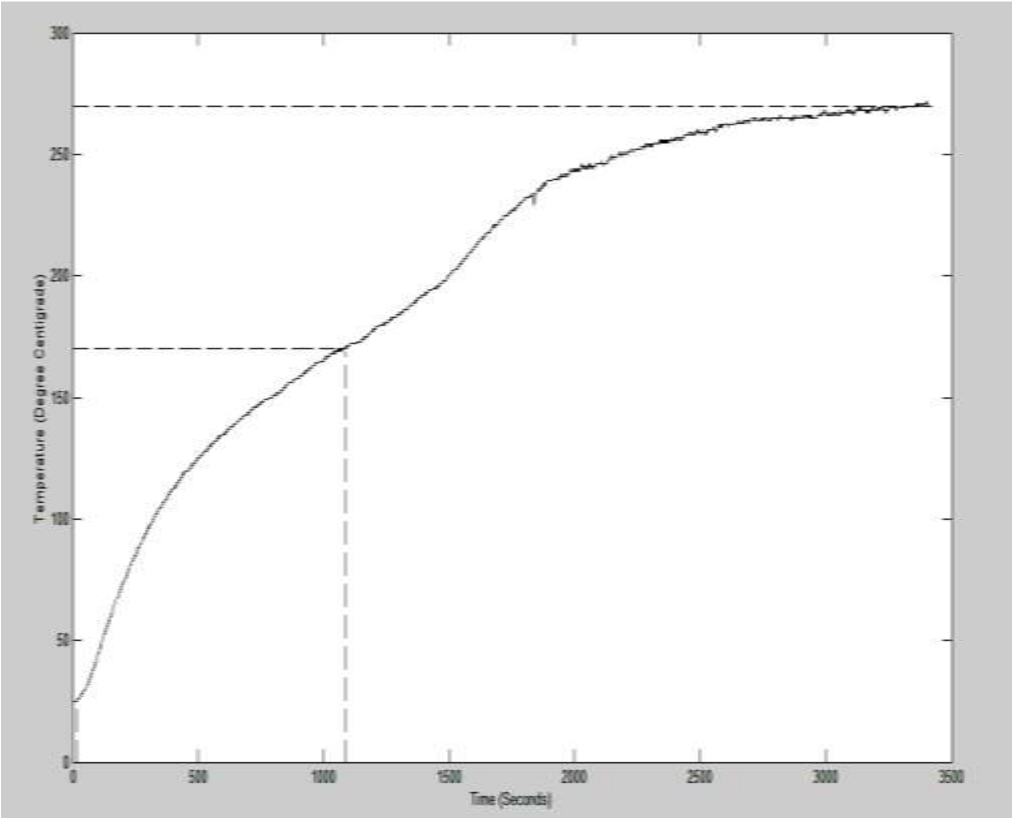

Fig 6: Graph of Temperature against Time

From the graph shown above, it can be seen that the temperature increases with time. At 270^{o}C the temperature of the oven is stabilizes.

6.2 Close loop Test

Thetemperature control capability of the system was investigated. The temperature ranges from 30 to 140 degree Celsius were set and compared with the measured steady state values as shown on table.

Table 1: Close loop results with the steady state error

S/N	Desired Temperature (^{o}C)	Steady state Measured Temperature (^{o}C)	Steady State Error
1	30	31	1
2	40	42	2
3	50	51	1
4	60	60	0
5	70	72	2
6	80	81	1
7	90	92	2
8	100	100	0
9	120	121	1
10	130	130	0

6.3 Complete system setup

Fig 7: Front view of a roasting machine

Fig 8: complete system circuitry

VII. Conclusion

Roasting machine was designed and implemented with the reliable components.

The software based PID control algorithm was successfully designed and implemented on ATMEL AT89S52 microcontroller. Close loop experimental test was conducted and the results obtained show that the candidate controller was able to track the reference temperature with minimal steady state error.

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