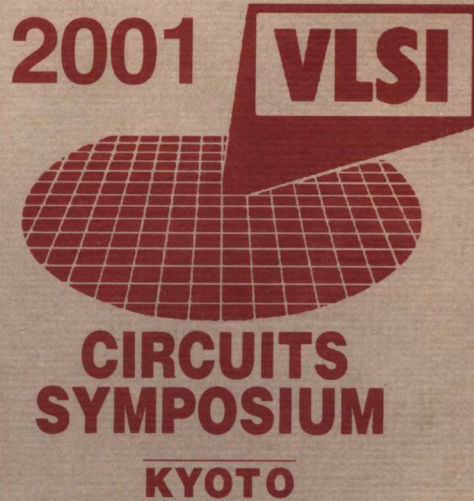


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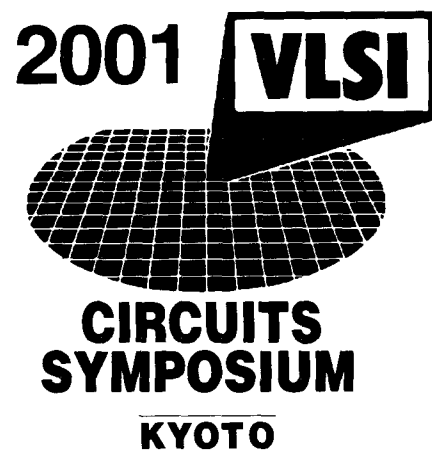


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FOREWORD

Welcome to the 2001 Symposium on VLSI Circuits

The Symposium on VLSI Circuits is sponsored by the Japan Society of Applied Physics and the IEEE Solid-State Circuits Society, in cooperation with the Institute of Electronics, Information and Communication Engineers of Japan and the IEEE Electron Devices Society.

The Symposium will celebrate its fifteenth anniversary, establishing as a major international forum for discussing recent advances in the design of VLSI circuits. This is the first symposium in the twenty first century, and we have expanded the scope to include new concepts in LSI and physical design tools, in addition to microprocessors, signal processors, memories, analog circuits, RF circuits and communication circuits. This year the Symposium has 22 daytime sessions and will present 76 outstanding papers selected from the 153 submitted papers from both industry and universities around the world. In addition, the Symposium will offer a one-day technical short course preceding the Symposium on June 13th. The topic is "Physical Design for Low-Power and High-Performance Microprocessor Circuits".

The Symposium features four invited talks covering its entire scope. The plenary session on June 14th opens with two invited talks. They are, "Digital Vision Chips and High-Speed Vision Systems" and "BSIM Model for Circuit Design Using Advanced Technologies". On June 15th the invited talk, "Development Trend of LTPS TFT LCD for Mobile Applications", is followed by another invited talk describing a unique video system application of MEMs.

VLSI Circuit Symposium evening rump sessions are well known for their selection of timely topics and lively discussions. This year there are four rump sessions. The first rump session, "Which Features of an IC Technology will Benefit Radio SOC?" is a joint rump session with the VLSI Technology Symposium scheduled on June 13th. The remaining three sessions are, "Will Start-Ups Outperform Big Companies?", "Power Supply for Future System LSIs" and "Diverse DRAM Architectures: Why and Who Wins?".

The excellent technical program represents the outstanding efforts of the Technical Program Committees under the leadership of the Program Chair, Masakazu Yamashina, and Co-Chair, Shekhar Borkar. The Committee members, all world-leaders in the field of VLSI design, have solicited strong and interesting papers, selected, and organized them into attractive technical sessions. We express our sincere thanks to all the members for their highly-skilled efforts. We do hope that you not only enjoy the presentation of the papers but join the lively discussions in and outside the sessions.

Next year, the Symposium will return to the Hilton Hawaiian Village in Honolulu, Hawaii, together with the Technology Symposium. We do hope you will attend again.

June 2001

Takayasu Sakurai
Symposium Chair

David Scott
Symposium Co-Chair

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CONTENTS

Thursday, June 14

Session 1: Welcome and Plenary Session I [Suzaku]

Chairpersons: M. Yamashina, *NEC*
S. Borkar, *Intel*

8:30	1-1	Welcome and Opening Remarks.....	T. Sakurai D. Scott	
8:45	1-2	Digital Vision Chips and High-Speed Vision Systems (Invited).....	M. Ishikawa and T. Komuro	1
9:30	1-3	BSIM Model for Circuit Design Using Advanced Technologies (Invited).....	C. Hu	5

Session 2: RF Front End I [Suzaku]

Chairpersons: T. Mori, *Fujitsu Labs.*
G. Nasserbakht, *Proxim*

10:35	2-1	Full-CMOS 2.4GHz Wideband CDMA Transmitter and Receiver with Direct Conversion Mixers and DC-Offset Cancellation... K.-Y. Lee, S.-W. Lee, Y. Koo, H.-K. Huh, H.-Y. Nam, J.-W. Lee, J. Park, K. Lee, D.-K. Jeong and W. Kim		7
11:00	2-2	Single-Chip IF Transceiver IC with Wide Dynamic Range Variable Gain Amplifiers for Wideband CDMA Applications... T. Maruyama, K. Kaneki, K. Takahashi, H. Sato, T. Iga and N. Kato		11
11:25	2-3	A 0dB-IL, 2140±30 MHz Bandpass Filter Utilizing Q-Enhanced Spiral Inductors in Standard CMOS	T. Soorapanth and S.S. Wong	15
11:50	2-4	A 2 GHz Merged CMOS LNA and Mixer for WCDMA	A. Karimi-Sanjaani, H. Sjöland and A.A. Abidi	19

Session 3: High Speed Circuits [Suzaku I]

Chairpersons: M. Motomura, *NEC*
J. Goodman, *Chrysalis-ITS*

13:45	3-1	Robustness of sub-70nm Dynamic Circuits: Analytical Techniques and Scaling Trends.....	M. Anders, R. Krishnamurthy, R. Spotten and K. Soumyanath	23
14:10	3-2	A 0.13μm 6GHz 256x32b Leakage-tolerant Register File	R. Krishnamurthy, A. Alvandpour, G. Balamurugan, N. Shanbhag, K. Soumyanath and S. Borkar	25
14:35	3-3	480ps 64-bit Race Logic Adder.....	S.-J. Lee, R. Woo and H.-J. Yoo	27
15:00	3-4	A Conditional Keeper Technique for Sub-0.13μ Wide Dynamic Gates	A. Alvandpour, R. Krishnamurthy, K. Soumyanath and S. Borkar	29

Session 4: High Performance DRAM [Suzaku II]

Chairpersons: C. Kim, *Samsung Electronics*
H. Pon, *Intel*

13:45	4-1	A Cell Transistor Scalable Array Architecture for High-Density DRAMs	31
		D. Takashima and H. Nakano	
14:10	4-2	Bit Line Coupling Scheme and Electrical Fuse Circuit For Reliable Operation of High Density DRAM. . . K. Lim, S. Kang, J. Choi, J. Joo, Y. Lee, J. Lee, S. Cho and B. Ryu	33
14:35	4-3	An Area-Efficient 2GB/s 256Mb Packet-based DRAM with Daisy-Chained Redundancy Scheme B-S. Moon, J-W. Chai, J-S. Kim, S-M. Yim, S-A. Kim, C. Kim and S-I. Cho	35
15:00	4-4	A 66-400 MHz, Adaptive-Lock-Mode DLL Circuit with Duty-Cycle Error Correction Y. Okuda, M. Horiguchi and Y. Nakagome	37

Session 5: PLLs and Frequency Synthesizers [Suzaku III]

Chairpersons: T. Kamei, *Oki Electric*
G. Nasserbakht, *Proxim*

13:45	5-1	A Stabilization Technique for Phase-Locked Frequency Synthesizers	39
		T.-C. Lee and B. Razavi	
14:10	5-2	A Fully-Integrated CMOS Frequency Synthesizer with Charge-Averaging Charge Pump and Dual-Path Loop Filter for PCS- and Cellular-CDMA Wireless Systems. . . Y. Koo, H. Huh, Y. Cho, J. Lee, J. Park, K. Lee, D.-K. Jeong and W. Kim	43
14:35	5-3	1-GHz and 2.8-GHz CMOS Injection-locked Ring Oscillator Prescalers R.J. Betancourt-Zamora, S. Verma and T.H. Lee	47
15:00	5-4	Automatic Calibration of Modulated Σ - Δ Frequency Synthesizers. . . D.R. McMahon and C.G. Sodini	51

Session 6: Design Optimizations and New Technologies [Suzaku I]

Chairpersons: H. Kabuo, *Matsushita Electric*
S. Borkar, *Intel*

15:45	6-1	Autonomous-Decentralized Low-power System LSI Using Self-Instructing Predictive Shutdown Method T. Shimizu, F. Arakawa and T. Kawahara	55
16:10	6-2	ASIC Design Methodology with On-Demand Library Generation. H. Onodera, M. Hashimoto and T. Hashimoto	57
16:35	6-3	Scaling trends of Cosmic Rays induced Soft Errors in static latches beyond 0.18 μ m T. Karnik, B. Bloechel, K. Soumyanath, V. De and S. Borkar	61
17:00	6-4	Single-Electron Pass-Transistor Logic and its Application to a Binary Adder Y. Ono and Y. Takahashi	63

Session 7: Memory Redundancy [Suzaku II]

Chairpersons: M. Hiraki, *Hitachi*
D. Scott, *Texas Instruments*

15:45	7-1	A Post-Package Bit-Repair Scheme Using Static Latches with Bipolar-Voltage Programmable Antifuse Circuit for High-Density DRAMs K.-S. Min, J.-T. Park, S.-P. Lee, Y.-H. Kim, T.-H. Yang, J.-D. Joo, K.-M. Lee, J.-K. Wee and J.-Y. Chung	67
16:10	7-2	A New Column Redundancy Scheme for Yield Improvement of High Speed DRAMs with Multiple Bit Pre-fetch Structure . . . J.-G. Lee, Y.-H. Jun, K.-H. Kyung, C. Yoo, Y.-H. Cho and S.-I. Cho	69
16:35	7-3	A system LSI memory redundancy technique using an ie-Flash (inverse-gate-electrode flash) programming circuit M. Yamaoka, K. Yanagisawa, S. Shukuri, K. Norisue and K. Ishibashi	71

Session 8: Variable Gain Amplifiers [Suzaku III]

Chairpersons: A. Wada, *Sanyo Electric*
K. Azadet, *Agere Systems*

15:45	8-1	A 50-MHz 98-dB Dynamic-Range dB-Linear Programmable-Gain Amplifier with 2-dB Gain Steps for 3-V Power Supply K. Nah and B. Park	73
16:10	8-2	A Temperature Stable CMOS Variable Gain Amplifier with 80-dB Linearly Controlled Gain Range T. Yamaji, N. Kanou and T. Itakura	77
16:35	8-3	A Variable Gain IF Amplifier with -67dBc IM ₃ -Distortion at 1.4V _{pp} Output in 0.25μm CMOS K. Philips and E.C. Dijkmans	81

20:00 Rump Sessions:

Organizers: M. Hiraki, *Hitachi*
B. Gieseke, *AMD*

R-1	Will Start-Ups Outperform Big Companies? K. Azadet, N. Lu	83
R-2	Power Supply for Future System LSIs S. Kosonocky, T. Kuroda, M. Matsui	83
R-3	Diverse DRAM Architectures: Why and Who Wins? H. Pon, M. Motomura, B. Martino	84
J-R	Which Features of an IC Technology will Benefit Radio SOC? . . . H. Iwai, S. Shichijo, M. Hotta, A. Abidi	84

Friday, June 15

Session 9: Plenary Session II [Shunju]

Chairpersons: M. Yamashina, *NEC*
S. Borkar, *Intel*

8:30	9-1	Development Trends of LTPS TFT LCDs for Mobile Applications (Invited)..... K. Yoneda, R. Yokoyama and T. Yamada	85
9:15	9-2	Electronics for DLP™ Technology Based Projection Systems (Invited) P.F. van Kessel	91

Session 10: Multimedia and Networking [Shunju]

Chairpersons: M. Matsui, *Toshiba*
C.-T. Chuang, *IBM T.J. Watson Research Ctr.*

10:20	10-1	A 120mW Embedded 3D Graphics Rendering Engine with 6Mb Logically Local Frame-Buffer and 3.2GByte/s Run-time Reconfigurable Bus for PDA-Chip R. Woo, C.-W. Yoon, J. Kook, S.-J. Lee, K. Lee, Y.-H. Park and H.-J. Yoo	95
10:45	10-2	Low Power Motion Compensation Block IP with embedded DRAM Macro for Portable Multimedia Applications C.-W. Yoon, J. Kook, R. Woo, S.-J. Lee, K. Lee and H.-J. Yoo	99
11:10	10-3	Dynamically Reconfigurable Logic LSI - PCA-1..... H. Ito, R. Konishi, H. Nakada, K. Oguri, A. Nagoya, N. Imlig, K. Nagami, T. Shiozawa and M. Inamori	103
11:35	10-4	A 1GHz Power Efficient Single Chip Multiprocessor System For Broadband Networking Applications. . . S. Santhanam, R. Allmon, R. Blake, N. Bunger, B. Campbell, M. Carlson, Z. Chen, J. Cheng, T. Do, D. Dobberpuhl, J. Ingino, D. Kidd, D. Kruckemyer, J. Lee, D. Murray, S. Nishimoto, L. O'Donnell, M. Oyker, M. Panich, M. Pearce, D. Priore, R. Rogenmoser, D. Suh, V. Sundaresan, E. Supnet, V.V. Kaenel, G. Yee and C. Vo	107

Session 11: RF VCOs [Shunju I]

Chairpersons: D.-K. Jeong, *Seoul National Univ.*
G. Taylor, *Intel*

13:30	11-1	A 1.57 GHz Fully integrated Very Low Phase Noise Quadrature VCO P. Vancorenland and M. Steyaert	111
13:55	11-2	An optimally coupled 5 GHz quadrature LC oscillator P. van de Ven, J. van der Tang, D. Kasperkovitz and A. van Roermund	115
14:20	11-3	A Highly-Tunable 12 GHz Quadrature LC-VCO in SiGE BiCMOS Process..... A.L. Coban, K. Ahmed and C. Chang	119
14:45	11-4	A 1.8 GHz CMOS VCO with Reduced Phase Noise P. Andreani and H. Sjöland	121

Session 12: Nonvolatile Memories [Shunju II]

Chairpersons: K. Kotani, *Tohoku Univ.*
J. Bowles, *AMD*

13:30	12-1	A Novel Sensing Scheme for a MRAM with a 5% MR Ratio. . . K. Yamada, N. Sakai, Y. Ishizuka and K. Mamenno	123
13:55	12-2	A Pulse-Tuned Charge Controlling Scheme for Uniform Main and Reference Bitline Voltage Generation on 1T1C FeRAM. . . H.-B. Kang, H.-W. Kye, D.-J. Kim, G.-I. Lee, J.-H. Park, J.-K. Wee, S.-S. Lee, S.-K. Hong, N.-S. Kang and J.-Y. Chung	125
14:20	12-3	A Bit-Line GND Sense Technique for Low-Voltage Operation FeRAM. S. Kawashima, T. Endo, A. Yamamoto, K. Nakabayashi, M. Nakazawa, K. Morita and M. Aoki	127
14:45	12-4	A 512 Kbit low-voltage NV-SRAM with the size of a conventional SRAM T. Miwa, J. Yamada, H. Koike, T. Nakura, S. Kobayashi, N. Kasai and H. Toyoshima	129

Session 13: Voltage and Current Generation [Shunju III]

Chairpersons: Y. Ohtomo, *NTT Electronics*
S. Kosonocky, *IBM, T.J. Watson Research Center*

13:30	13-1	An Efficient Digital Sliding Controller for Adaptive Power Supply Regulation J. Kim and M. Horowitz	133
13:55	13-2	A 1.8V Single-Inductor Dual-Output Switching Converter for Power Reduction Techniques D. Ma, W.-H. Ki, C.-Y. Tsuij and P.K.T. Mok	137
14:20	13-3	A 0.6-V Voltage Reference Circuit Based on Σ -V _{TH} Architecture in CMOS/SIMOX M. Ugajin and T. Tsukahara	141
14:45	13-4	Sub-1 V Process-Compensated MOS Current Generation Without Voltage Reference. S. Narendra, D. Klowden and V. De	143

Session 14: Data Transmission [Shunju I]

Chairpersons: Y. Ohtomo, *NTT Electronics*
A. Abidi, *Univ. of California*

15:30	14-1	A Single-Chip 12.5Gbaud Transceiver for Serial Data Communication D. Friedman, M. Meghelli, B. Parker, J. Yang, H. Ainspan and M. Soyuer	145
15:55	14-2	An 84-mW 4-Gb/s Clock and Data Recovery Circuit for Serial Link Applications. . . M.-J.E. Lee, W.J. Dally, J.W. Poulton, P. Chiang and S.F. Greenwood	149
16:20	14-3	An SOI CMOS LVDS Driver and Receiver Pair. B. Young	153
16:45	14-4	A 15-GHz Wireless Interconnect Implemented in a 0.18- μ m CMOS Technology Using Integrated Transmitters, Receivers, and Antennas . . . B.A. Floyd, C.-M. Hung and K.K. O	155

Session 15: Emerging Technology [Shunju II]

Chairpersons: M. Hiraki, *Hitachi*
B. Gieseke, *AMD*

- 15:30 15-1 Effects of Power-Supply Parasitic Components on Substrate Noise Generation in Large-Scale Digital Circuits M. Nagata, T. Ohmoto, Y. Murasaka, T. Morie and A. Iwata 159
- 15:55 15-2 Parametric Yield Enhancement System via Circuit Level Device Optimization using Statistical Circuit Simulation M. Miyama, S. Kamohara, K. Okuyama and Y. Oji 163
- 16:20 15-3 A Floating-Body Charge Monitor Circuit for Partially Depleted SOI CMOS..... J.B. Kuang, M.J. Saccamango and S. Ratanaphanyarat 167

Session 16: Sensor and Filters [Shunju III]

Chairpersons: A. Hyogo, *Science Univ. of Tokyo*
H. Pon, *Intel*

- 15:30 16-1 A Pixel-Level Automatic Calibration Circuit Scheme for Sensing Initialization of a Capacitive Fingerprint Sensor LSI H. Morimura, S. Shigematsu, T. Shimamura, K. Machida and H. Kyuragi 171
- 15:55 16-2 A 200MHz 7th-order Equiripple Continuous-Time Filter by design of nonlinearity suppression in 0.25 μ m CMOS Process..... T. Morie, H. Fujiyama and S. Dosho 175
- 16:20 16-3 A Micropower Log-Domain Filter Using Enhanced Lateral PNPs in a 0.25 μ m CMOS Process N. Krishnapura and Y. Tsvividis 179

Saturday, June 16

Session 17: Clock Distributions and Bus Drivers [Shunju I]

Chairpersons: K. Kobayashi, *Kyoto Univ.*
G. Taylor, *Intel*

8:30	17-1	A Low-Swing Clock Double-Edge Triggered Flip-Flop	C. Kim and S.-M. Kang	183
8:55	17-2	On-die Clock Jitter Detector for High Speed Microprocessors . . .	R. Kuppuswamy, K. Callahan, K. Wong, D. Ratchen and G. Taylor	187
9:20	17-3	P-boosted Source Followers: A Robust Energy-efficient Bus Driver Technique . . .	R. Krishnamurthy, K. Soumyanath and D. Ayers	191
9:45	17-4	Two schemes to reduce interconnect delay in bi-directional and uni-directional buses	K. Nose and T. Sakurai	193

Session 18: Passive Elements and Test [Shunju II]

Chairpersons: M. Motomura, *NEC*
K. Azadet, *Agere Systems*

8:30	18-1	Accurate Analysis of On-Chip Inductance Effects and Implications for Optimal Repeater Insertion and Technology Scaling	K. Banerjee and A. Mehrotra	195
8:55	18-2	Silicon Integrated High Performance Inductors in a 0.18 μ m CMOS Technology for MMIC	H.-M. Hsu, J.-G. Su, S.-C. Wong, Y.-C. Sun, C.-Y. Chang, T.-Y. Huang, C.C. Tsai, C.H. Lin, R.S. Liou, R.Y. Chang, T.H. Yeh, C.H. Chen, C.F. Huang, H.D. Huang and C.W. Chen	199
9:20	18-3	Design and Characterization of Vertical Mesh Capacitors in Standard CMOS	K.T. Christensen	201
9:45	18-4	A JTAG Based AC Leakage Self Test	T. Rahal-Arabi and G. Taylor	205

Session 19: ADC and Track/Hold [Shunju III]

Chairpersons: T. Mori, *Fujitsu Labs.*
C.-T. Chuang, *IBM T.J. Watson Research Center*

8:30	19-1	A 1V operational, 20Ms/s and 57dB of S/N, Current-mode CMOS Sample-and-hold IC	Y. Sugimoto	207
8:55	19-2	An 8-bit 30MS/s 18mW ADC with 1.8V single power supply . . .	T. Sigenobu, M. Ito and T. Miki	209
9:20	19-3	A 12-bit Mismatch-Shaped Pipeline A/D Converter	A. Shabra and H.-S. Lee	211
9:45	19-4	An 8-GHz Bandwidth 1-GS/s GaAs HBT Dual Track-and-Hold	J.P.A. van der Wagt and M. Teshome	215

Session 20: Low Power Design [Shunju I]

Chairpersons: K. Seno, *Sony*
S. Borkar, *Intel*

10:30	20-1	Comparative Performance, Leakage Power and Switching Power of Circuits in 150nm PD-SOI and Bulk Technologies Including Impact of SOI History Effect . . . S. Narendra, J. Tschanz, A. Keshavarzi, S. Borkar and V. De	217
10:55	20-2	A 0.5V Power-Supply Scheme for Low Power LSIs using Multi-Vt SOI CMOS Technology. T. Fuse, A. Kameyama, M. Ohta and K. Ohuchi	219
11:20	20-3	A 0.9- μ A Standby Current DSP Core Using Improved ABC-MT-CMOS with Charge Pump Circuit. H. Notani, M. Koyama, R. Mano, H. Makino and Y. Matsuda	221
11:45	20-4	A 63 μ W-Standby-Power Microcontroller with On-Chip Hybrid Regulator Scheme M. Hiraki, T. Ito, K. Ashiga, A. Fujiwara, T. Ohashi, T. Hamano and T. Noda	225

Session 21: Embedded RAMs [Shunju II]

Chairpersons: N.C.C. Lu, *Etron Technology*
J. Bowles, *AMD*

10:30	21-1	Quasi-Worst-Condition Built-In-Self-Test Scheme for 4-Mb Loadless CMOS Four-Transistor SRAM Macro K. Takeda, Y. Aimoto, K. Nakamura, S. Masuoka, K. Ishikawa, K. Noda, T. Takeshima and T. Murotani	229
10:55	21-2	A 800MHz Single Cycle Access 32entry Fully Associative TLB With A 240ps Access Match Circuit. M. Sumita	231
11:20	21-3	A Reconfigurable Multilevel Parallel Graphics Cache Memory with 75GB/s Parallel Cache Replacement Bandwidth S.-J. Park, J.-S. Kim, R. Woo, S.-J. Lee, K.-M. Lee, T.-H. Yang, J.-Y. Jung and H.-J. Yoo	233
11:45	21-4	A 6.25ns Random Access 0.25 μ m Embedded DRAM P. DeMone, M. Dunn, D. Haerle, J.-K. Kim, D. Macdonald, P. Nyasulu, D. Perry, S. Smith, T. Wojcicki and Z. Zhang	237

Session 22: RF Front End II [Shunju III]

Chairpersons: T. Miki, *Mitsubishi Electric*
J. Goodman, *Chrysalis-ITS*

10:30	22-1	A Fully-Integrated 900-MHz CMOS Wireless Receiver with On-Chip RF and IF Filters and 79-dB Image Rejection. . . C. Guo, C.-W. Lo, Y.-W. Choi, I. Hsu, T. Kan, D. Leung, A. Chan and H.C. Luong	241
10:55	22-2	A Single-Chip 2.4GHz Direct-Conversion CMOS Transceiver with GFSK Modem for Bluetooth Application S.-W. Lee, K.-Y. Lee, E. Song, Y.-J. Jung, H. Jeong, J.-M. Kim, H.-J. Lim, J.-W. Lee, J. Park, K. Lee, S.-I. Chae, D.-K. Jeong and W. Kim	245
11:20	22-3	Concurrent Dual-Band CMOS Low Noise Amplifiers and Receiver Architectures. . . H. Hashemi and A. Hajimiri	247
11:45	22-4	Fully Integrated 2.2mW CMOS Front-End for a 900 MHz Zero-IF Wireless Receiver S. Mahdavi and A.A. Abidi	251

2001 VLSI Circuits Short Course

“Physical Design for Low-Power and High-Performance Microprocessor Circuits”

Wednesday, June 13 (Suzaku)

Organizers: M. Matsui, *Toshiba*
G. Taylor, *Intel*

9:30	Opening	
9:40	Overview of Physical Design	
10:00	Interconnect Design of Athlon™ Microprocessors	J. Moench, <i>AMD</i>
11:00	Substrate-Bias Techniques for SH4	K. Ishibashi, <i>Hitachi</i>
12:00	Lunch	
13:15	High-Performance SOI Digital Design: from Devices to Circuits	C.-T. K Chuang, <i>IBM</i>
14:15	Low-Power and High-Performance Circuit Design of General Purpose DSPs	H. Takahashi, <i>TI-Japan</i>
15:15	Break	
15:30	Embedded DRAM SOC's and its Application for MPEG4 Codec LSIs	S. Miyano, <i>Toshiba</i>
16:30	Circuit Design of XScale™ Microprocessors	L. T. Clark, <i>Intel</i>
17:30	Conclusion	

Digital Vision Chips and High-Speed Vision Systems

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Abstract

Conventional image processing has a critical limit of frame rate derived from serial transmission of the video signal. In order to overcome the limit, fully parallel processing architecture without scanning has been proposed. In this paper, vision chips with digital circuits and high speed application systems developed in our laboratory will be described.

Vision Chip

In the real world, sensory information is parallel. Especially visual information is high dimensional (3D or 4D) parallel information and is captured and processed parallelly in human retina. However, in the engineering world, a vision system uses serial transmission of video signal from an image sensor such as CCD to a processor. In such a system, transmission speed is limited on the video signal such as NTSC (33ms).

On the other hand, a device called vision chip has been proposed, in which photo detectors (PDs) and processing elements (PEs) are connected in each pixel. It captures and processes images parallelly without serial transmission. Therefore, not only it realizes high speed processing but the benefits of being a system VLSI are expected.

Design Concept

Most of existing research of vision chip use analog circuits in processing element[1-4]. Analog circuits cost lower area and therefore are easier to integrate than digital ones. However, they have demerits that the functions are almost fixed once designed. As a result, many special purpose chips have been developed but there have been few chips for general purpose. To make general purpose vision chip which can process various algorithms on one chip, it is necessary to develop a programmable processing element designed in digital circuits. We call such vision chip as digital vision chip.

On the basis of such concept, Ishikawa et al. proposed an architecture of a digital vision chip[5]. Using a scaled-up model of the vision chip, various application systems have been developed. These systems have realized high speed visual feedback at a sampling period of 1ms.

Research on digital vision chips has been done at a few other laboratories worldwide. In France, a compact digital vision chip called the programmable artificial retina has been proposed, and the researchers have successfully developed chips of 65x76 pixel[6] and 128x128 pixel. In Sweden a unique digital vision chip based on their near-sensor image processing concept was proposed and a 32x32 pixel chip has been developed[7].

One of the problems inherent in designing a digital vision chip is the difficulty of integrating many pixels on a

single chip since the digital approach requires more circuits than analog. Therefore, the vision chips mentioned above have taken approach to place a priority on either compactness or performance of the PE, not both.

However, in the background of rapid progress of semiconductor integration technology in recent years, general purpose digital vision chip has become a realizable technology.

Of course, to integrate a large number of pixels in one chip, we have to make an effort to design a compact PE, that is, a design of PE whose area is as small as possible is needed.

Architecture

Following the design concept above, Komuro et al. designed a new architecture S³PE (Simple and Smart Sensory Processing Element) [8] which aimed at further high integration. Fig. 1. shows the architecture of S³PE.

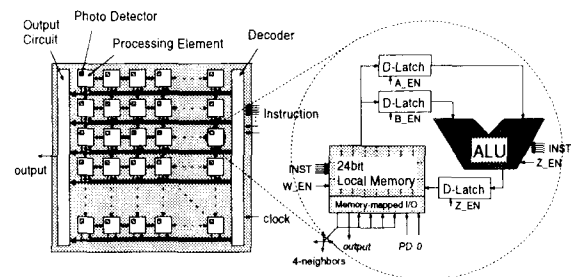


Fig. 1 Architecture of General Purpose Vision Chip

Each PE has an ALU which has bit-serial operation structure and 24 bit local memory in which each bit can be randomly accessed. It communicates with the photo detector and the neighbor PEs via 8 channel I/O which is mapped to memory address space.

The ALU has a simple structure consisting of a full-adder, a carry register and some multiplexers. It can process one of 10 kinds of logical and 8 kinds of arithmetic operations at each cycle. Bit-serial operation is a method that performs each bit of multi-bit operations in order. It is slower than bit-parallel operation but has merits of compact circuits and capability of variable bit length data operation.

In the local memory, 24 bit random access memory (RAM) and 8 bit I/O ports are allocated to the same address space. I/O ports are connected to up, down, left and right PEs, input from the sensor, and zero signal. Introducing the memory mapped I/O, all processing including not only operations but also I/O operation is performed by accessing the local memory.

As a result, the instruction code has a simple form : all

instructions consist of read address A, B (5 bits each), operation code (5 bits), and write address (5 bits). This 20 bit instruction is divided into four steps, and is transmitted and processed in order.

The A/D conversion of the analog signal from the photo detector is performed by measuring the time that the voltage of the capacitor discharged by the photo current crosses the threshold voltage. Using the PE as a counter, A/D conversion is realized without increasing circuit area.

These design policies give priority to the integrity over other performance such as processing speed. They depend on the idea that the power of massive parallelism is enormous and even if the performance of each PE is a little low, the total performance is still high.

Early Vision Algorithms

We implemented some early vision algorithms for evaluating the performance of this vision chip. Table1 shows the steps and processing time. This table shows that the vision chip can process most of early vision programs at the order of μs , which is much higher than conventional image processing systems.

Table1 Steps and processing time of early vision algorithms

Algorithm	steps	time
Edge Detection (binary)	8	0.64 μs
Smoothing (binary)	14	1.1 μs
Edge Detection (6bit)	47	3.8 μs
Smoothing (6bit)	41	3.3 μs
Thinning (binary) *	12	0.96 μs
Convolution (6bit)	986	80 μs
Poisson Equation (6bit) *	65	5.2 μs

* repeating operation

VLSI implementation and System Development

Based on the architecture, we have designed a schematic and a custom layout using 0.35 μm CMOS process[9]. The number of transistor per PE is about 400 and the PE area is as small as 105 $\mu m \times 105\mu m$. Using this design, we have developed a prototype chip of 64x64 pixels. Fig. 2 shows the chip photo.

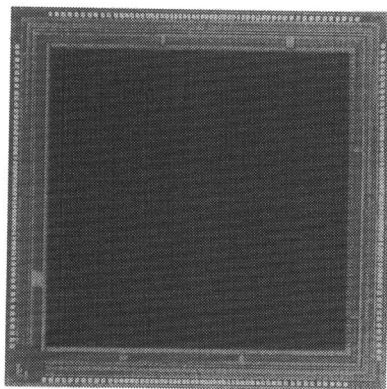


Fig.2 Chip Photo of General Purpose Vision Chip

To make a whole system using the vision chip, we have developed a controller which transmit instructions to the vision chip at the order of 100ns and also manage program control such as conditional jump and loop. The vision chip, controller, and memory are the components of the system.

We have also been developing a C-like programming language of the system (SPE-C) and its compiler. On the development environment, users can simulate and check their programs in a PC or a workstation.

Global Feature Extraction Circuit for Digital Vision Chip

One of the important issues of the vision chip we have to consider is how to output. In principle, the parallel processing in the PE array is transformation from 2D pattern to 2D pattern. However, if we try to output the whole 2D pattern via pins, we face again the I/O bottleneck problem which we solved for the input.

In a real application which requires high speed control, the final output needed is not a pattern but some feature extracted from the pattern in most cases. For example, visual feedback control of the robot gets the position of the target from the sensor and gives feedback to the actuator. In this case, pattern information is only an intermediate expression and the output of the vision chip can be scalar information.

For such purpose, we designed a global feature extraction circuit which calculates moment at high speed. Moment is a value which is widely used in a real application. This circuit has some features : i) it consists of digital circuits, ii) circuit scale is small, iii) it can calculate moments at high speed iv) it is easy to implement to VLSI. Fig. 3 shows the configuration.

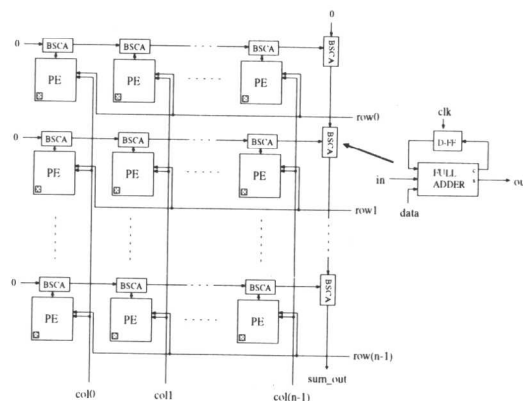


Fig. 3 Moment Extraction Circuit

High Speed Target Tracking Vision Chip

The digital vision chip based on S^3PE is designed putting emphasis on generality to answer to various uses. Therefore, the circuit scale becomes large to some extent though we have made an effort to design a compact circuit. However, there are some applications which require higher resolution. Especially in case to monitor a large range of view or track more than one objects, high resolution sensor is desired.

Then, we propose a new vision chip which aims to improve the resolution and speed by focusing the purpose of the chip to a specific task [10]. In this design we have chosen target tracking as the task with which we have