

VLSI DESIGN 2000

WIRELESS AND DIGITAL IMAGING IN THE MILLENNIUM

**PROCEEDINGS OF
THE 13th INTERNATIONAL CONFERENCE ON VLSI DESIGN**

Science City
Calcutta, India
3-7 January 2000

Sponsored by



VLSI SOCIETY OF INDIA (VSI)

DOE, GOVERNMENT OF INDIA

In cooperation with



ASSOCIATION FOR COMPUTING MACHINERY
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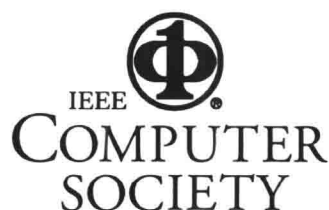
The logo for VLSI DESIGN 2000 features the letters V, L, S, and I each inside a separate square, which are arranged in a cross pattern. To the right of this graphic, the words "DESIGN 2000" are written in a large, bold, serif font.

VLSI DESIGN 2000

Thirteenth International Conference on VLSI Design

3-7 January 2000

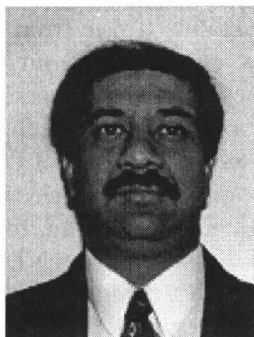
**Science City
Calcutta, India**



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General Chairs' Message



Debashis Bhattacharya



Bhargab B. Bhattacharya

Quest for scientific knowledge to enhance our understanding of the world around us has led to all technological innovations responsible for the progress of civilization. The tremendous advancement in science and technology stands on the contributions of numerous giants from Archimedes to Einstein, during the last 2500 years. Today, at the dawn of a new millennium, it is evident that computers and communication systems have the most profound impact on mankind, surpassed, perhaps, only by the invention of fire at the infancy of human civilization. Needless to say, it is Very Large Scale Integration (VLSI) technology that has made this evolution a reality. No other invention has changed the way human beings live, think, communicate, interact, invent, recreate, and develop, individually and as societies, as VLSI circuits have.

Welcome to the *International Conference on VLSI Design 2000*. This is the *thirteenth* in a series of meetings on VLSI Design, held annually in India, and the *first conference in the new millennium* dedicated to VLSI Design focusing on *wireless* and *digital imaging*, the two key technologies of the future. Over the years, this conference has blossomed into an internationally renowned forum for interaction among representatives from academia and businesses around the world. Through technical sessions, panels, tutorials, and industrial exhibits, it now brings together well over 700 participants, each year, who present their latest thoughts, technologies, and products, to the world at large. VLSI Design 2000 is sponsored by the VLSI Society of India, Department of Electronics (Government of India), and West Bengal Industrial Development Corp., and is held in cooperation with the ACM SIGDA, the IEEE Circuits and Systems Society and the Indian Statistical Institute, Calcutta. Other major sponsors include Intel Corporation, Texas Instruments, Lucent Technologies, Cadence Design Systems, Synopsys, Mentor Graphics, CMC, Interra, Delsoft, IKOS, National Semiconductors, Philips, NIIT, TranSwitch Corp., SAS, WEBEL, etc. The proceedings of this conference are published by the IEEE Computer Society Press, USA.

This year, we are proud to announce the inauguration of an *Industry Forum Day*, as part of the VLSI Design 2000. The primary goal of this forum is to facilitate the exchange of business vision related to all aspects of VLSI Design between the major industrial sponsors on the one hand, and between attendees from academia and local industry, on the other. The Industry Forum Day has received an energetic welcome from major

multinationals including Intel Corporation, Lucent Technologies, and Nortel, as well as from local participants, thus adding yet another dimension to this highly successful conference.

Over the past several years, two industries have undergone massive transformations due to the impact of ever-more-integrated ICs: the communications industry and the imaging industry. The combination of high-resolution imaging and high-speed communication (wired and wireless) holds the promise of transforming our lives, yet again, in ways that would be simply unthinkable just a few years ago. Already, movies are being created electronically, and plans are being made for elimination of the celluloid film from the movie industry! Highly specialized surgeons are already able to direct complex procedures from far away, connected via a high-resolution network and high-resolution imaging devices. In a major paradigm shift since the days of Alexander Graham Bell, a telephone now allows people not only to talk to each other, but also to see each other while they talk. Wireless communication has become an integral part of the lives of hundreds of millions of people throughout the world. VLSI Design 2000 recognizes the immense potential that is likely to be unleashed by the admixture of communication and imaging, by choosing, for the first time, two areas in theme of the conference, viz., wireless communication and digital imaging. VLSI Design 2000 is fortunate to have an excellent suite of technical papers focused on these two areas, as well as an impressive suite of invited talks by visionaries from leading companies around the world.

A conference of this magnitude is the result of the tremendous collective efforts by the chairs responsible for its various aspects. The program co-chairs, Naveed Sherwani and Partha P. Chakrabarti, have compiled a truly outstanding technical program that provides the right balance between theory and application, covering all aspects of VLSI design. Embedded tutorials are included at the beginnings of key sessions, to motivate and orient the audience towards key emerging technologies. As in previous years, six full-day tutorials are being offered covering major areas of VLSI design and test. The tutorial co-chairs, Sachin Sapatnekar and Susmita Sur-Kolay have selected an impressive set of tutorials by leading experts from industry and universities. The highly energetic efforts of the Industry Forum co-chairs, Tinku Acharya, Falguni Sarkar and Susanta Sen, were instrumental in the creation of an outstanding program for the first Industry Forum Day in the history of this conference. The publication chair, Tapan J. Chakraborty, was instrumental in putting together the proceedings, and ensuring its high quality. Special thanks go to Anne Rawlinson of IEEE Computer Society Press for her significant efforts in putting the proceedings together. The exhibits co-chairs, Sanjay Mittal and M. Chandrasekaran made a vigorous drive towards collection of sponsorship and attracting exhibits, and thus played a major role in fund raising. The publicity chairs, Sanjay Nayak, Srimat Chakradhar, Bernard Courtois, Vamsi Srikantam and Kozo Kinoshita, did a fantastic job in publicizing this conference in every continent on earth, and in creating and maintaining the Internet web site for VLSI Design 2000. Special thanks go also to Sukanya Sarkar of Delsoft, for her help with the Internet web site. This conference organizes a design contest that recognizes innovative VLSI designs that originate in India. Thanks to the energetic efforts of the design contest chair, Mahesh Mehendale, VLSI Design 2000 can boast a highly successful design contest.

The conference is being held in Calcutta, the Gateway to Eastern India and the Cultural Capital of India, after a gap of six years. Hosting a conference of this magnitude requires an elaborate organizational structure, which is provided, once again, by the Calcutta office of CMC Ltd. The organizing committee members, under the capable guidance of Alope Bhattacharya, have been instrumental in making this conference a success. Since 1994 – the first time the International Conference on VLSI Design was held in Calcutta – the conference steering committee has awarded fellowships to students and professors at various Indian universities, who are actively involved in VLSI design related work. These fellowships allow the recipient to register for the conference, attend tutorials, and pay for travel and boarding expenses. The fellowship chair, P. K. Nandi, has carefully handled the award of fellowships. We also take this opportunity to thank our Finance Chair - Avijit Basu, ACM Liaison - Sharad Seth, IEEE Liaison - N. Ranganathan, VSI Liaison - A. Prabhakar, and VSI Secretary - G. H. Sarma, for their services towards this conference.

As always, the Steering Committee chair, Vishwani Agrawal provided all the committee members with invaluable help, guidance, and support. The current success of VLSI Design conference can be attributed, in large part, to his vision and relentless efforts throughout its existence. Last, but not the least, we wish to thank all the authors, reviewers, program committee members, and participants, for their continued commitment which is key to the long-term success of any technical meeting. On behalf of the conference committee, we welcome all participants to Calcutta! We wish you a pleasant stay in this historic and eclectic city, and hope you will find the VLSI Design 2000 experience a memorable one.

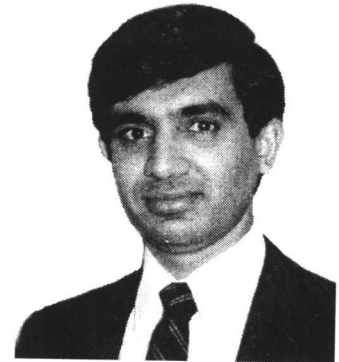
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VLSI Design 2000 General Co-Chairs

Program Co-Chairs' Message



Dr. P. P. Chakrabarti
IIT Kharagpur, India



Dr. Naveed Sherwani
Intel Corporation, USA

The International Conference on VLSI Design was started in 1985 as a small workshop at IIT Madras, under the visionary guidance of Dr. Vishwani Agrawal of Bell Laboratories and Prof. H.N. Mahabala of IIT Madras. From this small start, it has grown into a leading international conference on VLSI design, which draws around 700 attendees every year from India and from abroad. This conference is the 13th conference of the series, and the first conference to be held in the new millennium.

The theme of the conference this year is "Wireless and Digital Imaging in the Millennium." The five day conference program consists of regular paper sessions, short paper sessions, special sessions, tutorials, panel discussions and industrial exhibits. In addition, an industry-forum day is being organized to encourage interaction between academia and industry.

The two day technical program consists of eighteen sessions on a variety of VLSI topics including low power, formal verification, testing, embedded systems, synthesis, physical design, and analog design. We have a special session on Digital Imaging in line with the conference theme in addition to invited and keynote talks surrounding this theme.

The paper selection process was streamlined this year. Papers from USA were received by Naveed Sherwani and were reviewed by the US-based committee. Papers from rest of the world were handled by P. P. Chakrabarti and the India-based committee. The two committees met at the end of the review process to jointly select the papers for the conference.

This year our job was made difficult by submission of a significant number of excellent papers. We received just over 150 papers and selected 75 of these as regular or short papers. In addition, we have included several embedded tutorials and invited talks throughout the program to enrich the content.

We are very thankful to the entire program committee for the reviewing and selection of papers in a short duration. The selection process is also challenging, since a coordinated meeting between India and USA keeps at least one sub-committee sleepless one or two nights.

We are very thankful to all the reviewers (names are listed later in the Proceedings) for returning the reviews in a timely fashion. We are thankful to Professor Kaushik Roy and Professor Anantha Chandrakasan for helping with the special session on low power and want to acknowledge the help of Dr. Manuel d'Aberu on the manufacturing test session.

Naveed Sherwani would like to thank Satya Gupta for his help on the technical program, logistics of the program committee meeting and all other coordination efforts. His help and dedication was critical in the success and timeliness of the program. Naveed Sherwani would also like to thank the efforts of Billie Warrick for helping out on the technical program. Thanks are due to Vishwani Agrawal and Debashis Bhattacharya for setting up the program committee meeting and conducting it at three different sites in the USA. P. P. Chakrabarti would like to thank Ujjwal Konar, Jatin Deka, Santanu Chattopadhyay, Dipanwita Roy Chowdhury and Sudipto Kundu for their dedicated assistance during the review process. Special thanks are due to CMC Limited, Calcutta, for arranging the PC meeting of the India Committee in their Calcutta office, and IIT Kharagpur for much needed infrastructure support during the whole process.

It was great pleasure for us to serve as the program committee chairs and we look forward to the continued success of the VLSI conference and your participation.

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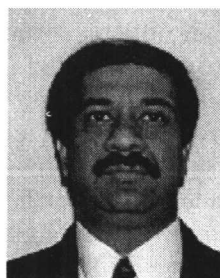
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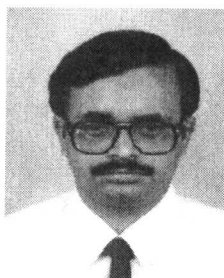
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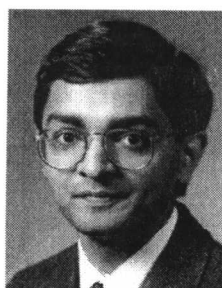
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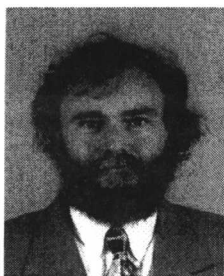


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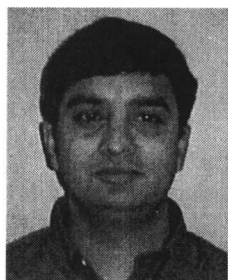
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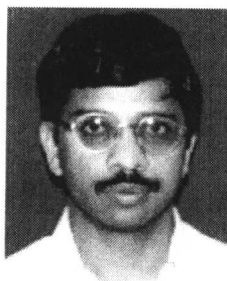
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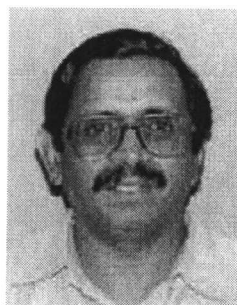
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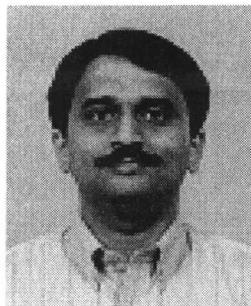
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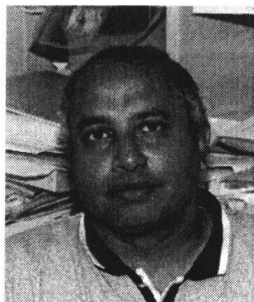
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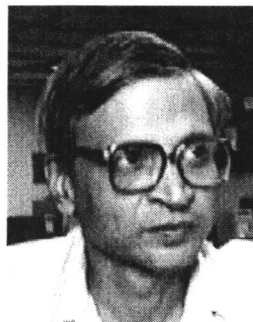
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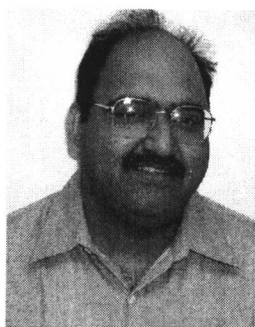
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Ankur Jain	Indian Institute of Technology	New Delhi
Anupam Rastogi	Indian Institute of Technology	New Delhi
Ashok Khandelwal	Indian Institute of Technology	New Delhi
Aviral Shrivastava	Indian Institute of Technology	New Delhi
Banani Saha	University of Calcutta	Calcutta
Basabi Bhaumik	Indian Institute of Technology	New Delhi
Bhaskara B Murthy	Regional Engineering College	Rourkela
Bindu John	Indian Institute of Technology	New Delhi
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C. P. Ravikumar	Indian Institute of Technology	New Delhi
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Debesh K. Das	Jadavpur University	Calcutta
Elizabeth Elias	Regional Engineering College	Calicut
Elwin C. Monie	Government College of Technology	Coimbatore
G. Ramachandra	Karnataka Regional Engineering College	Surathkal
G. S. Visweswaran	Indian Institute of Technology	New Delhi
H. S. Shivaram	National Institute of Engineering	Mysore
Hiranmay Saha	Jadavpur University	Calcutta
James Jacob	Indian Institute of Science	Bangalore
Jatindra K. Deka	Indian Institute of Technology	Kharagpur
K Bhagya Lakshmi	K R E C	Surathkal
K. G. N. Praveen	Indian Institute of Technology	Guwahati
K. S. Gurumurthy	U V C E	Bangalore
Kalyan Chakravarthy	Sri Vnekateswara College of Engineering	Chennai
M.C. Bhuvaneshwari	PSG College of Engineering	Coimbatore
M. Manikantan	Indian Institute of Technology	Mumbai
M. Naga Mahesh	Indian Institute of Science	Bangalore
Mrinal Bose	Indian Institute of Technology	Kharagpur
N. S. Murthy	Regional Engineering College	Warangal
Narayana Bhat M	Manipal Institute of Technology	Manipal
Niranjana N. Chiplunkar	N M A M Institute of Technology	Nitte
Om Prakash Gangwal	Indian Institute of Technology	New Delhi
P. Kumar	Indian Institute of Technology	Kharagpur
P. Sakthivel	PSG College of Technology	Coimbatore
Pabitra Pal Choudhuri	Indian Statistical Institute	Calcutta
Pankaj Bharti	Indian Institute of Technology	New Delhi
Pankaj Kansal	Indian Institute of Technology	Chennai
Parveen Kumar	Indian Institute of Technology	Guwahati
Pavan Kumar A.	Sri Venkateswara College of Engineering	Chennai

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Rajat K. Pal	University of Calcutta	Calcutta
Ravinder Agarwal	Thapar Institute of Engineering & Technology	Patiala
S. K. Ghosh	Indian Institute of Technology	Kharagpur
S. K. Jena	Regional Engineering College	Rourkela
S. Ramachandran	Indian Institute of Technology	Chennai
S. Ramesh	Indian Institute of Technology	Mumbai
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Sandip Das	North Bengal University	Darjeeling
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Sanjeev K. Maheshwari	Indian Institute of Technology	New Delhi
Satrajit Gupta	Indian Institute of Science	Bangalore
Satyabrata Sarkar	University of Calcutta	Calcutta
Saurabh Sandhir	Indian Institute of Technology	New Delhi
Shabbir H. Batterwala	Indian Institute of Technology	Mumbai
Shuvendu K. Lahari	Indian Institute of Technology	Kharagpur
Sumam David S.	Karnataka Regional Engineering College	Surathkal
Susanta Chakraborty	University of Kalyani	Kalyani
Sushant Jain	Indian Institute of Technology	New Delhi
Sushil C. Jain	Indian Institute of Technology	New Delhi
Susmita Sur-Kolay	Jadavpur University	Calcutta
Udipi C Niranjana	Manipal Institute of Technology	Manipal
V. Rajesh	Indian Institute of Technology	Kanpur
Vineet Sahula	Indian Institute of Technology	New Delhi
Vishal Choudhary	Indian Institute of Technology	New Delhi
W.S. Khokle	Visveswaraya Reg. College of Engineering	Nagpur

VLSI Design 1999 Conference Awards

Prof. A.K. Choudhury Best Paper Award

"Efficient DC Analysis of RVJ Circuits for Moment and Derivative Computations
of Interconnect Networks"

Shabbir H. Batterywala
H. Narayanan

I.I.T. Bombay
I.I.T. Bombay

Best Student Paper Award

(shared by the following two papers)

"Improving Area Efficiency of Residue Number System based Implementation of DSP Algorithms"

M.N. Mahesh
Satrajit Gupta
Mahesh Mehendale

I.I.Sc. Bangalore
I.I.Sc. Bangalore
Texas Instruments

"A Semi-Digital Delay Locked Loop for Clock Skew Minimization"

Joonbae Park
Yido Koo
Wonchan Kim

Seoul National University, Korea
Seoul National University, Korea
Seoul National University, Korea