VLSI DESIGN '97

VLSI IN MULTIMEDIA APPLICATIONS

PROCEEDINGS OF
THE 10th INTERNATIONAL CONFERENCE ON VLSI DESIGN

Hyderabad, India
January 4–7, 1997

Sponsored by

VLSI SOCIETY OF INDIA (VSI)

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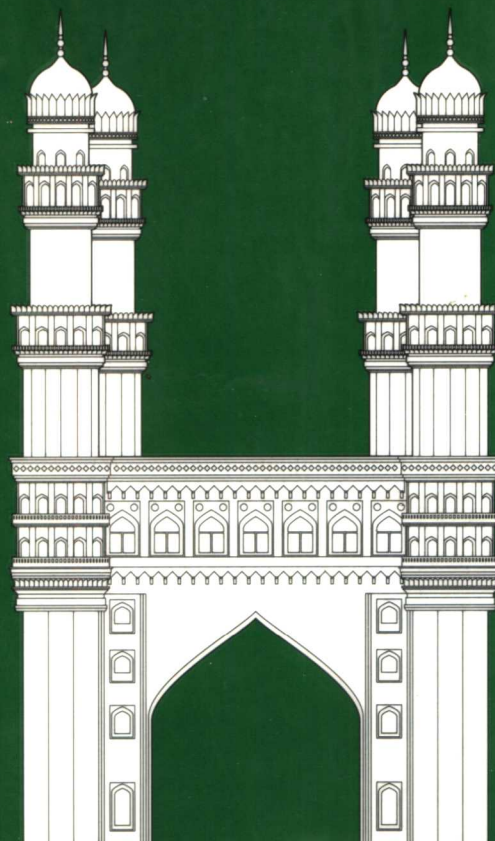SPECIAL INTEREST GROUP ON DESIGN AUTOMATION

IEEE CIRCUITS AND SYSTEMS SOCIETY

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Proceedings

Tenth International Conference on VLSI Design

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General Chair's Message
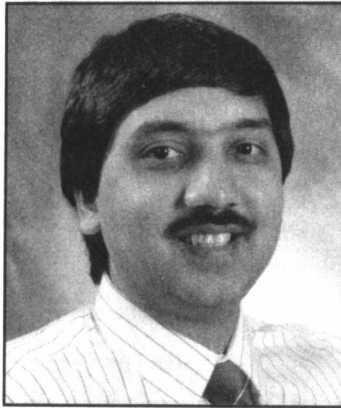
Srimat T. Chakradhar

A recurring theme in the history of mankind is the relationship between chance happenings and vigilant minds. Many instances of coincidence have led alert observers to unexpected discoveries. Just such an event, the invention of the transistor, launched a new era that was to be marked by advances so extraordinary as putting a man on the moon. Very large scale integration (VLSI) is the assembly on a single chip of millions of transistors that work together flawlessly to realize miracles as varied as multimedia, mobile communications, organ transplants and decoding of the human genome. Undisputedly, VLSI is the core technology that has been at the foundation of all progress during the 20th century.

Welcome to the *International Conference on VLSI Design*! This is the *tenth* of a series of meetings on VLSI Design held annually in India. The conference offers a unique forum for researchers, designers, and businessmen from around the world to present and discuss all aspects of integrated circuit design. It also provides an excellent opportunity for the exchange of ideas through technical papers, posters, tutorials, panel discussions, and industrial exhibits. Starting with a handful of participants in the first meeting at Madras in 1985, the attendance peaked to over 700 last year in Bangalore. The meteoric rise in attendance does not surprise me. This is the only international conference on integrated circuit design and technology being held annually in India. The conference is sponsored by the VLSI Society of India and the Department of Electronics (Government of India) in cooperation with the ACM SIGDA, IEEE Circuits and Systems Society and IEEE Computer Society (DATC and VLSI-TC). The proceedings of VLSI Design '97 are published by the IEEE Computer Society Press.

Probably the single most significant transformation of the last decade has been the rapid merging of the computer and communications industry. This merger has been fueled by the need to communicate and manipulate digital information to serve as an intimate supplement to the human mind. The merger of the computer and communications industry will radically alter the way we think, work, and interact. Last year, the theme of the conference was "VLSI in Mobile Communication" to focus on communications. This year, we focus on computers by adopting the theme "VLSI in Multimedia Applications." Several distinguished speakers — including the keynote speaker — will critically review and deliberate the economics, state-of-the-art, key advances, and future challenges that will have to be overcome to harness multimedia technology for the benefit of all of mankind.

We strive every year to make the conference valuable, interesting, and exciting to participants with an increasingly diverse range of interests. The program co-chairs, Debashis Bhattacharya and Bhargab Bhattacharya, have compiled an outstanding technical program that provides a good balance between theory and practice. This year, embedded tutorials are included at the beginning of sessions to introduce, survey, and motivate new, emerging topics. As in the past, five tutorials covering major areas of VLSI design and technology are being offered. This year, we have a sixth tutorial that is of general interest. This tutorial has been added to cater to the current interests of the student community. Tutorial chair, Yervant Zorian, has selected

these tutorials to reflect the theme of this year's conference and the current leading edge technology drivers for the VLSI industry. The publications chair, Prab Varma, performed the critical task of putting the proceedings together. The exhibit chair, M. Naresh Kumar Reddy, has assembled leading design automation vendors who will display their latest technology. Thanks to our publicity chairs — N. Ranganathan, Bernard Courtois, and K. Muralidharan — the conference has become a highly visible premier international meeting. The conference runs a design contest to recognize and reward novel VLSI designs. This year, the design contest program is ably co-ordinated by Susanta Misra.

Since 1994, the conference steering committee has been awarding fellowships to students and professors at various Indian universities. A fellowship allows the recipient to register for the conference, attend tutorials, and supports boarding, lodging, and travel expenses. The primary goal of these fellowships is to facilitate participation of individuals interested in understanding and contributing to the VLSI industry. We received a record number of applications for fellowships. The fellowship program is administered under the able direction of fellowship chair, P.V. Subba Rao.
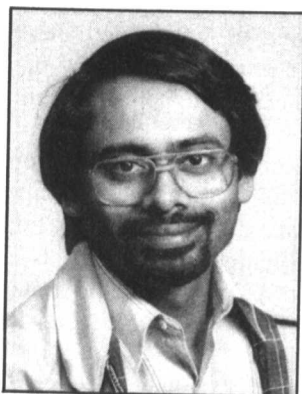
The conference is being held in Hyderabad for the first time this year. Hosting a gathering of this magnitude in a new city requires careful planning, meticulous organization, and above all, plenty of determination and courage. The organizing committee members, under the capable stewardship of Sandhya Kode, have played an invaluable role in hosting the conference in Hyderabad. The international nature of this conference committee makes it difficult to have program or organizing committee meetings. S. Kapoor's notable leadership, in the role of vice chair, has been invaluable in overseeing and maintaining excellent communication among the various committee members. The VLSI-net chair J.A. Chowdary has played a key role in introducing, for the first time, the VLSI-net that provides delegates with email accounts and full internet/web connectivity.

As always, the steering committee chair, Vishwani D. Agrawal, provided invaluable help, and guidance to all conference committee members. In 1985, along with H.N. Mahabala of IIT, Madras, Vishwani Agrawal founded this conference. His sterling leadership, clear vision, and unflinching support over the years has transformed a small gathering of VLSI professionals in 1985 into the premier international meeting you are attending today.

We thank all of the referees, authors, participants and members of various committees for helping us put together an exciting conference. On behalf of the steering and the conference committees, we heartily welcome you to Hyderabad! We are sure you will enjoy the conference as much as we did putting it together.

Srimat T. Chakradhar
1997 VLSI Design General Chair

Program Chairs' Message

Bhargab Bhattacharya
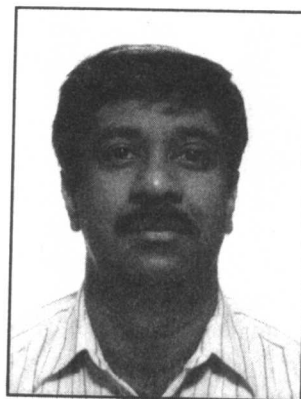
Debashis Bhattacharya

It is our pleasure to welcome all of you to VLSI Design '97, which is being held in Hyderabad for the first time. This is the tenth anniversary of the conference that was initiated as a tiny workshop in Madras with only 50 participants.

Advances in the technology of VLSI Design over the past two decades have significantly influenced almost every aspect of electronic design, computers and communication systems. The ubiquity of microchips can now be felt in all scientific, technological and social endeavors. Paralleling this growth in the importance of microchips, this conference has gained excellent momentum, visibility and stature in the international technical community, over the last ten years. As evidence of this visibility and stature, attendance at the VLSI Design '96 Conference in Bangalore rose to almost 750.

VLSI Design '97 will provide an excellent forum for students, researchers and other professionals to present and discuss various state-of-the-art of VLSI Design issues including synthesis, testing, EDA tools, mixed signal design and architecture with emphasis on multimedia applications. Compared to 137 papers submitted last year, we received 155 submissions this time — the second highest number in the history of this conference — from institutions located in every inhabited continent on the earth. Compared to last year, there was a significant increase in the number of submissions from Europe, while submissions from Asia, India, United States, and other parts of North and South America increased slightly. The quality of the submitted papers and their wide geographical distribution truly indicate the increasing popularity and importance of this conference around the globe.

The papers were reviewed by an international pool of 330 reviewers, which included a 69-member strong program committee (PC), consisting of top VLSI experts from all over the world. This year, all papers, whether submitted in India, or in the USA, were cross reviewed, i.e., papers submitted in USA had at least one Indian reviewer, and vice versa. Every paper was sent to at least seven reviewers including at least one PC member, and in most cases, two PC members. We made every effort to get reviews back, and the average number of reviews returned per paper, rose to 5.11 in India. However, the average number of reviews returned in USA fell to 3.21, putting the overall average at 4.06 reviews per paper. Also, almost all papers had at least one cross review.

In keeping with tradition, paper selection for the final program was done in two concurrent program committee meetings: one in India selecting papers from submissions made in India, and one in the USA selecting papers from submissions made in USA. Teleconferencing and fax were used to exchange opinions and decisions between the two committees in order to ensure uniformity of the paper selection process. To ensure objective evaluation, reviewers were asked to grade each paper numerically on a five-point scale with 30% weight on originality, 30% on the technical content, and 20% on presentation and relevance, respectively. The two committees looked into these grades along with other critical comments while examining each paper very carefully during the meetings. Based on the views of the referees and the PC members, the decision on selection of the papers was finalized unanimously from both ends. In the end, we were able to accept 75 papers in the regular and short

categories, and 18 more in the poster category. Unfortunately, due to conference size limitations, many good papers had to be rejected.

Seven of the selected papers were nominated for the Best Paper award. Two of these seven papers were also nominated for the Best Student Paper award. A blue-ribbon international panel reviewed the candidate papers, and ranked them against each other on a scale of 0 to 20. The panel members were chosen on the basis of their outstanding contributions to the areas of VLSI Design and CAD, with the requirement that none of them had submitted papers to VLSI Design '97.

The final program, in line with tradition, was formed by organizing the selected papers into appropriate groups, with one exception, viz., the "verification" session, which was pre-ordained. This year, for the first time, we introduced nine embedded tutorials in the technical program, on areas of current interest, apart from the six full-day regular tutorials. Some of these embedded tutorials were selected from proposals submitted to the tutorials chair, while others were selected through invitations sent to leaders in certain key areas of VLSI Design. The program also includes two invited plenary addresses, one keynote address, and a panel discussion by eminent experts in the industry.

Owing to the outstanding work of the tutorials chair, Yervant Zorian, we have an excellent program of six full-day tutorials. The tutorials are traditionally extremely popular with the attendees, and this year will be no exception.

On behalf of the VLSI Design '97 Program Committee, we thank all of the reviewers, the volunteers on the program committee, the awards committee, the conference steering committee, and the authors. In particular, we wish to thank Vishwani Agrawal, whose guidance and involvement continue to be invaluable resources behind the success of this conference. We wish to thank publication chair, Prab Varma of CrossCheck Technology, for his arduous task of managing all the camera-ready manuscripts, and Regina S. Sipple of the IEEE Computer Society Press for her assistance in printing the proceedings. Our special thanks go to T.R. Viswanathan and Bob Hewes of Texas Instruments, Dallas, for their support, and to M.L. Bushnell of Rutgers University and G.C. Basu of Calcutta Telephones for hosting program committee meetings with teleconferencing between the two committees. We are highly indebted to the general chair, Srimat T. Chakradhar, and the organizing chair, Sandhya Kode, for providing the infrastructure and financial support necessary for running the conference.

In addition, we wish to express our sincere thanks to the following individuals for their untiring efforts towards making this conference a success: administrative assistants Betty Pea and Mary Lu Rhoads of the DSP R&D Center, Texas Instruments, Dallas, and Barbara Daniels of CAIP Research Center, Rutgers University, all of whom provided invaluable help in the creation and maintenance of the various databases. We'd also like to recognize A. Basu of IIT Kharagpur; S. Sur-Kolay, D.K. Das and K. Mukhopadhyaya of Jadavpur University; B.P. Sinha and S.C. Nandy of ISI Calcutta, who all did an exceptional job of managing the program committee secretariat around the clock as well as allocating peer reviewers. Grateful acknowledgment is also due to of S. Chakraborty, S. Das, S. Mukherjee, and S. Majumder for their help with the many facets of the program committee. We extend special thanks to S.T. Chakradhar for his assistance in the selection of reviewers for all of the submitted papers and to N. Ranganathan for his generous help in the awards process. Finally, we would like to express our gratitude for the invaluable support provided by Texas Instruments Inc., Dallas; the Indian Statistical Institute, Calcutta; the Indian Institute of Technology, Kharagpur; Rutgers University, NEC USA; Princeton University; and Lucent Technologies.

We believe that you will have a stimulating and ultimately fruitful experience while attending the tenth VLSI Design Conference. Additionally, we hope that you will enjoy the beauty and vast cultural diversity of India, as reflected in the historic city of Hyderabad and its surrounding areas.

We look forward to your continued participation in the International Conference on VLSI Design, and welcome your comments and suggestions for further improvements in this conference in the years to come.

Welcome to VLSI Design '97!

Debashis Bhattacharya
Bhargab B. Bhattacharya
1997 VLSI Design Program Chairs

Welcome to the City of Hyderabad

On behalf of the VLSI Design '97 Organizing Committee, I welcome you to the *Tenth International Conference on VLSI Design*, January 4-7, 1997. For some of you this may be your first time in Hyderabad, a 400 year-old modern city with more than 100% growth in the software industry in each of the last four years.

Hyderabad is a "city of learning" with eight Universities and 28 national-level Research and Training Institutions. Premier centers of excellence located in Hyderabad include Defence Research and Development Laboratories, Defence Electronics and Research Laboratories, and the Center for Cellular and Molecular Biology. Andhra Pradesh Industrial Infrastructural Corporation (APIIC) is developing a world class INFOCITY with state-of-the-art infrastructure facilities spread over 170 acres. Software Technology Park (STP) at Hyderabad, provides a single window government cell in addition to infrastructural facilities including high speed communication links to easily set up software development centers.

With all this support, Hyderabad is destined to become a high-tech city of global standard before the turn of the century.

Enjoy yourself shopping (Hyderabadi's famous pearls and fancy bangles) and sight-seeing (world-famous Salar-Jung Museum, Charminar, and Golkonda Fort) in the city tours being organized. Lose yourself in the Cultural Program evening steeped in the traditions of South India that we have put together for you.

VLSI Design '97 offers a four-day program. Six tutorials on topics of current interest are offered on the first two days. The next two days are devoted to the technical program that includes paper presentations, posters, a panel, industrial exhibits and exhibitor presentations. This year, we bring the VLSInet for the first time. Thanks to J.A. Chowdary of STP Hyderabad, you will have e-mail and internet connectivity during the conference. We also have a full-fledged Internet web site reporting the latest information on the conference and Hyderabad.

The conference committee has worked with a single minded objective of giving you real value for your time, doing all that is required to put together a conference of this magnitude. I thank all the volunteers who gave of their valuable time. We look forward to getting our reward in your enjoyment of the conference.

Welcome to Hyderabad, home of the Tenth International Conference on VLSI Design. We hope you enjoy the sights and sounds of Hyderabad along with the sights and sounds of the "VLSI in Multimedia Applications" Conference.

Sandhya V. Kode
1997 VLSI Design Organizing Committee Chair

1996 Awards

| Arun Kumar Choudhury |
| Best Paper Award |
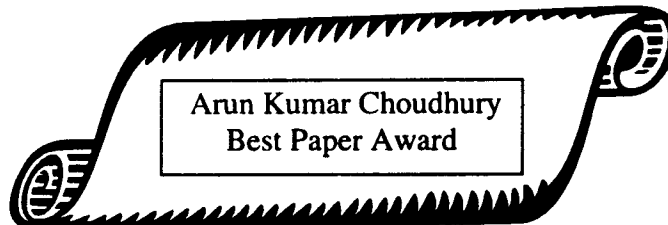
The following two winning papers shared the cash award of Rs. 12000 (about US$400):

1. *Low Power Realization of FIR Filters using Multirate Architectures*
M. Mehendale, Texas Instruments, Bangalore, India,
S.D. Sherlekar and G. Venkatesh, Silicon Automation Systems, Bangalore, India

2. *A Synchronous Test Generation Model for Asynchronous Circuits*
S. Banerjee, Lucent Technologies, Princeton, NJ,
S.T. Chakradharand R.K. Roy, NEC USA, Princeton, NJ.

Honorable Mention Award

Test Generation for Mixed-Signal Devices Using Signal Flow Graphs
R. Ramadoss and M.L. Bushnell,
Rutgers University, Piscataway, NJ.

Best Student Paper Award

Cubical CAMP for Minimization of Boolean Functions
N.N. Biswas, C. Srikanth and J. Jacob,
Indian Institute of Science, Bangalore, India
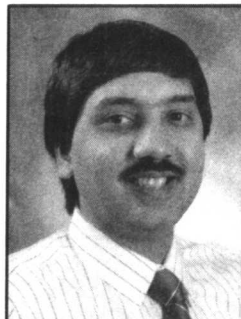
Design Contest Award

A Low Cost PC Based Hardware Emulator For Speeding up Logic Simulation
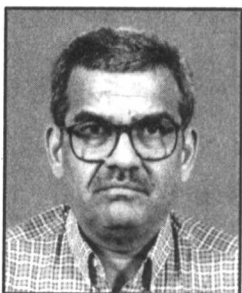A. Gupta

Conference Committee
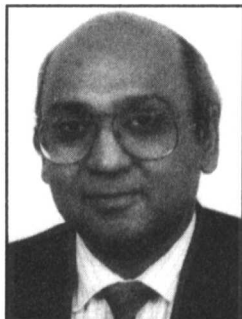
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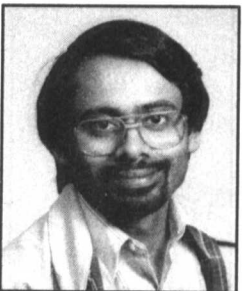Princeton, NJ 08540
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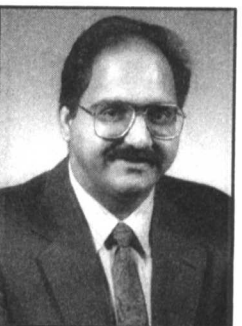Hyderabad 500 038 India
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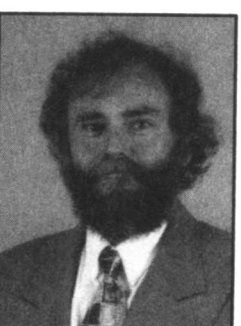91-33-5568085 ext. 3006
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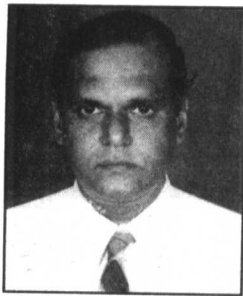214-995-6716
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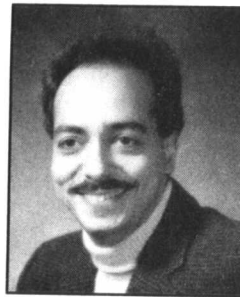813-974-4760
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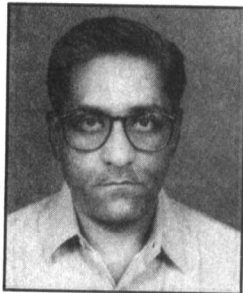
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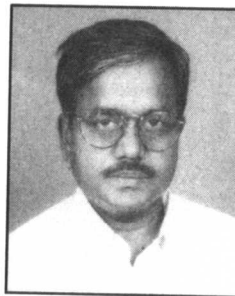
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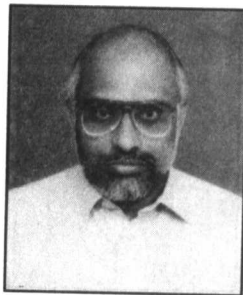
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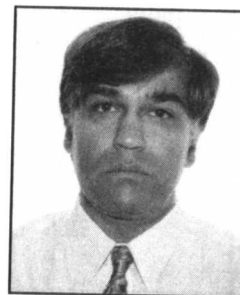
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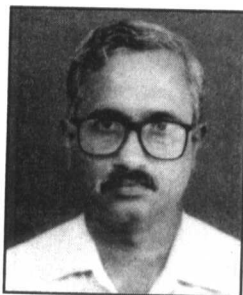
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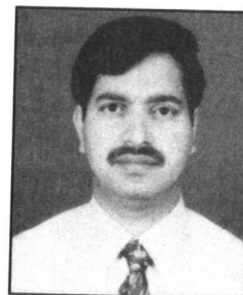
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1996 Fellowship Recipients

The Steering Committee awarded fellowship grants to 240 participants of the *Ninth International Conference on VLSI Design*, Bangalore, India, January 3-6, 1996.

Name	Affiliation	Location	Sponsor
Mohammed Fadle Abdulla	*Indian Inst. of Tech.*	*New Delhi*	*VLSI Soc. of India*
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Gaurav Aggarwal	*Indian Inst. of Tech.*	*New Delhi*	*Texas Instr.–India*
Kamal Aggarwal	*Indian Inst. of Tech.*	*New Delhi*	*NEC–USA*
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Swagata Biswas	Indian Inst. of Tech.	Kharagpur	VLSI Design '96
Swarup Bhunia	Indian Inst. of Tech.	Kharagpur	VLSI Design '96
Parbati Bose	Bengal Engineering College	Howrah	VLSI Soc. of India
Sanjay Bose	Indian Statistical Inst.	Calcutta	VLSI Design '96
Parbati Bose	Bengal Engineering College	Howrah	VLSI Soc. of India
Sindhu R. Chaitrananda	Regional Engineering College	Warangal	Texas Instr.–India
Dhruva Ranjan Chakrabarti	Indian Inst. of Tech.	Kanpur	Texas Instr.–India
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