URMIA UNIVERSITY
IRAN

۱۳۷۷/۸/۲۰

DESIGN OF AN ANALOG FUZZY LOGIC CONTROLLER CHIP

A thesis submitted in partial satisfaction of the
requirements for the degree Master of Science in
Electrical Engineering

by
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1998

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1998

۲۶۲۳۳

To

Birjand University
Shiraz University
Urmia University

and

my parents

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ACKNOWLEDGMENTS

I would like to tank Dr. A. Khoei and Dr. Kh. Hadidi for all the support and guidance they has given me all these years at urmia university.

I would also like to tank my thesis committee members, doctors Eshghi, Azarmanesh, and Abbaspour for taking the time to serve on my committee. The valuable contribution of Dr. A. Fottovat is also greatly appreciated.

I tank my friends and colleagues in the lab for the informative discussions.

Finally, I would like to tank Mr. Niknafs, Mrs. Touri and Mrs. Sarhangi for their's helps me in urmia university.

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- H. peyravi, A. Khoei, Kh. Hadidi, "Analog Realization of Fuzzifier and Defuzzifier Interfaces for Fuzzy Chips," accepted for presentation in :

1) 7th International Symposium on IC Technology, Systems & Applications (ISIC-1997), Singapore.

2) 5th International Conference on VLSI and CAD (ICVC-1997), Korea.

3) *4th IEEE International Conference on Electronics, Circuits, and Systems* (ICECS-1997), Egypt.

ABSTRACT OF THESIS

DESIGN OF AN ANALOG FUZZY LOGIC CONTROLLER CHIP

by

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M.S. Degree in Electrical Engineering
Urmia University, IRAN, 1998
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Fuzzy logic has been developed over the past three decades into a widely applied technique in classification and control engineering. Todey fuzzy logic control is one of the most important applications of fuzzy set theory and specially fuzzy logic. There are two general approachs for using of fuzzy control, software and hardware. Integrated circuits as a solution for hardware realization are used since the late 1980s. In this way two types of implementations, analog and digital are possible. In this dissertation we design an analog fuzzy logic controller chip. In this design we propose two novel analog circuits for fuzzifier and defuzzifier interfaces.

Finally we construct a two-input one-output fuzzy logic controller in a 3×3 configuration with 9 rules and test it in some aspects to confirm its performance. Inputs can be have three part membership functions that are tuneable. Also 9 rules are accessible and tuneable. All of tests are done using HSPICE, and simulation results indicate full functionality. This structure can be implemented in less than 0.7 mm^2 in a 1.2 μm double-metal CMOS technology.

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Introduction

Fuzzy set theory [2],[41],[46], introduced by prof. Zadeh in 1965 has had many applications in various of fields. Today fuzzy logic [2],[4],[44], is very considerable as one of the most important fruits of fuzzy set theory. Felexibility caused by gradual membership values in fuzzy logic has made it similar with human mind [43]. The use of fuzzy logic in control system design has become one of the most active and profitable areas in the applications of fuzzy set theory. Fuzzy Logic Controller (FLC) has had considerable success in Japan, where many commercial products using this technology have been built. Fuzzy control based on fuzzy logic provides a new design paradigm such that a controller can be designed for complex, ill-defined processes without knowing quantitative data regarding the input-output relations, which are otherwise required by conventional method.

There are two ways for using fuzzy control in a system, Software and Hardware. Hardware solution may be as descrete or integrated circuits. In integrated form two realizations, analog and digital, are possible. We prefered analog realization based on reasons mentioned in chapter 3. In this thesis we going to design a general purpose analog fuzzy logic controller chip. Analog fuzzy controller chips have the advantages of high speed while occuping a small area.

In this work, we introduce a novel fuzzifier and a novel defuzzifier interface for analog fuzzy controller chips. Inference engin in which an analog minimum circuit is used, has reported before in recent researchs by others and we have used it in this project. Inference is done by Min-Product method and output membership functions considered as singletons, also in defuzzifier interface, Center Of Area (COA) method is used.

Final architecture is a 3×3 analog fuzzy controller in which 9 fuzzy rules are accessible. Two inputs of controller have three segment membership functions.This controller is a general purpose analog fuzzy controller (3×3) in which input membership functions and fuzzy rules are changable externally. This structure can be implemented in less than 0.7 mm^2 in a 1.2 μm, CMOS technology. The maximum delay in output is about 160 nSec that corresponds to 6.25 MFLIPS. Also it is an outline of an analog fuzzy controller chip with 40 pins include membership functions and rules control pins.

The material is partitioned into five chapters. A brief outline of the following chapters is given below.

Chapter 2 under title "*Fundumentals of Fuzzy Set Theory and Fuzzy Logic*" is a theoretic base for the next chapters. Therefore it contains many examples in order to better teaching. In this chapter we give some of the basic definitions used in fuzzy set theory and fuzzy logic. The terms defined include, *fuzzy set*, *operations on fuzzy sets*, *extention principle*, *fuzzy numbers*, *linguistic variables* and *fuzzy relation*.

Chapter 3 under title "*Fuzzy Logic Control Strategy*" deals with control engineering on the basis of fuzzy sets. In this chapter fuzzy control theory and basic configuration of fuzzy controller is explained Briefly. Also various implementations of fuzzy controllers and a brief historical review of fuzzy chips design has been mentioned.

In chapter 4 under title "*Synthesis of Analog Fuzzy Functional Blocks*" we describe fuzzy functional blocks include Fuzzifier, Inference engine and Defuzzifier separately. The new fuzzifier and defuzzifier realizations with HSPICE simulation results are brouth up.

In chapter 5 under title "*Analog Fuzzy Logic Controller*" (3×3 architecture) to confirm the performance of the presented structures, circuits mentioned in chapter 4 are connected in a 3×3 fuzzy logic controller configuration. Also simulation results of some tests for determining performance characteristics are reported. These tests includes pulse response of the controller and it's response to inputs that are swept along the diagonal of the input state space. Also HSPICE simulation of the fuzzy controller working in a feedback loop include step response and its performance in control loop are discussed.

Chapter 6 summerizes the major results of the thesis, and discusses possible future research works.