# Fuzzy Controller Hardware Design and Implementation

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**abstract**: In this paper,we propose a new way to estabilish fuzzy logic controller automatically.We'll first introduce a new method to generate fuzzy sets and fuzzy rules of a fuzzy logic controller via neural net work study.Then we'll download the whole fuzzy logic control system to temperature control system with FPGA.

## Part One:foreword

After the concept of fuzzy sets and rules had been set up by L.A.Zadeh,fuzzy logic[1] has been widely applied in automatic control field[2],[3] .But till now,there are still two problems exist:the first is that the fuzzy sets and rules are determined by the designer manually.This limits the self adjusting property of the fuzzy control system because of the lack of the experience of the designer.To solve this problem we examin the defination of the fuzzy sets and rules and add some new characters to them. The second problem is the scale and speed of the fuzzy logic control system.In this paper,we use Xilinx 4010-6PG191 to design a temperature adjustment system.The scale of the final control system has been reduced and the speed has been promoted.

## Part two:theory background

The fuzzy sets are the subfields of the whole physical field.But the discrete scope of the sets have no physical meaning.Also the fuzzy reasoning rules have no physical meaning either.So if we use some method to determine the sets and rules,the main problem is the standard of how to determine the sets and rules.So if we want to establish the sets and rules of the fuzzy control system effectively we should give some physical meaning to sets and rules.We suppose the control system have two inputs x,y. Let's call the field of x 's is A, the y's is B. Now we reconsider the sets and rules as follows:

First, we divided the field A into several sets accordingly as $\{A_{-i}, A_{-i+1}, \ldots, A_0, \ldots, A_{i-1}, A_i\}$:

We also divided the field B into several sets accordingly as $\{B_{-j}, B_{-j+1}, \ldots, B_0, \ldots, B_{j-1}, B_j\}$:

We call the center of a fuzzy set $\bar{A}_j$ meet following condition:

$$\mu_{A_i}(A_j) = 1 \qquad (i=j) \qquad (1)$$

$$\mu_{A_i}(A_j) = 0 \qquad (i \neq j)$$

Samely we call the center of a fuzzy set $\bar{B}_j$ meet following condition:

$$\mu_{B_i}(B_j) = 1 \qquad (i=j)$$

$$\mu_{B_i}(B_j) = 0 \qquad (i \neq j)$$

We suppose $A_0, \bar{B}_0$ are the destination of control action.

Second:the rule of a fuzzy control system has such form as:

$$\text{if } x = \bar{A}_i, y = \bar{B}_j, \text{then } z = C_{ij}$$

Here, $\bar{A}_i, \bar{B}_j$ are both centers of fuzzy sets of different fuzzy fields, $\bar{C}_{ij}$ is the center of rules of control system.If the contol intervel time is t,the destination of the control system is that at time T,if $x = \bar{A}_i$ and $y = \bar{B}_j$,the $\bar{C}_{ij}$ is the rule acted on the system, the select of $\bar{C}_{ij}$ obeys following rule : at time T+t, the status of the system will be:

$$x = \bar{A}_{i-1} \ (i>0) \text{ or } x = \bar{A}_{i+1} \ (i<0) \qquad (2)$$
$$y = \bar{B}_{j-1} \ (j>0) \text{ or } y = \bar{B}_{j+1} \ (j<0)$$

## Part three:neural learning step

By such defination,we then use CMAC[6] net work to learn the action of the control system.The learning step is divived into two parts:

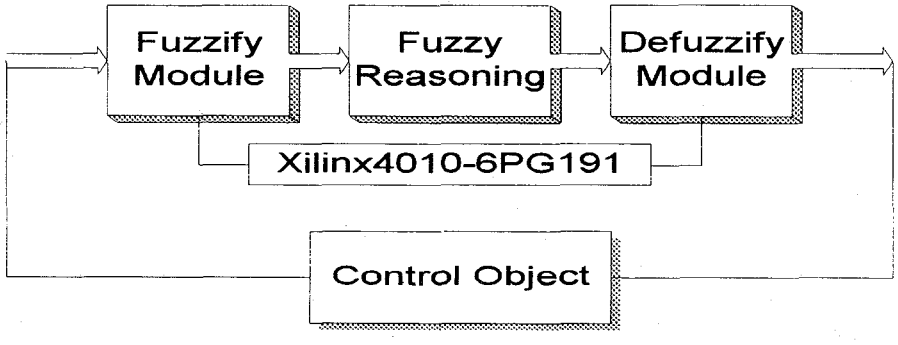
1 use $(x(T+t), y(T), C(T))$ as the input of CMAC, use $x(T)$ as destination to learn

2 use $(x(T), y(T), C(T))$ as input of CMAC,use $x(T+t)$ as destination to learn.

After the learning has been finished, then we can decided the sets and rules of fuzzy control system according to formula(1),(2).

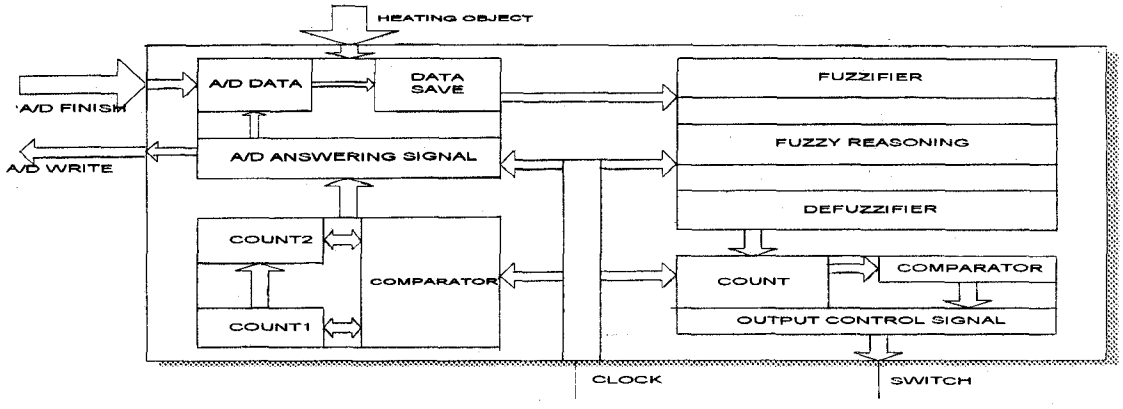
## Part four:hardware design and implementation

Now,we have finished the software design of a fuzzy control system.In such design,we redefine the fuzzy sets and rules of a fuzzy control system.So they have the physical meaning.Then we use netural net work to set up the control system.To reduce the scale and promote the speed of the final control system,we use Xilinx4010-6PG191 to design a temperature control system.The structure of the control system is denoted in picture1:



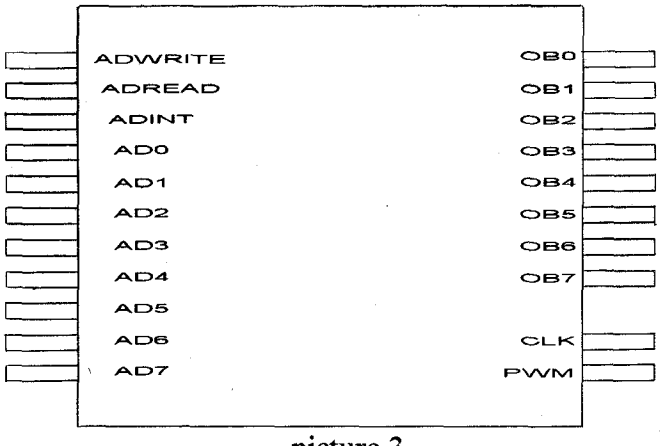

picture 1

The Xilinx4010PGA191 is composed of A/D signal input chanel,fuzzy logic calculator and PWM output control signal chanel. Picture 2 shows the logic structure of the FPGA.




picture 2

The outlook of the FPGA is showed as picture 3:

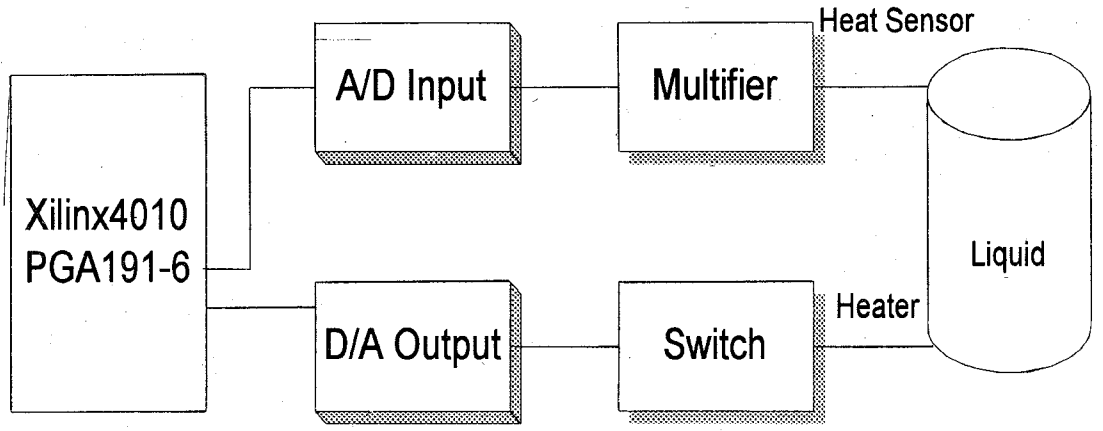



picture 3

| | | |
|---|---|---|
| CLK: | Input I/O , | clock signal input |
| OB0-7: | Input I/O , | objective temperature |
| ADWRITE: | Output I/O, | start A/D converter |
| ADINT: | Input I/O , | notify finish of A/D converter |
| ADREAD: | Output I/O , | get data from A/D |
| AD0-7: | Input I/O, | A/D data periphal |
| PWM: | Output I/O , | heater control periphal |

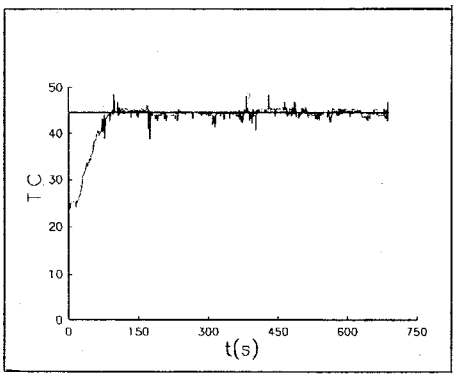
**Part five:Heating control :**

We use the FPGA4010PGA191-6 as the control center to design the heating control system. The system is composed of FPGA,heat sensor, input signal multifier and PWM output circuit. Picture 4 shows the logic circuit of the system.

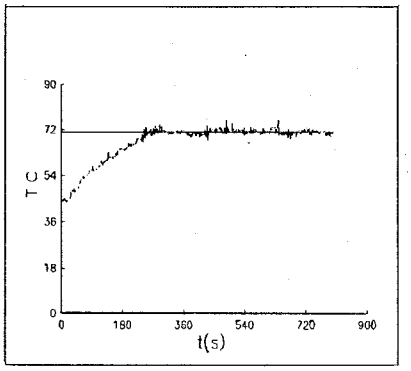



picture 4

We use this system to control the heating process of 5 litre liquid for twice.In the first process,the starting temperature is $25^{\circ}C$ ,the objective temperature is $45^{\circ}C$ ,the picture 5 shows the whole controllng process. In seond process,the starting temperature is $46^{\circ}C$ ,the objective temperature is $76^{\circ}C$ ,the picture 6 shows the whole controllng process.




picture 5




picture 6

## Part six:conclusion

We have proposed a new method to establish fuzzy control system.The most outstanding benefit of the method is that the whole process is carried out automatically.We also test this method by downloading the method to FPGA to fulfil the hardware design,the result is satisfying.Now we'll go on to design an IC circuit with Northern Telecom Corporation.

## reference:

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