TEMPERATURE CONTROL APPLICATIONS BY MEANS OF A PIC16F877 MICROCONTROLLER

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ABSTRACT

In this study, temperature of a closed environment is kept constant by a PIC16F877. The microcontroller holds the fuzzy control process or PID control process, individually. The temperature data is acquired from LM 35 temperature sensor and the control output determines speed of a 220V AC fan by means of a PWM and a triac triggering circuits. The heat control system will be used to cool a highly sensitive measurement device. Refer to the results, performances of these two control methods are compared.

I. INTRODUCTION

A glass container, dimensions of which is 20*20*30 cm is aimed to be cooled by PID and fuzzy control methods. The container is heated by a resistance and heat of the inner environment is increased depending on the outer environment. The microcontroller acquires the temperature data and its control output adjusts the cooling rate of the fan in order to decrease heat of the inner environment down to the outer conditions. The control system will be used to eliminate the self-heating effect of the resistors of a measurement device which increases uncertainties in the measurement. Fuzzy and PID control methods obtain a highly stable temperature in the container.

II. THE HEAT CONTROL SYSTEM

The system is composed of a 300W heater resistance, a temperature sensor, a measurement amplifier , a controller, a digital/analog converter, a pulse width modulator, a triac triggering circuit and a 220V AC fan. Programming of PID and fuzzy control algorithms are prepared in PIC assembler codes.

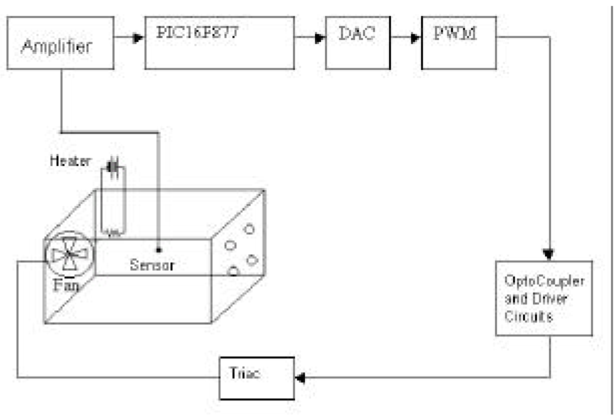

Figure.1- Block Diagram of the Control System

INPUT LAYER

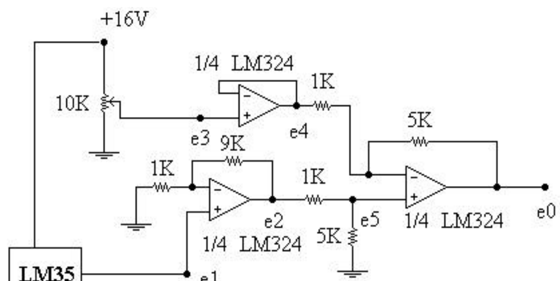

Figure.2- Heat Sensor and Measurement Amplifier [11]

The input layer contains a LM35 temperature sensor and a measurement amplifier. LM35 produces 10mV per ^{0}C [13]. Therefore 35 ^{0}C is represented by 350 mV. As shown in figure.2;

$$\frac{e_2}{e_1} = 1 + \frac{9}{1} = 10 \qquad (1)$$

$$e_4 = e_3 \quad , \quad \frac{e_2}{6}5 = e_5 \qquad (2)$$

Refer to Eq.1, e_2 will be 3,5V. If adjustable set value e_3 is set to 2.5V, then output e_0 will be

$$e_0 = e_5\left(1+\frac{5}{1}\right) - e_4\left(\frac{5}{1}\right) = 6e_5 - 5e_4 = 5e_2 - 5e_3 = 5(e_2 - e_3) = 5V \qquad (3)$$

MICROCONTROLLER SECTION

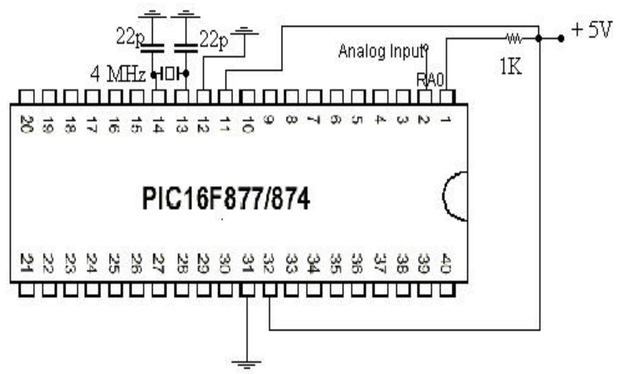

Figure3. Crystal and Voltage Supply Connections

The amplifier output e_0 is read by analog input (RA0) and converted to digital data by A/D converter of the microcontroller.[8]

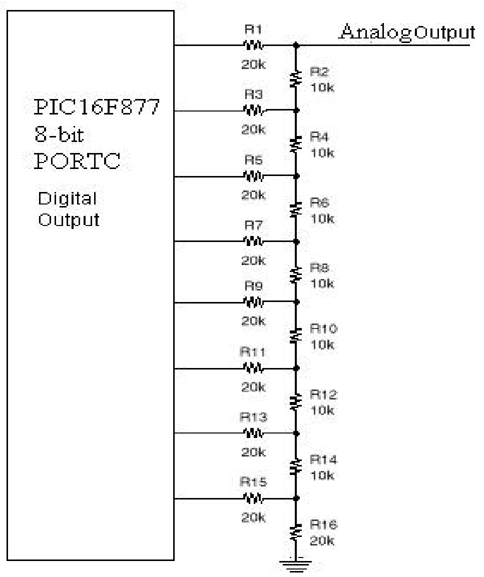

Figure4. 2-2R Ladder Scheme

The converted data is processed by the PID control or the fuzzy control programs.

The processed digital data which is received from port C of the microcontroller is reconverted to analog data by a 8 bit ladder 2-2R DAC circuit as shown in figure.4. [7]

OUTPUT LAYER

This section is consist of a PWM, a fan driver and an LCD driver.

Pulse Width Modulation Circuit:

DAC output is input modulation data of the PWM circuit and is required to determine speed or rotation interval time of the cooling fan.

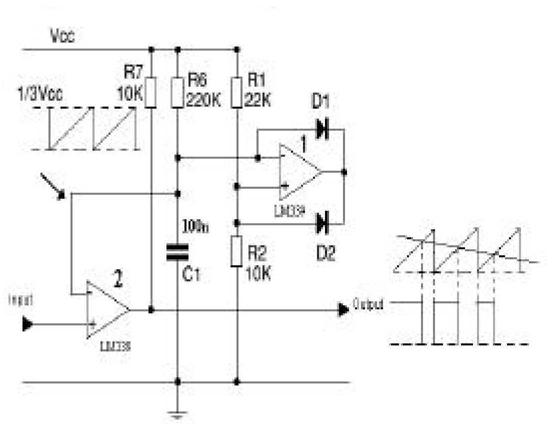

Figure5. Pulse Width Modulator

Charges and discharges of C_1 creates a sawtooth signal. The 2nd voltage comparator LM339 is used to compare sawtooth and input signals. [12] While amplitude of input signal is greater than the sawtooth's amplitude, the comparator output produces $+V_{CC}$. [14]

Circuit of The Fan Driver

PWM output is applied to an optocoupler which drives BD177 NPN transistor. The transistor supplies sufficient current to trigger the triac BT138 which adjusts the fan's speed refer to pulse wide of the trigerring signal.

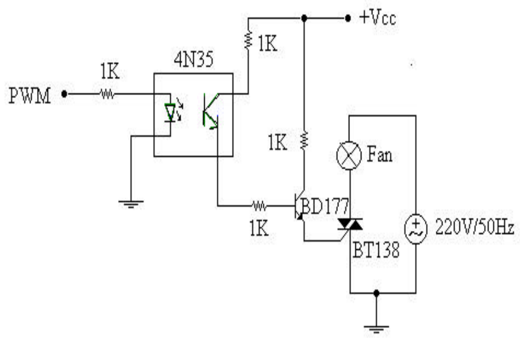

Figure.6- Triac Trigerring Circuit

LCD Heat Display Unit:

An LCD driver circuit is set to monitor temperature in the glass container. [10]

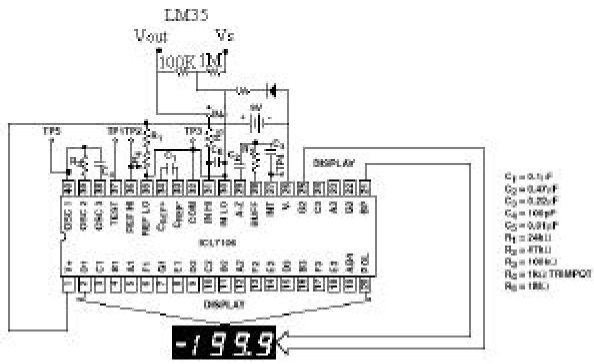

Figure.7- Circuit of the LCD Driver

II. CONTROL METHODS

The controllers allow to fix the heat of the system by means of adjusting the fan's cooling rate.

STAGES OF DIGITAL PID CONTROLLER DESIGN

The use of digital controllers are increasing gradually in the last decades . Developments in the electronics and microprocessor technology brings out the need for discrete approximation to PID controllers. Block diagram of a closed loop digital controller is shown below. [1]

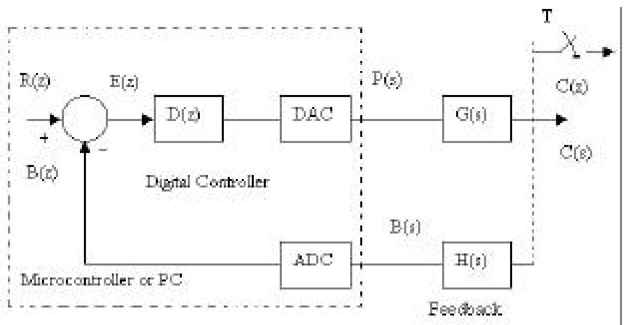

Figure.8- Block Diagram of a Closed Loop Digital Controller

Control signal of the PID controller for each sampling interval (T) is determined as;

$$P_1 = P_0 + (e_1 - e_2).Kp + (e_1 - 2e_2 + e_3).\frac{Kd}{T} + (e_1 + e_2).\frac{Ki.T}{2} \qquad (4)$$

where;

Kp, K_d and K_i are coefficients of proportional, integral and derivative elements, respectively. P0 is the the control signal of the previous sampling, e_1 is the current error, e_2 is error of previous sampling and e_3 is the error of the sampling before previous sampling. [4]

And the PID algorithm which is used in the microcontroller is obtained by using approximate trapezoidal iteration and derivative, as shown in figure.9 ;

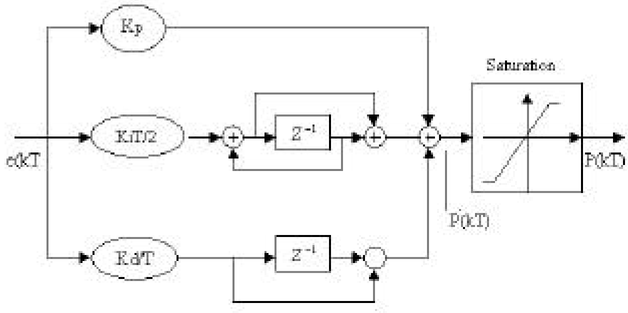

Figure.9- Structure of the Realized PID Controller

STAGES OF FUZZY CONTROLLER DESIGN

The heat of the system is sensed by a sensor and compared with the set value. The error between the actual and set value is called to be set/actual offset. This offset determines the main fuzzy linguistic rules of the system. They are as follows:

"If the offset is large, then cool the system, more"

"If the offset is very small, then don't change the cooler, much "

Fuzzy logic processing runs under these rules and the rules related to the rate of change of the set/actual offset. This allows us very smooth adjustment of cooling rate. Input data of the offset is calculated by means of taking relative heat difference of actual heat to the set value as shown below.

E= (Actual Heat of the System)-(Set Value) (5)

Input data for rate of change of offset (Δ E), is the difference between the last value of E, (E_n) and the previous value of E, (E_{n-1}):

Δ E= (E_n) - (E_{n-1})) (6)

The figures shown below represent condition and conclusion membership functions. Condition membership functions represent offset (E)

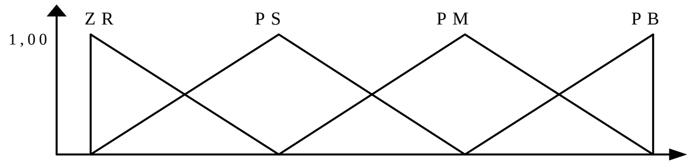

Figure 10. Membership Functions for E

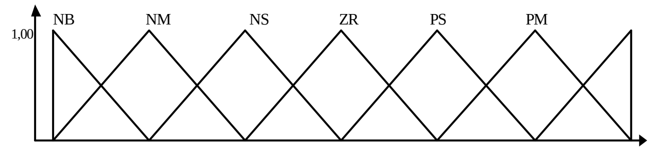

Figure.11 Membership Functions for Offset Change of Heat

and rate of offset change in heat (ΔE). Conclusion membership function represents adjustment of the fan's speed.

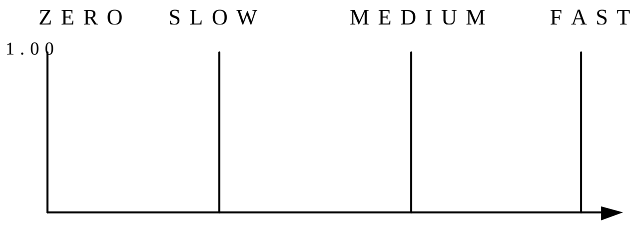

Figure.12- Membership Functions of the Variable That Adjusts the Fan's Speed

Rules are created by organizing our information and past experiences about a system, with expressions which is being used in daily life. In organizing these expressions a way may be followed such as below:

Table.1 Organising the Rules

Error	About Zero (Heat =Set Value)	Big (Heat > Set Value)		Very Big (Heat >> Set Value)
Change of Error	**ZR**	**PS**	**PM**	**PB**
Heat is Decreasing ***NB***	ZERO	ZERO	SLOW	MEDIUM
NM	ZERO	SLOW	SLOW	MEDIUM
NS	ZERO	SLOW	MEDIUM	MEDIUM
No Change ***ZR***	ZERO	SLOW	MEDIUM	FAST
PS	SLOW	SLOW	MEDIUM	FAST
PM	SLOW	MEDIUM	MEDIUM	FAST
Heat is Decreasing ***PB***	SLOW	MEDIUM	FAST	FAST

III. CONTROL PROGRAM

The control program is written in assembler codes and converted to hexadecimal codes by the MPLAB software. Hex codes are transferred to the PIC by a programmer that we've formed according to the scheme below[9];

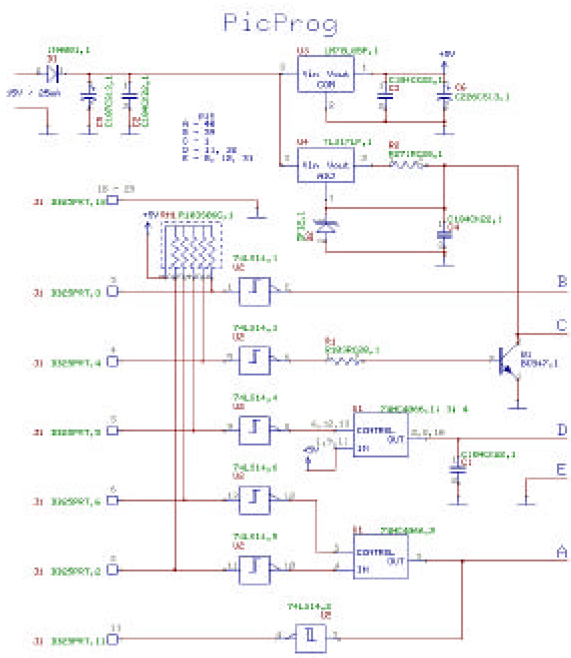

Figure13. PIC Programmer

Flowchart of the control program is shown in figure.14;

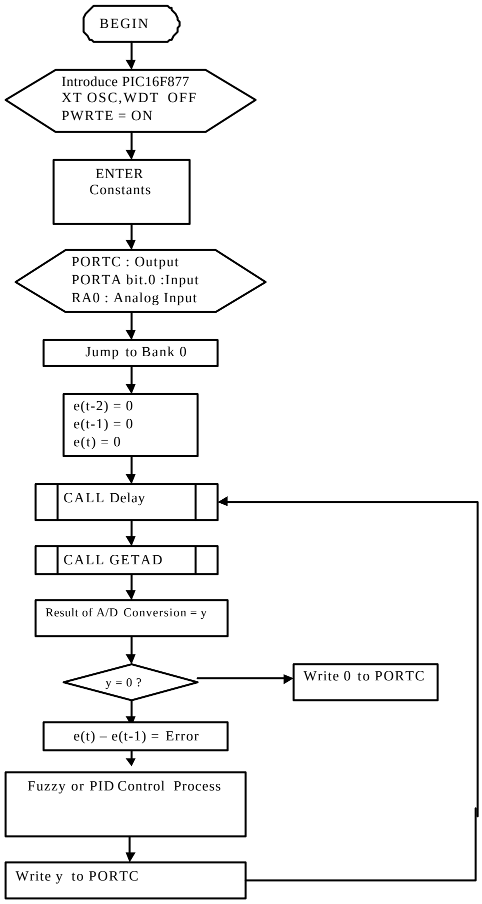

Figure14. Program Algorithm

IV. EXPERIMENTAL RESULTS

While temperature of the outer environment is 30^0C, the container is heated during 18 minutes and then heat of inner environment is measured as 39^0 C. Graph of heating versus time for the container is shown in figure.15. Using a 12 bit analog I/O card, the results are converted to graphs in computer environment by means of pascal programming language .

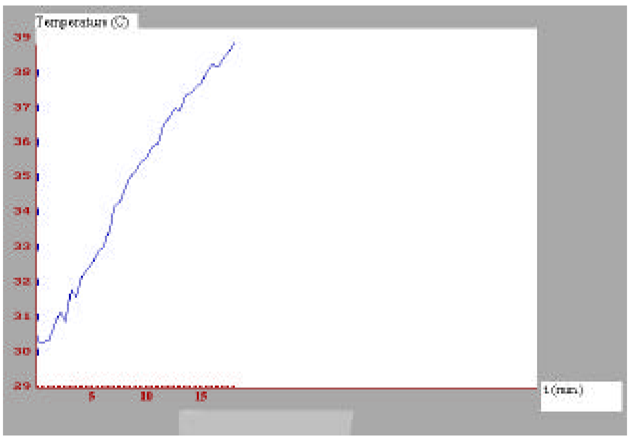

Figure15. Graph of System's Heating

RESULT OF PID CONTROL

After the heating process of 18 minutes, PID controller is started. PID coefficients are selected as;

Kp=0.1, Kd=0.2, Ki=0.01

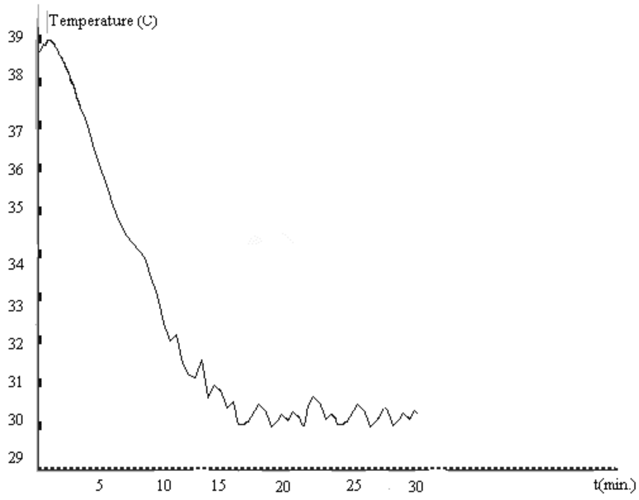

Figure.16- PID Control Result

As shown in the figure, against the heater resistance, the temperature is decreased linearly until 31^0C. Then, oscillations are occured.

RESULT OF FUZZY CONTROL

Settling time of the fuzzy controller was faster than the PID controller. Overshoots and undershoots were relatively small.

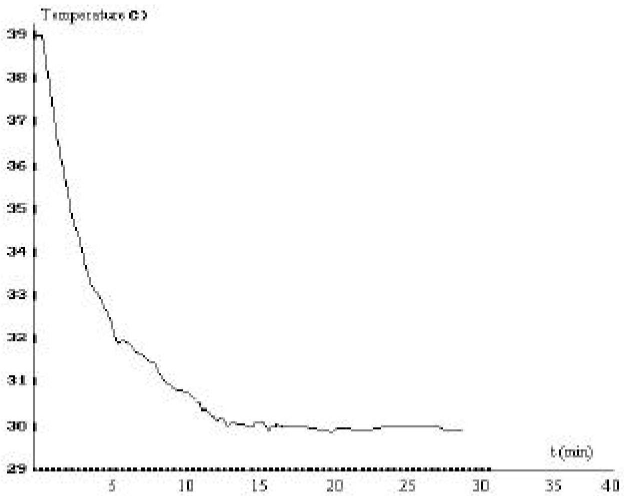

Figure17. Fuzzy Control Result

V. CONCLUSION

A container is aimed to be cooled by PID and fuzzy control methods. In the both methods, system is cooled linearly until a certain degree which is above the heat of outer environment. Oscillations after this temperature is sourced by rolling-off the motor speed. Cooling rate is reduced relative to the reduction in the error and could not remove the heated air away sufficiently. That's why, temperature is occasionally increases and reduces. In order to set the temperature under the heat of the outer environment, a cooler, such as peltier cooling elements can be used instead of the fan. These elements can reduce the temperature under negative degrees. This will also reduce the settling time.

REFERENCES

1. M.K Sarýoglu, Otomatik Kontrol (I) ITU, 1991.
2. I.Yuksel , Otomatik Kontrol Sistem Dinamigi ve Denetim Sistemleri, UU, 1995.
3. M.N. Özdas, A.T. Dinibutun, A. Kuzucu, Otomatik Kontrol Temelleri, ITU Makine Fakültesi Otomatik Kontrol Birimi, 1988.
4. N. Kuo, C. Benjamin, Digital Control Systems, Saunders College Publishing, 1992
5. J. Zeigler, N.B Nichols, Optimum Settings Of Automatic Controllers, Trans, Asme, pp: 64, 759-768, 1942
6. O. Altýnbasak, Mikrodenetleyiciler ve PIC Programlama, Altas Basým Yayým Dagitim, 2000.
7. PIC Microcontroller Uygulama Devreleri , Bilesim Yayýncýlýk, 2000.
8. Microchip Data Sheets, PIC16F87X28/40-Pin 8-Bit CMOS Flash Microcontrollers, www.microchip.com
9. Flash PIC Programmer, www.rotgradpsi.de/mc/index.html
10. Digital Panel Meter Design Application Note (An023), Intersil Corporation, 1999.
11. LM324 Operational Amplifier Datasheet, Fairchild Semiconductor Corporation, 2001, www.fairchildsemi.com
12. LM339 Comparator Datasheet, Fairchild Semiconductor Corporation , 2001, www.fairchildsemi.com
13. LM35 Precision Centigrate Temperature Sensors, National Semiconductor Corp. , December 1994
14. 4QD – TEC Pulse Width Modulators, www.4qd.co.uk