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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.
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

Authors: Guido Araujo, Sharad Malik
Affiliation: Univ. of Minnesota, Minneapolis, MN

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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Aharon Aharon                 Edward Buturla               Dileep A. Divekar
Suhail Ahmed                  Richard Byrne                Konrad Doll
Robert Aitken                 Gianpigro Cabodi             Rolf Drechsler
Thomas W. Albrecht            Ariel Cao                    Anthony D. Drumm
Michael J. Alexander          Wanlin Cao                   Michael Duane
Peter Alinke                  Joan E. Carletta             Mario Dufresne
Salahuddin Almajdoub          Robert Carragher            James R. Duley
Joachim Altmeyer              K. Chakrabarty               David Duncombe
Tod Amon                      Tapan J. Chakraborty        Debaprosad Dutt
Roger Ang                     Rajit Chandra                Nikil D. Dutt
Catia Marc Angelo             M.S. Chandrasekhar         Klaus Eckl
Kurt Antreich                 K.C. Chang                  Martyn Edwards
Mario Aranha                  Shih-Chieh Chang           Stephen A. Edwards
Lawrence Arnstein             Shir-Shen Chang            Avi Efrati
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Peter Bingley                 Robert Condon                Tomoo Fukazawa
Syed Bokhari                  Bob Conn                    Rich Goldman
Massimo Bombana               Tedd Corman                 George Gad elk karim
Richard Booth                 Fulvio Corno                Anthony J. Gadient
Bhaskar Bose                  Olivier Coudert             Patricia Graham
Daniel Brand                  Scott Cravens                Shantanu Ganguly
Daniel R. Brasen              Ajay J. Daga                 Andreas Ganz
Ansgar Bredenfeld             Peter Dahlgren               Don Gelosh
Melvin A. Breuer              Brian A. Dalio               Arnold Ginetti
Jay B. Brockman               Joseph P. Damore            James A. Goda
Richard B. Brown              Aurobindo Dasgupta          Nobuyuki Goto
Randal E. Bryant              Sumit Dasgupta               Ravender Goyal
# Table of Contents

General Chair’s Welcome ......................................................................................................................................... iii
Executive Committee ................................................................................................................................................ iv
Technical Program Committee .............................................................................................................................. vi
1996 Best Paper Award ........................................................................................................................................... viii
ACM Awards/Fellows and IEEE Fellows ........................................................................................................... viii
34th Call for Papers ................................................................................................................................................ ix
ACSEE Undergraduate Scholarships ................................................................................................................... x
Design Automation Conference Scholarship Awards ............................................................................................ x
Reviewers ............................................................................................................................................................... xii
Opening Keynote Address—Arati Prabhakar ......................................................................................................... xv
Wednesday Keynote Address—James Clark .......................................................................................................... xvi
Thursday Keynote Address—Eric Schmidt ........................................................................................................... xvii

## Session 1

### Executive Forum

**Panel: The EDA Year in Review: CEO’s, The Press, and Users**

Chair: John Cooley  
Organizer: John Cooley  
Panelists: Joe Costello, Aart de Geus, Richard Goering, Alain Hanover,  
Wally Rhines, Gary Smith ................................................................. 1

## Session 2

### High Speed Interconnect

Chair: Gary Smith  
Organizer: S. Roose  

**2.1 Package and Interconnect Modeling of the HFA3624, a 2.4GHz RF to IF Converter**  
Mattan Kamon, Steve S. Majors ............................................................... 2

**Panel: PCB Synthesis—Is the Technology Ready for High Speed Design?**  
Panelists: Robert Gonzales, Mark Leonard, Fred Saal, John Schoenfeld,  
Jonathan Weis, Mike White ................................................................. 8

## Session 3

### Power Analysis

Chair: Bob Frye  
Organizers: S. Nance, N. Weste  

**3.1 HEAT: Hierarchical Energy Analysis Tool**  
Janardhan H. Satyanarayana, Keshab K. Parhi ......................................................... 9

**3.2 Opportunities and Obstacles in Low-Power System-Level CAD**  
Andrew Wolfe ............................................................... 15

**3.3 POSE: Power Optimization and Synthesis Environment**  
Sasan Iman, Massoud Pedram ................................................................. 21

**3.4 Early Power Exploration—A World Wide Web Application**  
David Lidsky, Jan M. Rabaey ................................................................. 27
Session 4

Current Directions in High Level Synthesis
Chair: Hiroto Yasuura
Organizers: R. Walker, K. Wakabayashi

4.1 Tutorial: Behavioral Synthesis
Raul Camposano ................................................................. 33

4.2 A Register File and Scheduling Model for Application Specific Processor Synthesis
E. Ercanli, C. Papachristou .................................................. 35

4.3 Optimized Code Generation of Multiplication-Free Linear Transforms
Mahesh Meendale, G. Venkatesh, S. D. Sherlekar ................... 41

4.4 Concurrent Analysis Techniques for Data Path Timing Optimization
Chuck Monahan, Forrest Brewer ........................................... 47

4.5 HDL Optimization Using Timed Decision Tables
Jian Li, Rajesh K. Gupta ...................................................... 51

Session 5

Analysis and Synthesis of Asynchronous Circuits
Chair: Peter Beerel
Organizers: L. Lavagno, B. Lin

5.1 Efficient Partial Enumeration for Timing Analysis of Asynchronous Systems
Eric Verlind, Gjalt de Jong, Bill Lin .................................... 55

5.2 Verification of Asynchronous Circuits Using Time Petri Net Unfolding
Alexei Semenov, Alexandre Yakovlev .................................. 59

5.3 Methodology and Tools for State Encoding in Asynchronous Circuit Synthesis
Jordi Cortadella, Michael Kishinevsky, Alex Kondratyev,
Luciano Lavagno, Alex Yakovlev ....................................... 63

5.4 A Technique for Synthesizing Distributed Burst-Mode Circuits
Prabhakar Kudva, Ganesh Gopalakrishnan, Hans Jacobson ....... 67

5.5 Espresso-HF: A Heuristic Hazard-Free Minimizer for Two-Level Logic
Michael Theobald, Steven M. Nowick, Tao Wu ...................... 71

5.6 Synthesis of Hazard-free Customized CMOS Complex-Gate Networks Under Multiple-Input Changes
Prabhakar Kudva, Ganesh Gopalakrishnan, Hans Jacobson, Steven M. Nowick .......... 77

Session 6

New Frontiers in Partitioning
Chair: D. F. Wong
Organizers: A. Domic, A. B. Kahng

6.1 Tutorial: Partitioning of VLSI Circuits and Systems
Frank M. Johannes ........................................................... 83

6.2 New Spectral Linear Placement and Clustering Approach
Jianmin Li, John Lillis, Lung-Tien Liu, Chung-Kuan Cheng ...... 88

6.3 Characterization and Parameterized Random Generation of Digital Circuits
Michael Hutton, J. P. Grossman, Jonathan Rose, Derek Corneil . 94

6.4 A Probability-Based Approach to VLSI Circuit Partitioning
Shantanu Dutt, Wenyong Deng .......................................... 100
Session 7
Trends in Verification
Chair: James Rowson
Organizers: N. Collins, R. Goering
7.1 Tutorial: Verification of Electronic Systems
Alberto L. Sangiovanni-Vincenelli, Patrick C. McGeer, Alexander Saldanha....................106
Panel: Hot New Trends in Verification
Panelists: Anant Agarwal, Willis Hendley, Isadore Katz, Don McInnis, Patrick Scaglia, Alex Silbey.........................................................................................................112

Session 8
Specialized Design Techniques for Speed and Power
Chair: Scott Nance
Organizers: D. Stark, B. Frye
8.1 Design Considerations and Tools for Low-voltage Digital System Design
Anantha Chandrakasan, Isabel Yang, Carlin Vieri, Dimitri Antoniadis ......................113
8.2 VAMP: A VHDL Based Concept for Accurate Modeling and Post Layout Timing
Simulation of Electronic Systems
Bernhard Wunder, Gunther Lehmann, Klaus D. Müller-Glaser ........................................119
8.3 A Systematic Technique for Verifying Critical Path Delays in a 300MHz Alpha CPU
Design Using Circuit Simulation
Madhav P. Desai, Y. T. Yen....................................................................................................125

Session 9
Test and Fault Tolerance in High Level Synthesis
Chair: C. Papachristou
Organizers: K. Wakabayashi, R. Camposano
9.1 Tutorial: High-Level Synthesis for Testability: A Survey and Perspective
Kenneth D. Wagner, Sujit Dey...............................................................................................131
9.2 Introspection: A Low Overhead Binding Technique During Self-Diagnosing
Microarchitecture Synthesis
Balakrishnan Iyer, Ramesh Karri.........................................................................................137
9.3 Lower Bounds on Test Resources for Scheduled Data Flow Graphs
Ishwar Parulkar, Sandeep K. Gupta, Melvin A. Breuer .......................................................143

Session 10
Issues in Discrete Simulation
Chair: Jay Lawrence
Organizers: R. McGeer, K. Sakallah
10.1 Symphony: A Simulation Backplane for Parallel Mixed-Mode Co-Simulation
of VLSI Systems
Antonio R. W. Todesco, Teresa H.-Y. Meng .................................................................149
10.2 Oscillation Control in Logic Simulation Using Dynamic Dominance Graphs
Peter Dahlgren................................................................................................................155
10.3 Compact Vector Generation for Accurate Power Simulation
Shi-Yu Huang, Kuang-Chien Chen, Kwang-Ting Cheng, Tien-Chien Lee ......................161
10.4 Improving the Efficiency of Power Simulators by Input Vector Compaction
Chi-ying Tsui, Radu Marculescu, Diana Marculescu, Massoud Pedram .........................165
Session 11  
Issues in Design Environments  
Chair: Michaela Guiney  
Organizers: D. Ku, R. A. Rutenbar  

11.1 Efficient Communication in a Design Environment  
Idalina Videira, Paulo Veríssimo, Helena Sarmento ............................................................169  

11.2 A Description Language for Design Process Management  
Peter R. Sutton, Stephen W. Director ....................................................................................175  

11.3 Improved Tool and Data Selection in Task Management  
John W. Hagerman, Stephen W. Director .............................................................................181  

11.4 Application of a Markov Model to the Measurement, Simulation, and Diagnosis of an  
Iterative Design Process  
Eric W. Johnson, Luis A. Castillo, Jay B. Brockman............................................................185

Session 12  
Panel: Gearing Up for the Technology Explosion  
Chair: Gary Smith  
Organizer: M. Kenefick  
Panelists: Walt Davis, Glenn House, Kurt Keutzer, Jim Pena, Craig Peterson,  
Lawrence Rubin, Jim Solomon ....................................................................................................189

Session 13  
Tutorial: The SPICE FET Models: Pitfalls and Prospects  
(Are You An Educated Model Consumer?)  
Chair: Daniel Foty  
Organizer: J. Cooley  
Presenter: Daniel Foty........................................................................................................190

Session 14  
Combinational Logic Synthesis I  
Chair: Gary D. Hachtel  
Organizers: S. Malik, R. McGeer  

14.1 Tutorial: Design of a Logic Synthesis System  
Richard Rudell......................................................................................................................191  

14.2 On Solving Covering Problems  
Olivier Coudert.....................................................................................................................197

Session 15  
Pattern Generation for Test and Diagnosis  
Chair: Janusz Rajski  
Organizers: S. Kundu, Y. Zorian  

15.1 A New Complete Diagnosis Patterns for Wiring Interconnects  
Sungju Park...........................................................................................................................203  

15.2 A Satisfiability-Based Test Generator for Path Delay Faults in Combinational Circuits  
Chih-Ang Chen, Sandeep K. Gupta......................................................................................209  

15.3 On Static Compaction of Test Sequences for Synchronous Sequential Circuits  
Irith Pomeranz, Sudhakar M. Reddy ....................................................................................215
Session 16
CAD for Analog and Mixed Signal ICs
Chair: James Spoto
Organizers: R. A. Rutenbar, J. White

16.1 An $O(n)$ Algorithm for Transistor Stacking with Performance Constraints
Bulent Basaran, Rob A. Rutenbar .................................................................221

16.2 Use of Sensitivities and Generalized Substrate Models in Mixed-Signal IC Design
Paolo Millozzi, Iasson Vassiliou, Edoardo Charbon, Enrico Malavasi,
Alberto L. Sangiovanni-Vincentelli..........................................................227

16.3 RTL Emulation: The Next Leap in System Verification
Sanjay Sawant, Paul Giordano.................................................................233

16.4 Equation-Based Behavioral Model Generation for Nonlinear Analog Circuits
Carsten Borchers, Lars Hedrich, Erich Barke .............................................236

Session 17
Panel: Core-Based Design for System-Level ASICs—Whose Job Is It?
Chair: Lynn Watson
Organizer: R. Goldman
Panelists: Kim Asal, Andreas Danuser, Chris King, Susan Mason,
Jim Pena, Scott Runner..............................................................................240

Session 18
Panel: A Common Standards Roadmap
Chair: Alain Hanover
Organizer: J. Smith
Panelists: Rich Goldman, Andy Graham, Randolph E. Harr, Gregory W. Ledenbach,
A. Richard Newton, Robert Rozeboom, Tabuchi Kinya.................................241

Session 19
Combinational Logic Synthesis II
Chair: Iris Bahar
Organizers: R. McGeer, S. Malik

19.1 Multilevel Logic Synthesis for Arithmetic Functions
Chien-Chung Tsai, Malgorzata Marek-Sadowska.......................................242

19.2 Synthesis by Spectral Translation Using Boolean Decision Diagrams
Jeffery P. Hansen, Masatoshi Sekine.......................................................248

19.3 Delay Minimal Decomposition of Multiplexers in Technology Mapping
Shashidhar Thakur, D. F. Wong, Shankar Krishnamoorthy..........................254

19.4 Error Correction Based on Verification Techniques
Shi-Yu Huang, Kwang-Chien Chen, Kwang-Ting Cheng.............................258

Session 20
Design for Testability
Chair: Yervant Zorian
Organizers: S. Kundu, J. Rajski

20.1 Layout Driven Selecting and Chaining of Partial Scan Flip-Flops
Chau-Shen Chen, Kuang-Hui Lin, TingTing Hwang.................................262

20.2 Test Point Insertion: Scan Paths Through Combinational Logic
Chih-chang Lin, Malgorzata Marek-Sadowska, Kwang-Ting Cheng,
Mike Tien-Chien Lee ................................................................................268
Area Efficient Pipelined Pseudo-Exhaustive Testing with Retiming

Huoy-Yu Liou, Ting-Ting Y. Lin, Chung-Kuan Cheng

274

Session 21
Advances in Electrical Simulation
Chair: Peter Feldmann
Organizers: J. White, A. T. Yang

Stable and Efficient Reduction of Large, Multiport RC Networks by Pole Analysis via Congruence Transformations

Kevin J. Kerns, Andrew T. Yang

280

Homotopy Techniques for Obtaining a DC Solution of Large-Scale MOS Circuits

J. S. Roychowdhury, R. C. Melville

286

Efficient AC and Noise Analysis of Two-Tone RF Circuits

Ricardo Telichevesky, Ken Kundert, Jacob White

292

Session 22
Mixed Signal Design
Chair: Stephan Ohr
Organizers: S. Napper, R. A. Rutenbar

Tutorial: Synthesis Tools for Mixed-Signal ICs: Progress on Frontend and Backend Strategies

L. Richard Carley, Georges G. E. Gielen, Rob A. Rutenbar, Willy M. C. Sansen

298

Panel: Mixed Signal Designs: Are There Solutions Today?
Panelists: Ariel Cao, Georges Gielen, Felicia James, Rob A. Rutenbar, Baker P. Scott, David Squires

304

Session 23
Functional Verification of Microprocessors
Chair: Rajesh Raina
Organizers: N. Weste, P. Duncan

Code Generation and Analysis for the Functional Verification of Microprocessors

Anoosh Hosseini, Dimitrios Mavroidis, Pavlos Konas

305

Innovative Verification Strategy Reduces Design Cycle Time for High-End SPARC Processor

Val Popescu, Bill McNamara

311

Hardware Emulation for Functional Verification of K5

Gopi Ganapathy, Ram Narayan, Glenn Jorden, Denzil Fernandez, Ming Wang, Jim Nishimura

315

Functional Verification Methodology for the PowerPC 604™ Microprocessor

James Monaco, David Holloway, Rajesh Raina

319

I’m Done Simulating: Now What? Verification Coverage Analysis and Correctness Checking of the DECchip 21164 Alpha Microprocessor

Michael Kantrowitz, Lisa M. Noack

325

Session 24
High Level Power Optimization
Chair: David Knapp
Organizers: R. Camposano, R. Walker

Glitch Analysis and Reduction in Register Transfer Level Power Optimization

Anand Raghunathan, Sujit Dey, Niraj K. Jha

331
24.2 An Effective Power Management Scheme for RTL Design Based on Multiple Clocks
  C. Papachristou, M. Spinning, M. Nourani ................................................................. 337

24.3 Power Optimization in Programmable Processors and ASIC Implementations of Linear
  Systems: Transformation-Based Approach
  Mani Srivastava, Miodrag Potkonjak ........................................................................ 343

24.4 Scheduling Techniques to Enable Power Management
  José Monteiro, Srinivas Devadas, Pranav Ashar, Ashutosh Mauskar ......................... 349

24.5 Electromigration Reliability Enhancement Via Bus Activity Distribution
  Aurobindo Dasgupta, Ramesh Karri ............................................................................ 353

Session 25
3-D Parasitic Extraction
Chair: Andrew T. Yang
Organizers: J. White, A. Yang

25.1 A Sparse Image Method for BEM Capacitance Extraction
  Byron Krauter, Yu Xia, Aykut Dengi, Lawrence T. Pileggi ........................................ 357

25.2 A Parallel Precorrected FFT Based Capacitance Extraction Program for Signal Integrity
  Analysis
  N. R. Aluru, V. B. Nadkarni, J. White ........................................................................... 363

25.3 Multipole Accelerated Capacitance Calculation for Structures with Multiple Dielectrics
  with High Permittivity Ratios
  Johannes Tausch, Jacob White ..................................................................................... 367

25.4 Fast Parameters Extraction of General Three-Dimension Interconnects Using Geometry
  Independent Measured Equation of Invariance
  Weikai Sun, Wayne Wei-Ming Dai, Wei Hong .............................................................. 371

25.5 Efficient Full-Wave Electromagnetic Analysis Via Model-Order Reduction of Fast
  Integral Transforms
  Joel R. Phillips, Eli Chiprout, David D. Ling ................................................................. 377

Session 26
Routing Optimization for Performance
Chair: M. Marek-Sadowska
Organizers: A. B. Kahng, Y.-L. Lin

26.1 Useful-Skew Clock Routing with Gate Sizing for Low Power Design
  Joe G. Xi, Wayne W.-M. Dai ......................................................................................... 383

26.2 Sizing of Clock Distribution Networks for High Performance CPU Chips
  Madhav P. Desai, Radenko Cvijetic, James Jensen ...................................................... 389

26.3 New Performance Driven Routing Techniques With Explicit Area/Delay Tradeoff and
  Simultaneous Wire Sizing
  John Lillis, Chung-Kuan Cheng, Ting-Ting Y. Lin, Ching-Yen Ho .............................. 395

26.4 Constructing Lower and Upper Bounded Delay Routing Trees Using Linear
  Programming
  Jaewon Oh, Iksoo Pyo, Massoud Pedram ................................................................. 401

26.5 Fast Performance-Driven Optimization for Buffered Clock Trees Based on Lagrangian
  Relaxation
  Chung-Ping Chen, Yao-Wen Chang, D. F. Wong ........................................................ 405
Session 27

Tutorial: How to Write AWK and PERL Scripts to Enable Your EDA Tools to Work Together

Chair: Shankar Hemmady
Organizer: J. Cooley
Presenters: Robert C. Hutchins, Shankar Hemmady ..........................................................409

Session 28

Functional Verification Techniques

Chair: Neil Weste
Organizers: B. Frye, D. Stark

28.1 The Automatic Generation of Functional Test Vectors for Rambus Designs
K. D. Jones, J. P. Privitera .........................................................................................................415

28.2 Functional Verification Methodology of Chameleon Processor
François Casaubieilh, Anthony McIsaac, Mike Benjamin, Mike Bartley, François Pogodalla,
Frédéric Rocheteau, Mohamed Belhadj, Jeremy Eggleton, Gérard Mas,
Geoff Barrett, Christian Berthet ..............................................................................................421

28.3 Experience in Designing a Large-scale Multiprocessor Using Field-Programmable Devices and Advanced CAD Tools
S. Brown, N. Manjikian, Z. Vranesic, S. Caranci, A. Grbic, R. Grindley, M. Gusat,
K. Loveless, Z. Zilic, S. Srbljic .............................................................................................427

Session 29

Power Estimation

Chair: Lawrence T. Pileggi
Organizers: K. Sakallah, P. McGeer

29.1 Power Estimation of Cell-Based CMOS Circuits
Alessandro Bogliolo, Luca Benini, Bruno Riccò ........................................................................433

29.2 A New Hybrid Methodology for Power Estimation
David Ihsin Cheng, Kwang-Ting Cheng, Deborah C. Wang,
Malgorzata Marek-Sadowska .................................................................................................439

29.3 A Statistical Approach to the Estimation of Delay-Dependent Switching Activities in CMOS Combinational Circuits
Yong Je Lim, Kyung-Im Son, Heung-Joon Park, Mani Soma ..................................................445

Session 30

Optimization of Sequential Circuits

Chair: Gary D. Hachtel
Organizers: F. Somenzi, B. Lin

30.1 Engineering Change in a Non-Deterministic FSM Setting
Sunil P. Khatri, Amit Narayan, Sriram C. Krishnan, Kenneth L. McMillan,
Robert K. Brayton, A. Sangiovanni-Vincentelli ....................................................................451

30.2 Identifying Sequential Redundancies Without Search
Mahesh A. Iyer, David E. Long, Miron Abramovici ..................................................................457

30.3 A Fast State Reduction Algorithm for Incompletely Specified Finite State Machines
Hiroyuki Higuchi, Yusuke Matsunaga ...................................................................................463

30.4 Symbolic Optimization of FSM Networks Based on Sequential ATPG Techniques
Fabrizio Ferrandi, Franco Fummi, Enrico Macii, Massimo Poncino,
Donatella Sciuto ......................................................................................................................467
Session 31
Topics in Physical Design
Chair: Lou Scheffer
Organizers: A. B. Kahng, A. Domic
31.1 Module Compaction in FPGA-based Regular Datapaths
Andreas Koch........................................................................................................................471
31.2 Network Partitioning into Tree Hierarchies
Ming-Ter Kuo, Lung-Tien Liu, Chung-Kuan Cheng.............................................................477
31.3 Efficient Approximation Algorithms for Floorplan Area Minimization
Danny Z. Chen, Xiaobo (Sharon) Hu...................................................................................483
31.4 Optimal Wire-Sizing Formula Under the Elmore Delay Model
Chung-Ping Chen, Yao-Ping Chen, D. F. Wong .................................................................487

Session 32
Consumer Product Design
Chair: Takayasu Sakurai
Organizers: T. Sakurai, S. Trimberger
32.1 VLSI Design and System Level Verification for the Mini-Disc
Tetsuya Fujimoto, Takashi Kambe........................................................................................491
32.2 Design Methodologies for Consumer-Use Video Signal Processing LSIs
Hisakazu Edamatsu, Satoshi Ikawa, Katsuya Hasegawa.....................................................497
32.3 Design Methodology for Analog High Frequency ICs
Yasunori Miyahara, Yoshitomo Oumi, Seijiro Moriyama.....................................................503

Session 33
Tutorial: Issues and Answers in CAD Tool Interoperability
Chair: Mike Murray
Organizer: M. Murray
Presenters: Mike Murray, Uwe B. Meding, Bill Berg, Yatin Trivedi, Bill McCaffrey,
Ted Vucurevich .............................................................................................................................509

Session 34
Hardware-Software Co-Design
Chair: Frank Vahid
Organizers: R. Gupta, L. Lavagno
34.1 Tutorial: The Design of Mixed Hardware/Software Systems
Jay K. Adams, Donald E. Thomas........................................................................................515
34.2 Constructing Application-Specific Heterogeneous Embedded Architectures from
Custom HW/SW Applications
Steven Vercauteren, Bill Lin, Hugo De Man ........................................................................521
34.3 A Hardware/Software Partitioning Algorithm for Designing Pipelined ASIPs with Least
Gate Counts
Nguyen Ngoc Binh, Masaharu Imai, Akichika Shiomi, Nobuyuki Hikichi...........................527

Session 35
Timing and Power
Chair: Andrew T. Yang
Organizers: J. White, A. T. Yang
35.1 Analysis of RC Interconnections Under Ramp Input
Andrew B. Kahng, Sudhakar Muddu....................................................................................533
35.2 An AWE Technique for Fast Printed Circuit Board Delays
Bernie Sheehan.....................................................................................................................539

35.3 RC-Interconnect Macromodels for Timing Simulation
Florentin Dartu, Bogdan Tutuianu, Lawrence T. Pileggi.....................................................544

35.4 iCET: A Complete Chip-Level Thermal Reliability Diagnosis Tool for CMOS VLSI Chips
Yi-Kan Cheng, Chin-Chi Teng, Abhijit Dharchoudhury, Elyse Rosenbaum,
Sung-Mo Kang......................................................................................................................548

Session 36
Verification of Sequential Systems
Chair: Randal E. Bryant
Organizers: F. Somenzi, A. Kuehlmann

36.1 Techniques for Verifying Superscalar Microprocessors
Jerry R. Burch.......................................................................................................................552

36.2 A Scalable Formal Verification Methodology for Pipelined Microprocessors
Jeremy Levitt, Kunle Olukotun.............................................................................................558

36.3 State Reduction Using Reversible Rules
C. Norris Ip, David L. Dill...................................................................................................564

36.4 Formal Verification of Embedded Systems Based on CFSM Networks
Felice Balarin, Harry Hsieh, Attila Jurecska, Luciano Lavagno,
Alberto Sangiovanni-Vincentelli...........................................................................................568

Session 37
Panel: Electronic Connectivity + EDA Data = Electronic Commerce
Chair: Sean Murphy
Organizer: S. Murphy
Panelists: Jeff Allison, Jake Karrfalt, Michael McClure, Preston Roper,
Dennis Wilson ..............................................................................................................................572

Session 38
Experience with High Level Synthesis
Chair: Rajiv Jain
Organizers: S. Trimberger, P. Duncan

38.1 Combined Control Flow Dominated and Data Flow Dominated High-Level Synthesis
E. Berrebi, P. Kission, S. Vernalde, S. De Troch, J. C. Herluison, J. Fréhel,
A. A. Jerraya, I. Bolsens.......................................................................................................573

38.2 FADIC: Architectural Synthesis Applied in IC Design
J. Huisken, F. Welten .............................................................................................................579

38.3 Domain-Specific High-Level Modeling and Synthesis for ATM Switch Design Using VHDL
Mike Tien-Chien Lee, Yu-Chin Hsu, Ben Chen, Masahiro Fujita ........................................585

Session 39
Analysis and Compilation for Embedded Software
Chair: Steve Tjiang
Organizers: L. Lavagno, R. Gupta

39.1 Using Register-Transfer Paths in Code Generation for Heterogeneous Memory-Register Architectures
Guido Araujo, Sharad Malik, Mike Tien-Chien Lee .............................................................591
39.2 Address Calculation for Retargetable Compilation and Exploration of Instruction-Set Architectures
Clifford Liem, Pierre Paulin, Ahmed Jerraya

39.3 Analysis of Operation Delay and Execution Rate Constraints for Embedded Systems
Rajesh K. Gupta

39.4 Efficient Software Performance Estimation Methods for Hardware/Software Codesign
Kei Suzuki, Alberto Sangiovanni-Vincentelli

Session 40
Timing Modeling and Optimization
Chair: Andrzej J. Strojwas
Organizers: K. Sakallah, S. Malik

40.1 An Explicit RC-Circuit Delay Approximation Based on the First Three Moments of the Impulse Response
Bogdan Tutuianu, Florentin Dartu, Lawrence Pileggi

40.2 Modeling the Effects of Temporal Proximity of Input Transitions on Gate Propagation Delay and Transition Time
V. Chandramouli, Karem A. Sakallah

40.3 Optimal Clock Skew Scheduling Tolerant to Process Variations
José Luis Neves, Eby G. Friedman

Session 41
Decision Diagrams and Their Applications
Chair: Rick Rudell
Organizers: A. Kuehlmann, F. Somenzi

41.1 An Efficient Equivalence Checker for Combinational Circuits
Yusuke Matsunaga

41.2 High Performance BDD Package By Exploiting Memory Hierarchy
Jagesh V. Sanghavi, Rajeev K. Ranjan, Robert K. Brayton, Alberto Sangiovanni-Vincentelli

41.3 Implementation of an Efficient Parallel BDD Package
Tony Stornetta, Forrest Brewer

41.4 Word Level Model Checking—Avoiding the Pentium FDIV Error
E. M. Clarke, M. Khaira, X. Zhao

Session 42
Formal Methods
Chair: Carl Pixley
Organizers: B. Frye, N. Weste

42.1 Formal Verification of PowerPC™ Arrays Using Symbolic Trajectory Evaluation
Manish Pandey, Richard Raimi, Derek L. Beatty, Randal E. Bryant

42.2 RuleBase: an Industry-Oriented Formal Verification Tool
Ilan Beer, Shoham Ben-David, Cindy Eisner, Avner Landver

42.3 Bit-Level Analysis of an SRT Divider Circuit
Randal E. Bryant

42.4 Integrating Formal Verification Methods with A Conventional Project Design Flow
Ásgeir Th. Eiríksson

Session 43
Applications of Hardware/Software Codesign
Chair: Wayne Wolf
Organizers: D. Stark, N. Weste

43.1 A System Design Methodology for Software/Hardware Co-Development of Telecommunication Network Applications
Bill Lin
43.2 A Strategy for Real-Time Kernel Support in Application-Specific HW/SW Embedded Architectures
Steven Vercauteren, Bill Lin, Hugo De Man ................................................................. 678

43.3 Software Development in a Hardware Simulation Environment
Benny Schmaider, Einat Yogev ......................................................................................... 684

43.4 Compiled HW/SW Co-Simulation
Vojin Živojnović, Heinrich Meyr ...................................................................................... 690

Session 44
Power Estimation and Retiming
Chair: Bill Lin
Organizers: F. Somenzi, B. Lin

44.1 Stochastic Sequential Machine Synthesis Targeting Constrained Sequence Generation
Diana Marculescu, Rada Marculescu, Massoud Pedram ................................................. 696

44.2 Energy Characterization Based on Clustering
Huzefa Mehta, Robert Michael Owens, Mary Jane Irwin ................................................. 702

44.3 Architectural Retiming: Pipelining Latency-Constrained Circuits
Soha Hassoun, Carl Ebeling ............................................................................................... 708

44.4 Optimizing Systems for Effective Block-Processing: The $k$-Delay Problem
Kumar N. Lalgudi, Marios C. Papaefthymiou, Miodrag Potkonjak .................................. 714

Session 45
Technology Dependent Performance Driven Synthesis
Chair: Gabriele Saucier Co-Chair: Hamid Savoj
Organizers: M. Pedram, G. Saucier

45.1 Optimal Clock Period FPGA Technology Mapping for Sequential Circuits
Peichen Pan, C. L. Liu ........................................................................................................ 720

45.2 Structural Gate Decomposition for Depth-Optimal Technology Mapping in LUT-based FPGA Design
Jason Cong, Yeany-Yow Hwang ....................................................................................... 726

45.3 A Boolean Approach to Performance-Directed Technology Mapping for LUT-Based FPGA Designs
Christian Legl, Bernd Warth, Klaus Eckl ........................................................................... 730

45.4 New Algorithms for Gate Sizing: A Comparative Study
Olivier Coudert, Ramsey Haddad, Srilatha Manne .......................................................... 734

45.5 Post-Lay-Out Optimization for Deep Submicron Design
Koichi Sato, Masamichi Kawarabayashi, Hideyuki Emura, Naotaka Maeda ..................... 740

Session 46
Layout Analysis and Optimization
Chair: Alan Cave
Organizers: Y.-L. Lin, A. Domic

46.1 Enhanced Network Flow Algorithm for Yield Optimization
Cyrus Bamji, Enrico Malavasi ............................................................................................. 746

46.2 Hierarchical Electromigration Reliability Diagnosis for VLSI Interconnects
Chin-Chi Teng, Yi-Kan Cheng, Elyse Rosenbaum, Sung-Mo Kang ................................... 752

46.3 Using Articulation Nodes to Improve the Efficiency of Finite-Element Based Resistance Extraction
A. J. van Genderen, N. P. van der Meij ............................................................ 758

46.4 Extracting Circuit Models for Large RC Interconnections That Are Accurate up to a Predefined Signal Frequency
P. J. H. Elias, N. P. van der Meij ............................................................ 764
Session 47
Panel: System Synthesis: Can We Meet the Challenges to Come?
Chair: Robert A. Walker
Organizer: R. Walker
Panelists: Daniel D. Gajski, Raul Camposano, Pierre Paulin, Laurent Bergher,
Barry Shackleford, Randy Steck .................................................................770

Session 48
Hardware Description Language Techniques
Chair: Hilary J. Kahn
Organizers: D. Stark, B. Frye
48.1 Tutorial: VHDL & Verilog Compared & Contrasted—Plus Modeled Example Written
in VHDL, Verilog and C
Douglas J. Smith .........................................................................................771
48.2 VHDL Development System and Coding Standard
Hans Sahm, Claus Mayer, Jörg Pleickhardt, Johannes Schuck, Stefan Späth ..............777

Session 49
Power Minimization in IC Design
Chair: Massoud Pedram
Organizers: M. Pedram, F. Somenzi
49.1 An Exact Algorithm for Low Power Library-Specific Gate Re-Sizing
De-Sheng Chen, Majid Sarrafzadeh ..................................................................783
49.2 Reducing Power Dissipation after Technology Mapping by Structural Transformations
Bernhard Rohfleisch, Alfred Kölbl, Bernd Wurth ..............................................789
49.3 Desensitization for Power Reduction in Sequential Circuits
Xiangfeng Chen, Peicheng Pan, C. L. Liu ..........................................................795

Session 50
Advanced Test Solutions
Chair: Sandip Kundu
Organizers: J. Rajski, Y. Zorian
50.1 Serial Fault Emulation
Luc Burgun, Frédéric Reblewski, Gérard Fenelon, Jean Barbier, Olivier Lepape .......801
50.2 Partial Scan Design Based on Circuit State Information
Dong Xiang, Srikanth Venkataraman, W. Kent Fuchs, Janak H. Patel .....................807
50.3 Pseudorandom-Pattern Test Resistance in High-Performance DSP Datapaths
Laurence Goodby, Alex Orailoğlu .................................................................813

Session 51
Technology Optimization for Cells and Systems
Chair: D. M. H. Walker
Organizers: J. White, R. A. Rutenbar
51.1 Hot-Carrier Reliability Enhancement via Input Reordering and Transistor Sizing
Aurobindo Dasgupta, Ramesh Karri ................................................................819
51.2 A Methodology for Concurrent Fabrication Process/Cell Library Optimization
Arun N. Lokanathan, Jay B. Brockman, John E. Renaud .......................................825
51.3 Computing Parametric Yield Adaptively Using Local Linear Models
Mien Li, Linda Milor .......................................................................................831
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- 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
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- T4.3 Sequential logic synthesis and optimization
- T4.4 High-level synthesis
- T4.5 Asynchronous logic synthesis
- T5.1 Hardware Description Languages
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- T5.3 Software synthesis and retargetable compilation
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- T6.2 Signal integrity and reliability analysis
- T6.3 Analog and mixed-signal design tools
- T6.4 Microsensor and microactuator design tools
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M4.1 Complete DA systems
M4.2 Management of DA systems
M4.3 Standardization

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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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- The following signed statement: “All appropriate organizational approvals for the publication of this paper have been obtained. If accepted, the author(s) will prepare the final manuscript in time for inclusion in the Conference proceedings and will present the paper at the Conference.”

To permit a blind review, do not include name(s) or affiliation(s) of the author(s) on the manuscript. Include:

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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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Sessions

Session 1  Executive Forum Panel: The EDA Year in Review: CEO’s, The Press, and Users
Session 2  High Speed Interconnect
Session 3  Power Analysis
Session 4  Current Directions in High Level Synthesis
Session 5  Analysis and Synthesis or Asynchronous Circuits
Session 6  New Frontiers in Partitioning
Session 7  Trends in Verification
Session 8  Specialized Design Techniques for Speed and Power
Session 9  Test and Fault Tolerance in High Level Synthesis
Session 10 Issues in Discrete Simulation
Session 11 Issues in Design Environments
Session 12 Panel: Gearing Up for the Technology Explosion
Session 13 Tutorial: The SPICE FET Models: Pitfalls and Prospects
Session 14 Combinational Logic Synthesis I
Session 15 Pattern Generation for Test and Diagnosis
Session 16 CAD for Analog and Mixed Signal Ics
Session 17 Panel: Core-Based Design for System-Level ASICS— Whose Job Is It?
Session 18 Panel: A Common Standards Roadmap
Session 19 Combinational Logic Synthesis II
Session 20 Design for Testability
Session 21 Advances in Electrical Simulation
Session 22 Mixed Signal Design
Session 23 Functional Verification of Microprocessors
Session 24 High Level Power Optimization
Session 25 3-D Parasitic Extraction
Session 26 Routing Optimization for Performance
Session 27 Tutorial: How to Write AWK Scripts to Enable Your EDA Tools to Work Together
Session 28 Functional Verification Techniques
Session 29 Power Estimation
Session 30 Optimization of Sequential Circuits
Session 31 Topics in Physical Design
Session 32 Consumer Product Design
Session 33 Tutorial: Issues and Answers in CAD Tool Interoperability
Session 34 Hardware-Software Co-Design
Session 35 Timing and Power
Session 36 Verification of Sequential Systems
Session 37 Panel: Electronic Connectivity + EDA Data = Electronic Commerce
Session 38 Experience with High Level Synthesis
Session 39 Analysis and Compilation of Embedded Software
Session 40 Timing Modeling and Optimization
Session 41 Decision Diagrams and Their Applications
Session 42 Formal Methods
Session 43 Applications of Hardware/Software Codesign
Session 44 Power Estimation and Retiming
Session 45 Technology Dependent Performance Driven Synthesis
Session 46 Layout Analysis and Optimization
Session 47 Panel: System Synthesis: Can We Meet the Challenges to Come?
Session 48 Hardware Description Language Techniques
Session 49 Power Minimization in IC Design
Session 50 Advanced Test Solutions
Session 51 Technology Optimization for Cells and Systems
Conference Author/Panelist Index

A
Abramovici, M. 457
Adams, J. K. 515
Agarwal, A. 112
Allison, J. 572
Aluru, N. R. 363
Antoniadis, D. 113
Araujo, G. 591
Asal, K. 240
Ashar, P. 349

B
Balarin, F. 568
Bamji, C. 746
Barbier, J. 801
Barke, E. 236
Barrett, G. 421
Bartley, M. 421
Basaran, B. 221
Beatty, D. L. 649
Beer, I. 655
Belhadj, M. 421
Ben-David, S. 655
Benini, L. 433
Benjamin, M. 421
Berg, B. 509
Bergher, L. 770
Berrebi, E. 573
Berthet, C. 421
Binh, N. N. 527
Bogliolo, A. 433
Bolsens, I. 573
Borchers, C. 236
Brayton, R. K. 451, 635
Breuer, M. A. 143
Brewer, F. 47, 641
Brockman, J. B. 185, 825
Brown, S. 427
Bryant, R. E. 649, 661
Burch, J. R. 552
Burgun, L. 801

C
Camposano, R. 33, 770
Cao, A. 304
Caranci, S. 427
Carley, L. R. 298
Casaubieilh, F. 421
Castillo, L. A. 185
Chandramouli, V. 617
Chang, Y.-W. 405
Charbon, E. 227
Chen, B. 585
Chen, C.-A. 209
Chen, C.-P. 405, 487
Chen, C.-S. 262
Chen, D.-S. 783
Chen, D. Z. 483
Chen, K.-C. 161, 258
Chen, X. 795
Chen, Y.-P. 487
Cheng, C.-K. 88, 274, 395, 477
Cheng, D. I. 439
Cheng, K.-T. 161, 258, 268, 439
Cheng, Y.-K. 548, 752
Chiprodt, E. 377
Clarke, E. M. 645
Cong, J. 726
Corneil, D. 94
Cortadella, J. 63
Costello, J. 1
Coudert, O. 197, 734
Cvijetic, R. 389
D
Dahlgren, P. 155
Dai, W. W.-M. 371, 383
Danuser, A. 240
Dartu, F. 544, 611
Dasgupta, A. 353, 819
Davis, W. 189
def Geus, A. 1
def Jong, G. 55
De Man, H. 521, 678
De Troch, S. 573
Deng, W. 100
Deng, A. 357
Desai, M. P. 125, 389
Devadas, S. 349
Dey, S. 131, 331
Dharchoudhury, A. 548
Dill, D. L. 564
Director, S. W. 175, 181
Dutt, S. 100

E
Ebeling, C. 708
Eckl, K. 730
Edamatsu, H. 497
Eggleton, J. 421
Eiriksson, A. Th. 666
Eisner, C. 655
Elias, P. J. H. 764
Emura, H. 740
Ercanli, E. 35

F
Fenelon, G. 801
Fernandez, D. 315
Ferrandi, F. 467
Foty, D. 190
Frehel, J. 573
Friedman, E. G. 623
Fuchs, W. K. 807
Fujimoto, T. 491
Fujita, M. 585
Fummi, F. 467

G
Gajaksi, D. D. 770
Ganapathy, G. 315
Gielen, G. E. 298, 304
Giordano, P. 233
Goering, R. 1
Goldman, R. 241
Gonzales, R. 8
Goodby, L. 813
Gopalakrishnan, G. 67, 77
Graham, A. 241
Grbic, A. 427
Grindley, R. 427
Grossman, J. P. 94
Gupta, R. K. 51, 601
Gupta, S. K. 143, 209
Gusat, M. 427

H
Haddad, R. 734
Hagerman, J. W. 181
Hanover, A. 1
Yakovlev, A. 59, 63
Yang, A. T. 280
Yang, I. 113
Yen, Y. T. 125
Yogev, E. 684

Zhao, X. 645
Zilic, Z. 427
Zivojnovic, V. 690