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FPGA IMPLEMENTATION OF FUZZY LOGIC CONTROL SYSTEM FOR INDUSTRIAL AUTOMATION APPLICATIONS

RAJESH.THUMMA Assistant Professor, Dept of ECE, ANURAG GROUP OF INSTITUTIONS,TS, India.

M.YAMUNA PG Scholar, Dept of ECE, ANURAG GROUP OF INSTITUTIONS, TS, India.

ABSTRACT

In this project fuzzy logic controller (FLC) will be implemented in VHDL for FPGA platform. This is a general purpose controller that can be used for different applications. This controller has three stages: the fuzzification, the inference and the defuzzification. The first component in the FLC is the fuzzifier that transforms crisp inputs into a set of membership values in the interval [0,1] in the corresponding fuzzy sets. The knowledge base of the fuzzy controller consists of a database of linguistics statements (rules), which states the relationship between the input domain fuzzy sets and output domain fuzzy sets. Inference block implements this logic. The last step is the defuzzification and the final output is determined by weighted average of all contributions of the output sets. The fuzzy logic controller used to control the voltage at constant.When different voltages are given as input at voltage source, the output will not change as giving 1v. Modelsim Xilinx Edition (MXE) and Xilinx ISE will be used simulation and synthesis respectively. The Xilinx Chipscope tool will be used to test the FPGA inside results while the logic running on FPGA. The Xilinx Spartan 3 Family FPGA development board will be used this project.

KEYWORDS : Fuzzy logic controller,Transfer logic block,Xilinx synthesis technology

I.INTRODUCTION

Now Fuzzy Logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system. For example consider what you do in the shower if the voltage is too cold: you will make the water comfortable very quickly with little trouble. FL is capable of mimicking this type of behavior but at very high rate.

FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. For example, a simple voltage control system could use a single voltage feedback sensor whose data is subtracted from the command signal to compute "error" and then time-differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". Error might have units of degs F and a small error considered to be 2F while a large error is 5F. The "error-dot" might then have units of degs/min with a small error-dot being 5F/min and a large one being 15F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance. Generally, FL is so forgiving that the system will probably work the first time without any tweaking.

.II.DESCRIPTION

FL offers several unique features that make it a particularly good choice for many control problems. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations. Since the FL controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can easily be incorporated into the system simply by generating appropriate governing rules. FL is not limited to a few feedback inputs and one or two control outputs, nor is it necessary to measure or compute rate-of-change parameters in order for it to be implemented. Any sensor data that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low. Because of the rule-based operation, any reasonable number of inputs can be processed (1-8 or more) and numerous outputs (1-4 or more) generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined. It would be better to break the control system into smaller chunks and use several smaller FL controllers distributed on the system, each with more limited responsibilities. FL can control nonlinear systems that would be difficult or impossible to model mathematically. This opens doors for control systems that would normally be deemed unfeasible for automation.

III.OPERATION

The Fuzzy Logic Controller (FLC) has two inputs the error (e) and its change (Δe) and one output the change of control (Δu). This controller follows in its logic the three stages:

1) Fuzzification,
2) inference and
3) Defuzzification.

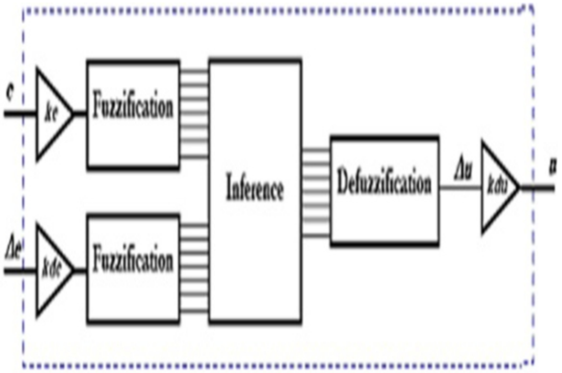


Fig:3.1 fuzzy logic controller

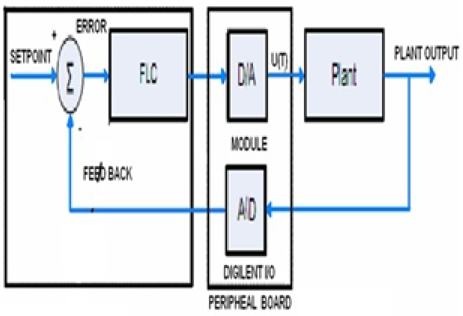
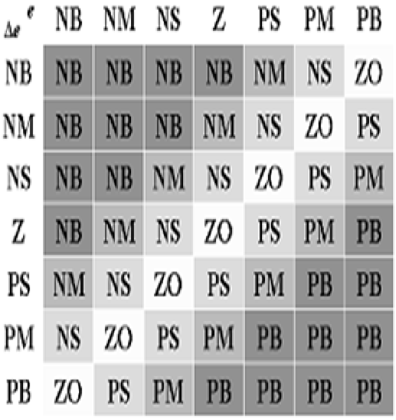


Fig.3.2 Blocks diagram of the project

The first component in the FLC is the fuzzifier that transforms crisp inputs into a set of membership values in the interval [0,1] in the corresponding fuzzy sets. The membership function shapes are typically triangular, trapezoidal or exponential. In this, the membership functions are triangular-shaped and the maximum value is scaled to 40 instead of 1 which is found in other documents describing fuzzy theory. This way the calculation complexity is greatly reduced because the multiplying operation becomes only one addition or subtraction. With a setpoint and a measure coded on 8 bits, the intervals of the fuzzy sets are selected in order to cover all the range between -127 and 127.

Inference

The knowledge base of the fuzzy controller consists of a database of linguistics statements (rules), which states the relationship between the input domain fuzzy sets and output domain fuzzy sets. For a system with two inputs, the error (e) and change of error (Δe), and single output, each having seven fizzy sets, the rules can be represented in tabular form as shown in Table I. A maximum of 4 rules can be active at any time with triangular membership functions. The min-max inference method uses the min operator to find the minimum membership degree between the two inputs resulting from rule conditions and the rules are finally combined by using the OR operator and interpreted as the max operation for each possible value of the output variable.



Δe \ e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
Z	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

TABLE .I. Mac Vicar-Whelan Rules Base

Defuzzification

The last step is the defuzzification and the final output is determined by weighted average of all contributions of the output sets. It is obtained by finding the centroid point of the function which is the result of the multiplication of the output membership function and the Inference output vector Y. The general mathematical formula which is used to obtain the centroid point is:

$$\Delta u = \frac{\sum_{i=1}^{5} Y[i] \times S[i]}{\sum_{i=1}^{5} Y[i]}$$

Y(i) are the i-th members of the output vector,

S(i) are the multiplying coefficients of the output membership function.

IV.SIMULATION RESULTS

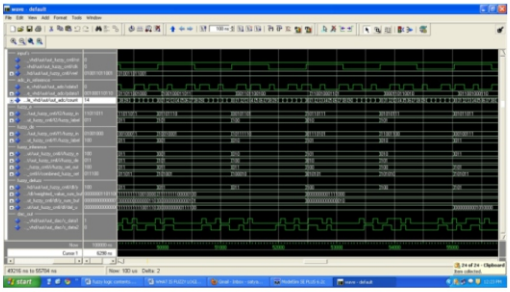


Fig. 4.1 Simulation results of fuzzy control system

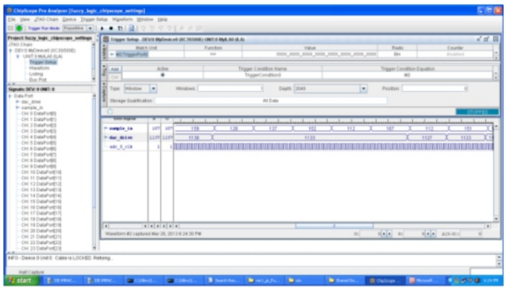


Fig 4.2. Chipscope results of fuzzy logic control system Input 0.1v Output 1v

Fig.4.3. Input 2v

Fig.4.4. Output 1v

Hardware implementation of fuzzy logic control system

V.ADVANTAGES & APPLICATIONS

- FPGA solution hence works very fast
- Less visible, but of growing importance, are applications relating to data processing, man-machine interfaces, quality control and decision support systems.
- Fuzzy controller is better than normal PI like control loops

Applications:

- Any fuzzy logic control system implementation where high speed switching is useful
- Flight control systems
- Car speed control system
- Room temperature control system

VI.CONCLUSION

This paper presents an approach for the implementation of a fuzzy logic controller on an FPGA using VHDL. A fuzzy logic controller with 2-inputs and 1-output is simulated and each block's verification is carried out using logic simulator. The FLC is implemented on a Xilinx Spartan-3 FPGA and used to control first order system to demonstrate its validity. The controller with the analog to digital and digital to analog interfaces was found to be fully functional. The FLC can also be used for control purposes in other applications. Also the length of input and output of the FLC can be increased to achieve better results.

VII.FUTURE SCOPE

If the inference block is for 4 bit then the persecution will be improved presently the total system has been build for the 3 bit in it the inference block consists of 7x 7 inference block if it is increased to 16 x16 inference block then the fuzzy logic will work more effectively.

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