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DAC96

33rd Design Automation Conference
June 3-7, 1996
Las Vegas, Nevada

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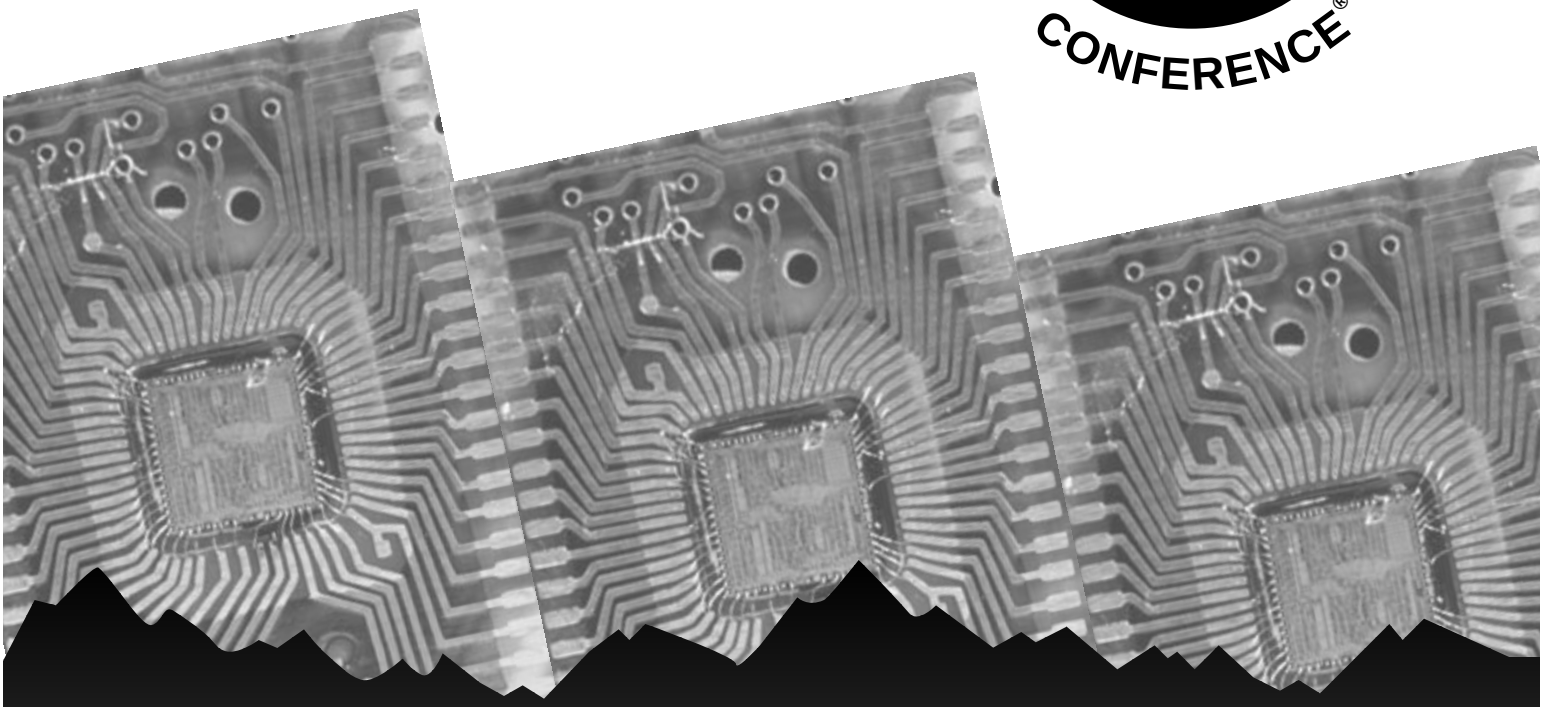

PROCEEDINGS 1996

Las Vegas Convention Center
Las Vegas, NV ¥ June 3-7, 1996

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PROCEEDINGS OF THE 33rd DESIGN AUTOMATION CONFERENCE

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General Chair's Welcome

Welcome to the 33rd annual Design Automation Conference...the leading technical conference for the presentation of design automation research and development work. DAC is where the Electronic Design Automation industry exhibits the leading edge technology driving today's integrated circuit and electronic systems industry. Increasingly, design engineers come to DAC to learn about design solutions and improving productivity with design automation methodologies.

The mission of the conference is to provide a forum whose participants include the Design Automation research and development community, the Electronic Design Automation industry, and design and product engineers who use EDA tools to design electronic circuits and systems. The conference also seeks to promote the professional growth of our participants through the interchange of ideas and by providing educational opportunities.

These proceedings, representing an outstanding expanded technical program, were assembled under the very able direction of this year's Co-Technical Program Chairs Giovanni De Micheli and Steve Trimberger. Three hundred, seventy-seven papers were reviewed by 572 people with DA experience. These reviews, along with the detailed examination by the Technical Program Committee, yielded 142 technically superior papers. Complimented by panel discussions addressing critical topics in engineering design solutions and embedded tutorials aimed at increasing DAC's value to its participants, this Technical Program is the very best our industry can offer. Many thanks to the volunteer reviewers, the Technical Program Committee members and its Co-Chairs and to all the contributors whose work is represented in these proceedings.

Our sponsors include ACM/SIGDA, EDAC and IEEE Circuits and Systems Society. They broadly represent the DAC participant community and we are thankful for their continued and active support. Finally, I wish to recognize the members of the Executive Committee who, with the support of MP Associates, make this the premier conference for electronic design automation and engineering methodologies.

Welcome to Las Vegas and the 33rd Design Automation Conference. We wish you a very productive and fun filled week, and hope you will find these proceedings to be a valuable information reference for many years.

Thomas P. Pennino
General Chair, 33rd Design Automation Conference

OPENING KEYNOTE ADDRESS

Arati Prabhakar
National Institute of Standards and Technology
Gaithersburg, Maryland

TECHNOLOGY TRENDS DRIVING OUR 21st CENTURY ECONOMY

We live today in the knee in the curve of the information revolution, at the threshold of a transformation fueled by the circuits and systems that this community builds. A century ago, the idea of interchangeable parts was shaping the industrial revolution, leading to economies of scale and the vast, intricate system of customers and suppliers in our economy. At the turn of the 21st century, the cacophony of computers and communications is harmonizing into a practical, useable, interoperable information infrastructure. The information revolution, for so long the dream of engineers and scientists, is becoming the creature of the school teacher, the machine operator, the health care provider, and the citizen. In terms of its impact on society, it is fair to say that "we ain't seen nothin' yet".

A look back at the last major technology revolution shows us how far-reaching the implications of such a change can be. Obviously, industrialization transformed the patterns of work. But with that came dramatic changes – in education, in social patterns – across our society. And much of today's societal fabric – from antitrust policy to unemployment compensation to Social Security to the regulatory system – is the legacy of that same transformation.

Another legacy of the industrial revolution is our national technology system – the very system that spawned this information revolution. Industrial support for research and development blossomed with the growth of corporations during this century and remains a majority share of the U.S. R&D investment. Rooted in a post-WWII understanding that science and technology are vital components in national security and economic prosperity, the federal government has long invested in R&D as part of missions such as national security and health, and in a broad base of university scientific research.

But like many other social contracts, our technology system is struggling with the challenge of reinventing itself for the coming century. Vigorous global competition has driven companies to narrow and sharpen the focus of their R&D, with the result that most companies today capture more value on the R&D dollar than in the past. This also means, however, that the longer-term, broader-based R&D – the type that is so valuable to the wider community but is not often captured by the performing company – has fallen off, with dangerous long-term implications in many fields. It is no longer a valid assumption that taxpayer-supported research will automatically move into the U.S. economy, where its benefits can be reaped.

These deep-seated changes mandate a new kind of relationship among players in our technology system. Over the past few years, a number of important experiments have been launched to combine the strengths of industry, academia and government in novel, synergistic ways. How these efforts play out will be critical to our ability to develop the new R&D paradigms we need for the next century. The opportunity for success is significant. We can lay the foundations for a new R&D culture that values partnership and team work along with entrepreneurial vision and vigorous competition. This culture of cooperation and competition will continue to drive the information revolution – and enable us to reap its benefits.

WEDNESDAY KEYNOTE ADDRESS

James Clark
Netscape Communications Corp.
Mountain View, CA

The foundations of the information superhighway are in place. The Internet -- an interconnection of tens of thousands of public and private networks worldwide -- today provides more than 30 million users with access to information from around the globe. This complex of networks forms the initial pathway for the global information revolution that will eventually link businesses, public and private agencies and educational centers with one another and with consumers in their homes. Navigating successfully through the mountains of data available on these vast networks may be the greatest challenge the information age presents.

Jim Clark is Chairman of Netscape Communications Corporation. Prior to founding the company, Clark was chairman of Silicon Graphics, Inc., a computer systems company he founded in 1982 that now has annual revenues of $1.5 billion and is among the Fortune 500's fastest growing companies. Prior to founding Silicon Graphics, Clark was an associate professor at Stanford University, where he and a team of graduate students developed the initial technology on which Silicon Graphics was built.

Clark resigned as chairman of Silicon Graphics in February 1994 to undertake a new venture with the young programming team that created the widely-used NCSA Mosaic graphical user interface.

Clark holds a Ph.D. in Computer Science from the University of Utah.

THURSDAY KEYNOTE ADDRESS

Eric Schmidt
Sun Microsystems, Inc.
Mountain View, CA

Internet is Java™'s launch pad. Sun's Java™ language is poised to fill World Wide Web browsers everywhere with animation, audio, and real-time interactivity. The Net, supported by the Java™ language, offers a new economic model for the software industry, including the Electronic Design Automation industry. Will the Net and Java™ support DA software subscriptions rather than perpetual licenses thereby creating a paradigm shift in the EDA industry? Nothing in the design of Java™ limits it to Unix or any other operating system. Will it successfully cross over into the non-Unix marketplace?

Dr. Eric Schmidt is responsible for coordinating all aspects of Sun's core and emerging technologies, including SPARC microprocessors, the Solaris operating environment and networking. Dr. Schmidt also examines emerging areas such as interactive multimedia and broadband networks.

Prior to joining Sun, Dr. Schmidt was a member of the research staff at the Computer Science Lab at Xerox Palo Alto Research Center (PARC) and he also held positions at Bell Laboratories and Zilog.

Dr. Schmidt has a B.S. in electrical engineering from Princeton University, and a M.S. in electrical engineering and a Ph.D. in computer science from the University of California at Berkeley.

1996 Best Paper Award

This year, awards are made for the best papers in five categories. Winners are determined from detailed reviews of the accepted papers in the technical sessions. Each award is accompanied by a plaque and a cash award of $400. The awards are given by ACM/SIGDA (Special Interest Group on Design Automation), IEEE/CAS (Institute of Electrical and Electronics Engineers/Circuits and Systems Society) and EDAC (Electronic Design Automation Companies).

PHYSICAL DESIGN, ELECTRICAL SIMULATION, HIGH SPEED AND ANALOG DESIGN

Paper 6.4: "A Probability-Based Approach to VLSI Circuit Partitioning"
Authors: Shantanu Dutt, Wenyong Deng
Affiliation: Univ. of Minnesota, Minneapolis, MN

HIGH-LEVEL AND SYSTEM SYNTHESIS AND FRAMEWORKS

Paper 39.1: "Using Register-Transfer Paths in Code Generation for Heterogeneous Memory-Register Architectures"
Authors: Guido Araujo, Sharad Malik — Mike Tien-Chien Lee
Affiliation: Princeton Univ., Princeton, NJ — Fujitsu Labs. of America, Santa Clara, CA

LOGIC SYNTHESIS, VERIFICATION AND TEST

Paper 45.4: "On Solving Binate Covering Problems"
Author : Olivier Coudert
Affiliation: Synopsys, Inc., Mountain View, CA

DESIGN METHODOLOGY

Paper 3.1: "HEAT: Hierarchical Energy Analysis Tool"
Authors: J. Satyanarayana, Keshab K. Parhi
Affiliation: Univ. of Minnesota, Minneapolis, MN

DESIGN EXPERIENCES AND MANAGEMENT OF DA SYSTEMS

Paper 3.3: "POSE: Power Optimization and Synthesis Environment"
Authors: Sasan Iman, Massoud Pedram
Affiliation: Univ. of Southern California, Los Angeles, CA

1995 SIGDA Meritorious Service Awards

Steve Levitan - Univ. of Pittsburgh, Pittsburgh, PA

1996 ACM Fellows

The ACM Fellow Program recognizes and honors outstanding ACM members for their achievements in computer science and information technology and for their significant contributions to the mission of ACM. Among the ACM Fellows of 1996 are the following who have made contributions to the field of electronic CAD and VLSI systems.

Mary Jane Irwin - Pennsylvania State Univ., University Park, PA

Bryan Preas - Xerox Parc, Palo Alto, CA

Sartaj Sahni - Univ. of Florida, Gainesville, FL

1996 IEEE FELLOWS

The grade of Fellow recognizes unusual distinction in the profession and shall be conferred only by invitation of the Board of Directors upon a person of outstanding and extraordinary qualifications and experience in IEEE designated fields, who has made important individual contributions to one or more of these fields.

Tushar Gheewala - Crosscheck Technology, Los Altos, CA

Kurt Keutzer - Synopsys, Inc., Mountain View, CA

Majid Sarrafzadeh - Northwestern Univ., Evanston, IL

Design Automation Conference Scholarship Awards

Each year the Design Automation Conference sponsors several $12,000 scholarships to support graduate research and study in Design Automation (DA), with emphasis in "design and test automation of electronic and computer systems." Each scholarship is awarded directly to a university for the Faculty Investigator to expend in direct support of one or more DA graduate students.

The criteria for granting such a scholarship expanded in 1996 to include financial need. The criteria are: the academic credentials of the student(s); the quality and applicability of the proposed research; the impact of the award on the DA program at the institution; and financial need. Preference is given to institutions that are trying to establish new DA research programs.

Information on next year's DAC scholarship award program will be available on the DAC World Wide Web page at: http://www.dac.com/dac/scholarship.html

1995 Design Automation Conference Scholarship Awards

The 1995 DAC Scholarship Committee was comprised of the following people:

Herschel H. Loomis, Naval Postgraduate School (Chair)
Sylvia A. Chanak, Cadence Design Systems, Inc.
Ian Getreu, Analogy, Inc.

1995 Design Automation Conference Scholarship Awards

- Dr. Jay Brockman of the University of Notre Dame for Arumugamangala Lokanathan and Eric Johnson. Their project is entitled “Multidisciplinary Design Methodologies for Integrated Circuits”.
- Professor Malgorzata Chrzanowska-Jeske of Portland State University for Zhi Wang and Jinsong Zhang. Their project is entitled “Fine-Grain Locally-Connected FPGAs; Synthesis and Architecture”.
- Professor Andrew Kahng of University of California, Los Angeles for Charles Alpert and Chung-Wen Albert Tsao. Their projects are entitled “New Approaches to Partitioning and Clustering”, and “New Methods for Clock Distribution”.
- Professor Alex Orailoglu of University of California, San Diego for Ian Harris. Their project is entitled “Synthesis of Self-Testable VLSI Designs”.
- Professor Majid Sarrafzadeh of Northwestern University for Salil Raje and Amir H. Farrahi. Their project is entitled “Behavioral Power Estimation and Optimization”, and is a renewal of a 1994 DAC Scholarship.

1996 Design Automation Conference Scholarship Awards

The 1996 DAC Scholarship Committee was comprised of the following people:

Sylvia A. Chanak, Cadence Design Systems, Inc. (Chair)
James P. Cohoon, Univ. of Virginia
Philip V. Lopresti, Independent Consultant

The 1996 Design Automation Conference Scholarship Awards

- Prof. Srinivasa Vemuru of The City University of New York, for Ali Duale. Their project is entitled "High-Level Test Generation".
- Prof. Peichen Pan of the Clarkson University for Arvind Karandikar. Their project is entitled "Clustering for Sequential Circuits".
- Prof. Frank Vahid of The University of California, Riverside for Linus Tauro and Thuy Le. Their project is entitled "Hardware/Software Partitioning and Communication".
- Prof. Adnan Aziz of The University of Texas at Austin for Khurram Sajid. Their project is entitled "Formal Design Verification and Sequential Synthesis".

Advancement in Computer Science and Electrical Engineering Undergraduate Scholarships

The objective of the ACSEE Scholarship program is to increase the pool of professionals in Electrical Engineering and Computer Science from under-represented groups (Women, African American, Hispanic, Native American, and Physically Challenged). In 1989, ACM Special Interest Group on Design Automation (SIGDA) began providing the program. Beginning in 1993, the Design Automation Conference provides the funds for the scholarship and SIGDA continues to administer the program for DAC. DAC funds two $4000 scholarships renewable up to 5 years to graduating high school seniors. The former International Daisy User Group funds one $1000 one-time-only scholarship.

The 1996 winners will be announced at the Conference. The 1995 winners were:

1995 DAC/IDUG ACSEE Undergraduate Scholarships

DAC $4K: Amy Wai-Yee Ng, Sugarland, TX - attending MIT

DAC $4K: Micah Tremayne Hawthorne, Ocean Springs, MS - attending MIT

IDUG $1K: Helen Bui, Pasadena, MD

This year, the first graduates of the ACSEE scholarship program will be attending DAC. They are Ms. Ender Bilir from Princeton who graduated with a degree in Computer Science, Ms. Tessa Wilbert from the University of California at Davis who graduated with a double major in Computer Science and Electrical Engineering and Mr. Alonzo Castro from MIT who graduated with a degree in Electrical Engineering.

For more information about ACSEE, please contact Dr. Cherrice Traver, EE/CS Department, Union College, Schenectady, NY 12308. email: traverc@doc.union.edu

REVIEWERS

A total of 377 manuscripts were submitted to the 1996 DAC. The Conference Executive and Technical Program Committees wish to acknowledge the time and effort spent by the following people who reviewed these manuscripts and returned the review forms completed. Our thanks to all of those who participated and contributed to the success of the Conference.

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T1.1 Electrical-level circuit and timing simulation
T1.2 Discrete simulation
T1.3 Critical path analysis and timing verification
T1.4 Power estimation
T2.1 Testing, fault modeling and simulation, TPG, test validation and DFT
T2.2 Design and implementation verification (excluding layout verification)
T3.1 Floorplanning and placement
T3.2 Global and detailed routing
T3.3 Module generation and compaction, transistor sizing and cell library optimization, layout verification
T4.1 Technology independent, combinational logic synthesis
T4.2 Technology dependent logic synthesis, library mapping, interactions between logic design and layout
T4.3 Sequential logic synthesis and optimization
T4.4 High-level synthesis
T4.5 Asynchronous logic synthesis
T5.1 Hardware Description Languages
T5.2 Hardware/Software co-design, partitioning, system-level specification and design aids
T5.3 Software synthesis and retargetable compilation
T5.4 Hardware/Software co-simulation
T6.1 Interconnect and packaging modeling and extraction
T6.2 Signal integrity and reliability analysis
T6.3 Analog and mixed-signal design tools
T6.4 Microsensor and microactuator design tools
T6.5 Statistical design and yield maximization
T7.1 Frameworks, intertool communication, WWW-based tools and databases

DESIGN METHODS TRACK:

M1 Design Methodologies and Case Studies

Use of design automation in state-of-the-art systems, integrated and tested design flows, solutions for actual design tasks, practical design examples, and illustrative case studies.

M1.1 Simulation and estimation
M1.2 Verification, test and debugging
M1.3 Physical design
M1.4 Logic and high-level synthesis
M1.5 System-level design and co-design
M1.6 Analog Synthesis

M2 Application-Specific Design Flows

Design-solutions for specific application domains, such as (but not limited to) ASIC, DSP, RF, Consumer, Automative, Communications, Multimedia, Microprocessor.

M3 Design Technologies and Technology Drivers

"How to " techniques for challenging areas where design automation is in its infancy, exposition of important design issues using real design examples.

M3.1 Basic design technologies (e.g. Deep sub-micron, Low Power, Signal Integrity, Mixed-Signal)
M3.2 Fast prototyping technologies
M3.3 Emerging design technologies (e.g. MEMS, Net-based design, Self-timed design, Intellectual Property)

M4 Integration and Management of DA Systems

Tool integration, partnering with DA vendors, standards issues: VHDL/EDIF/CFI; component libraries; quality management.

M4.1 Complete DA systems
M4.2 Management of DA systems
M4.3 Standardization

REQUIREMENTS FOR SUBMISSION OF PAPERS

Authors should submit their papers to the Program Chair postmarked no later than October 4, 1996. **Previously published papers, including workshop proceedings, will not be considered.** Each submission should include one cover page and ten (10) stapled copies of the complete manuscript.

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- 60-word abstract indicating significance of contribution. The abstracts of accepted papers will appear on the World Wide Web before the Conference.
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Proposals for Panels, Tutorial Sessions, and Full-Day Tutorials should be submitted to the Program Chair no later than October 4, 1996. Proposals should not exceed two pages in length and should describe the topic and intended audience. They must include a list of all participants, including the moderator for Panels. **For proposal instructions, send a one-line email message to proposals@dac.com.**

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Session 6	New Frontiers in Partitioning
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