

A FRAMEWORK FOR STRUCTURED DESIGN OF DIGITAL SYSTEMS
IN A CAD ENVIRONMENT

by

ANSHUL KUMAR
ELEC. ENGG. DEPT.

Submitted in fulfilment of the requirements for the
Ph.D. degree

to

INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI, INDIA

May 1980

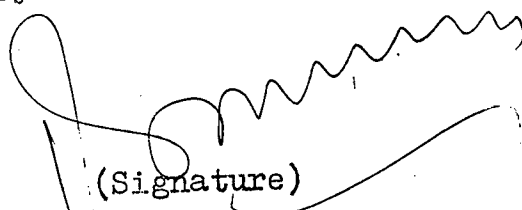
TO MY PARENTS

CERTIFICATE

i) I am satisfied that the thesis presented by Anshul Kumar is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under my guidance and supervision and that the results contained in it have not been submitted in part or full to any other university or Institute for award of any degree/diploma.

ii) I certify:

- a) that he has persued the prescribed course of research.
- b) that he is of good moral character.



(Signature)

Supervisor of the Candidate

Address: Prof. P.C.P. BHATT

Elec. Engg. Deptt.

I.I.T. DELHI

(Signature)

Chairman, D.R.C.

Elec. Engg. Deptt.

I.I.T., DELHI

ACKNOWLEDGEMENTS

I am extremely grateful to my research supervisor Prof. P.C.P. Bhatt for his guidance and encouragement throughout the course of this work. It has been a pleasure to be associated with him.

I am deeply indebted to Prof. R. Narasimhan, Director, NCSDCT, TIER, for providing me the computing facilities of the centre. I wish to express my thanks to many other staff members of NCSDCT, in particular, Mr. S.C. Gupta and Dr. S.P. Mudur, for their help and cooperation. I am also grateful to my friends at TIER who were very helpful while I was doing the software implementation work at TIER.

I owe my special thanks to my colleague Mr. N.C. Kalra for reading through the manuscripts of the thesis and offering useful suggestions. I am thankful to Dr. M. Ibramsha, Mr. Shashi Kumar, and Mr. M. Balakrishnan for the useful discussions I had with them. I would also like to express my thanks to Dr. Ashok Agrawal of University of Maryland and Prof. D. Aspinall of UMIST for having spared time for discussions during their visits to IIT Delhi.

I gratefully acknowledge the support and encouragement received from Prof. P.V. Indiresan,

Ex-Head, Centre for Applied Research in Electronics, I.I.T. Delhi, while working in his group, and also the support received from Dr. N.W. Nerurkar, Director, Department of Electronics, Govt. of India.

I wish to express my sincere thanks to Mrs. Sashikala and Mrs. R. Mansukhani for carefully typing this thesis and Mr. R. Kapoor for neatly preparing the diagrams.

Finally, I express my thanks to members of my family and my friends for their patience and moral support.

Anshul Kumar

ABSTRACT

Computer Aided Design techniques are essential to cope up with the problems arising out of the need to achieve short design cycle times for complex digital systems and due to an increase in emphasis on correctness of a design. A conceptual framework in which a design may be conceived and communicated to a computer forms the basis of these techniques. In this thesis, a language RACHNA and associated conceptual model are presented, constituting the necessary framework for digital system design. It supports a structured design approach by permitting a design to be evolved in a top down manner, expressing a subsystem as a well defined composition of smaller subsystems. With this structured design approach, it is easy to establish correctness of a design.

The conceptual framework which has been presented includes models for basic entities like data carriers, operators, expressions and various forms of descriptions for systems synthesized from these. RACHNA is introduced using these definitions. It is primarily for describing behaviour of a digital system in a procedural manner, but also permits a designer to contribute to structural details. Various hardware features like parallelism, pipelining, asynchronism, timing, and

delays can be described conveniently. A directed graph representation called R-Net, derived from Petri-Net, has been presented for RACHNA. This is a concise form of representation for simulation and logic translation. It is also helpful in understanding the language semantics. Because of the structured nature of RACHNA constructs, R-Nets are 'live' and 'safe'.

In the context of RACHNA, major design activities, namely, design evaluation and logic translation or synthesis are discussed, demonstrating the feasibility of the approach. A simulator has been implemented through which a design can be evaluated and various design alternatives can be explored. Techniques which can be used in a simulator for detecting design inconsistencies have been discussed. This provides very useful information to a designer for debugging a design. Procedures for obtaining a detailed structural form of description for a given behavioural design are discussed. This could subsequently be used for component level synthesis.

CONTENTS

1.	INTRODUCTION	1
	1.1 Need for CAD of digital systems	2
	1.2 Basis of a CAD system	3
	1.3 Previous work	5
	1.4 Proposed approach	7
	1.5 Layout of the thesis	10
2.	HARDWARE DESCRIPTION LANGUAGES AND CAD SYSTEMS	13
	2.1 Structure description languages	14
	2.2 Languages specially developed for hardware	18
	2.3 HDL's adapted from programming languages	28
	2.4 Languages derived from theoretical models	32
	2.5 Approach for RACHNA	35
3.	CONCEPTUAL FRAMEWORK FOR DESCRIPTION OF HARDWARE	36
	3.1 Metasystem and digital hardware	38
	3.2 Data carriers and operators	44
	3.3 Behavioural and structural descriptions	52
	3.4 Hierarchical description	62
	3.5 Directed graph representation	66
	3.6 Conclusions	73

4.	RACHNA	74
4.1	A top-down overview of RACHNA	76
4.2	Details of the language : Bottom-up	90
4.3	Graph model representation	103
4.4	Conclusions	124
5.	SIMULATION OF A DIGITAL SYSTEM DESIGN	125
5.1	Simulation strategy	128
5.2	Simulation control	132
5.3	Internal representation of RACHNA descriptions	139
5.4	Lexical and syntax analysis of RACHNA	152
5.5	Semantic processing	158
5.6	Simulation procedure	165
5.7	Conclusions	170
6.	DETECTION OF INCONSISTENCIES	171
6.1	Data operation clashes	173
6.2	Timing analysis	182
6.3	Deadlocks	195
6.4	Zero time loops	199
6.5	Conclusions	203
7.	TRANSLATION FROM BEHAVIOURAL TO STRUCTURAL DESCRIPTION	204
7.1	Structural form of representation	207
7.2	Overview of the translation	212

7.3 Synthesis of the control part	214
7.4 Clock, data, and address expressions	231
7.5 Functions and function arguments	237
7.6 Process and module arguments	244
7.7 Conclusions	246
8. DESIGN EXAMPLES	247
8.1 Asynchronous systems	249
8.2 Pipelined systems	265
8.3 Array systems	286
9. CONCLUSIONS	299
9.1 Summary of the achievements	300
9.2 Extensions and future work	304
REFERENCES	306
APPENDIX A	320
Syntax of RACHNA	
APPENDIX B	323
Proof of lemmas used in chapter 4	