Chip Design and EDA in China

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ICT, Chinese Academy of Sciences
The People’s Republic of China

A supernova of science, marketing and industry with great potentials!
Important Event

- 2008, Olympic Games, Beijing
- 2010, Expo, Shanghai
One of the four world’s earliest civilizations with approximately 4100-year recorded history.

Chinese Philosophy: **Confucianism**

A complex system of moral, social, political, philosophical, and quasi-religious that has had tremendous influence on East Asia.
Ancient Chinese Discoveries and Inventions

- The Four Great Inventions
  - Compass
  - Printing
  - Gunpowder
  - Papermaking
In 2009, over 50,000 Ph.D., and 5,500,000 BSc graduates

The world's second-largest publisher of scientific papers, producing 121,500 in 2010, 5,200 in leading international scientific journals
Fastest Computers in the world

- **Tianhe-1, 2011, No.1**

- **Dawning Nebulae, 2010, No.2**
China’s IC Industry

- China’s IC industry has 3X in the past 10 years
- IC has exceeded oil import to become China’s No.1 import commodity.

<table>
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<tr>
<th></th>
<th>2005</th>
<th>2010</th>
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<tbody>
<tr>
<td>Pieces</td>
<td>265.8 B</td>
<td>652.5 B</td>
<td>2.5X</td>
</tr>
<tr>
<td>Sales</td>
<td>702 B</td>
<td>1440 B</td>
<td>2X</td>
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</tbody>
</table>

IC global market share

- 4.5%, 2005
- 9.8%, 2011
Leading IC design and EDA companies

- 60+ IC design companies’ sale over 100M yuan (16M $).
- **Hisilicon**, No.1, 6.7B yuan (1B $).
- **Spreadtrum**, No.2, 4.3B yuan (0.7B $)

- Security and Surveillance
- Set Top Box
- Smart Phone
- Wireless Terminal

Hisilicon

- Smartphone, feature phone (2G, 3G, 4G) with GSM, GPRS, EDGE, TD-SCDMA, W-CDMA, HSPA+, and TD-LTE.
- Basebands
- RF Transceivers
- Mocor Platform
Major IC design and EDA Companies in China

Status of China’s Fabless Model (2011)

- Hisilicon, Shenzhen
- Spreadtrum Shanghai
- CEC Huada Electronic Design Co., Ltd, Beijing
- Datang Microelectronics, Beijing
- Silan Microelectronics, Hangzhou
- Vmicro, Beijing
- Empyrean EDA, Beijing

Hisilicon, ranked No. 16 in 2011
Chips designed in China (Category 1/2)

Source: Empyrean 2009/12
Chips designed in China (Category 2/2)

- Video monitoring: 5%
- Military & space: 11%
- Info security: 9%
- Power electronics: 2%
- Industry control: 8%
- Medical electronics: 6%
- Auto electronics: 9%
- Computer & network: 5%
- Consumer electronics (Digital TV): 27%
- Mobile communication: 11%
- Info security: 9%
- Other (Smart card): 7%

Source: Empyrean 2009/12
Papers in DAC

- Start research in CAD and test since 1980s

Annually published papers in DAC

<table>
<thead>
<tr>
<th>Year</th>
<th>Papers</th>
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<tbody>
<tr>
<td>2003-2008</td>
<td>1</td>
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<tr>
<td>2008</td>
<td>3</td>
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<tr>
<td>2009</td>
<td>3</td>
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<tr>
<td>2010</td>
<td>4</td>
</tr>
<tr>
<td>2011</td>
<td>6</td>
</tr>
<tr>
<td>2012</td>
<td>5</td>
</tr>
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</table>
The Godson project, the first series of high-performance general-purpose microprocessors in mainland China.

“Verification-Testing-Recovery Technique with application to on-board microprocessor systems” was granted the 2012 National Technology Invention Award, the most prestigious national award in China.
CPU plan of Godson Project

Part of the National S&T Major Project for CPU. It already has three generations so far.

2001-2005:
- Startup and key technology research.
- Four-Issue OOO Architecture, 1.0GHz.

2006-2010:
- From emulation to innovation, low- to high-end, research to product.
- Multi-core CPU with leading performance, CPU company setup.

2011-2020:
- Build a new ecosystem to support the IT industry in China
Godson CPU Products

Research Stage: started in 2001
- The 32-bit Godson-1 in 2002 is the first CPU in China
- The 64-bit Godson-2B in 2003
- The 64-bit Godson-2C in 2004
- The 64-bit Godson-2E in 2006

SPEC int2000 and SPEC fp2000 of Godson-2E > 500
Each Triple the performance of its previous one

Godson-3B 1500, the newest product
- fabricated in 32nm high-k metal-gate (HKMG) low-power bulk CMOS
- contains 1.14 billion transistors within 182.5 mm² die area
- support a wide voltage range from 0.9V to 1.3V
- can operate at extreme frequencies in excess of 1.5GHz
- achieve 192GFLOPS within limit of 40W power dissipation
Godson-T Manycore Processor

- 64 light-weight processing mini cores currently
- 16-core sample: 130nm, 230mm², SMIC
- Target to domain-specific parallel acceleration
Impact: Godson Processor

The hottest presentation at the recent Hot Chips Symposium at Stanford University was the world’s first look at the Godson-3, the latest generation of China’s most powerful microprocessor family. It was the first time a Chinese CPU architect visited the U.S. to lift the curtain on a home-grown Chinese processor at a major technical conference. Journalists from industry publications as well as from mainstream media eagerly joined the usual Hot Chips audience of engineers for a peek at the design.

There was much to admire. The Godson-3, also known as the Longson-3, is the 20-year-old Chinese microprocessor family. The initial Godson-3, stopgap but well-integrated four MIPS-compatible 64-bit processor cores in a crossbar network. This quad-core block is scalable, so future implementations may have dozens of cores. Smaller implementations are planned, too. The first chips will be fabricated in 65nm CMOS, and clock speeds are expected to hit 1GHz.

Equally interesting is an optional on-chip coprocessor for signal processing and high-performance floating-point math. The initial quad-core Godson-3 won’t have this coprocessor, but a second implementation, scheduled for 2009, will have four of them, along with four of the MIPS-compatible cores. By leveraging this extra horsepower, the Chinese hope to build a supercomputer within two years that executes one trillion floating-point operations per second. That performance would match the latest supercomputers in the world today.

As if those revelations aren’t enough, the Godson-3 has another starting feature: more than 300 new instructions and other modifications that accelerate x86-to-MIPS dynamic binary translation. In other words, the Godson-3 applies hardware optimization to x86 emulation, much as Transmeta did with its Crusoe and Effponent microprocessors.

That feature raised a few eyebrows. Godson processors are designed at the Institute of Computing Technology (ICT), part of the Chinese Academy of Sciences in Beijing. ICT does not have a license for either the MIPS or x86 architectures. Last year, ICT resolved an intellectual-property dispute with MIPS Technologies by partnering with STMicroelectronics, a MIPS license. But the x86-to-MIPS conversion requires another translation. ICT, however, has the Chinese equivalent of the National Institute of Standards and Technology at its disposal.

Godsong isn’t an x86 clone. At Microprocessor Report, we aren’t patent attorneys, but our initial analysis is that the Godson-3’s extensions probably don’t trample on intellectual property owned by Intel (the inventor of the x86 architecture) or Transmeta (whose hardware-assisted “code morphing software” advanced the art of x86 emulation). The Godson-3 doesn’t appear to go as far toward x86 compatibility as Transmeta’s processors did, and Transmeta has no legal

In California last week, Chinese researchers unveiled details of a microprocessor that they hope will bring personal computing to most ordinary people in China by 2010. The chip, code-named Godson-3, was developed with government funding by more than 100 researchers at the Chinese Academy of Sciences’ Institute of Computing Technology (ICT).

China is making a late entry into chip making, admits Zhengwei Xu, deputy director of ICT. “Twenty years ago in China, we didn’t support R&D for microprocessors,” he said during a presentation last week at the Hot Chips conference in Palo Alto. “The decision makers and [Chinese] IT community have come to realize that CPUs [central processing units] are important.”

Tom Halfhill, an analyst at research firm In-Stat, says
EDA research in Tsinghua University

- Tsinghua University, one of the representative research entity in physical design, has made many achievements in:
  - Power/ground network analysis & optimization
  - Physical design flow & optimization
  - Parallel EDA computing with graphics processor
- There are multiple related research papers awarded (or nominated) the DAC and ICCAD best paper.
Power/Ground Network Analysis & Optimization by C.S., Tsinghua

- **P/G network IR-drop noise analysis**
  - Pattern based 3D P/G model for P/G networks and P/G analysis method (ISPD2006, TCAD2007)
  - GPU-based simulation for large-scale P/G networks (DAC2009 *Best Paper candidate*)
  - Fast poisson solver preconditioned method for robust power grid analysis (ICCAD2011)

- **Decap optimization**
  - Decap budgeting aware placement algorithm (ICCAD2009)

- **PowerRush Simulator**
  - *First Place* in 2011 TAU Power Grid Simulation Contest
  - Special Session of ICCAD’11

- **PowerRushTran Simulator**
  - *Second Place* in 2012 TAU Transient Power Grid Simulation Contest
  - Special Session of ICCAD’12
Physical Design & Optimization Platform by C.S., Tsinghua

- Physical design, optimization and verification platform
- Base on industrial Open Access Database
- Include floorplanning, placement, routing, STA, CTS and PG simulator
- Cooperating development with industrial companies
- DAC2001, DAC2003, DAC2005
Parallel EDA Computing with Graphics Processors by EE & M.E., Tsinghua

- GPU based sparse matrix computation
  - >10GFLOPS on EDA matrices with applications in delay calculation, placement, and graph traversal (ICCAD’09)

- Massively parallel logic simulation
  - World’s first GPU based conservative simulator (DAC’10)
  - Invited talk on GTC’12

- NICSLU: a parallel sparse solver for SPICE simulators
  - Multithreaded algorithm published in [ASP-DAC 2012 (best paper nomination)]
  - GPU-accelerated algorithm published in [DAC 2012]
  - Sequential algorithm is 1.5X faster than KLU on circuit matrices
EDA research in Fudan University

ASIC & System State Key Lab., Fudan

- Circuit Modeling and Simulation
- Nano-Scale VLSI Design Optimization
- Cooperative work with Synopsys
Circuit Modeling and Simulation in Fudan

- **AMOR: An Efficient Aggregating Based MOR for Many Terminal Circuits**
  - Published in DAC’2012
  - Prototype tool has been applied in China’s EDA company Empyrean

- **Transfermer: A Functional-Driven Cycle-Accurate Multicore Simulator**
  - Published in DAC’2012
  - An extensible, fast, and cycle-accurate full-system multicore simulator

- **Statistical Reliability Analysis Under Process Variation and Aging Effects**
  - Published in DAC’2009
  - A framework for NBTI aging and process variation analysis
Nano-Scale VLSI Design Optimization in Fudan

- **Provably Good and Practically Efficient Algorithm for CMP Dummy Fill**
  - published in DAC’2009
  - Reduce computation complexity to $O(n^2 \log n)$
  - Prototype tool has been applied in SMIC

- **Multicore Parallel Min-Cost Flow Algorithm for CAD Applications**
  - published in DAC’2009
  - explore concurrency via Nondeterministic Transactional Algorithm design

- **Timing Yield Driven Clock Skew Scheduling**
  - published in DAC’2008
  - Considering non-Gaussian Distributions of Critical Path Delays
  - 17.7% yield improvement from simulation results
Fudan’s cooperative work with Synopsys

- **3D-IC TSV assign algorithm**
  - Published in DAC’2010 and DAC’2011
  - Proposed algorithm can find the near optimal results in seconds
  - Integrated into Synopsys flow

- **Lithographic hotspot classification**
  - Published in DAC’2012
  - 37.5% accuracy improvement by using improved tangent space based distance metric
Galaxy CPU in NUDT

Galaxy FT-1000 CPU

- TSMC 65nm process, 350 millions transistor
- 8-core, 64-thread
- Working frequency: 800MHz-1GHz
- I/O: 3 HTT buses, 4 DDR3 channels, bandwidth 32GB/s, 8 PCIE 2.0 channels
SMIC's IP offerings include the following:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Third Party &amp; SMIC IP</th>
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<tbody>
<tr>
<td>90nm</td>
<td>Mixed signal: ADC, DAC, PLL, DLL, Voltage Regulator, Crystal Oscillator, Audio Codec, Touch Screen ADC</td>
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<tr>
<td></td>
<td>Embedded Memory: OTP</td>
</tr>
<tr>
<td></td>
<td>High-speed I/O interface: USB2.0 OTG, USB2.0 PHY, LVDS, SSTL</td>
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<tr>
<td></td>
<td>High-speed I/O interface: HDMI, LVDS, PCI, PCI-X, PCI-Express, SSTL-18, SSTL-2, USB 1.1, USB2.0/OTG, HSTL, HVPECL, SSTL-2&amp; LVTTL combo, USB2.0 Device Controller, 10/100 Ethernet PHY, SATA II, DDR2 I/O, MDDR I/O, Metal Programmable I/O, USB2.0 OTG nanoPHY, DVI Tx, DisplayPort, CCP2 PLL, DLL, Codec, DAC, BGAP, Voltage Regulator, ADC, Ring Oscillator, Crystal Oscillator, VCXO</td>
</tr>
<tr>
<td>0.13μm</td>
<td>Mixed signal: 1T-SRAM-Q (low power, High speed), Logic OTP, dySRAM, 1T-Flash, Novea</td>
</tr>
<tr>
<td></td>
<td>Embedded memory: 1T-SRAM-Q (low power, High speed), Logic OTP, dySRAM, 1T-Flash, Novea</td>
</tr>
<tr>
<td></td>
<td>ARM926EJ, ARM7EJ, ZSP500, ZSP520, ARM7TDMI, ZSP560, VSI410, CK510, CK520, CK560, CK510E</td>
</tr>
<tr>
<td>0.15μm</td>
<td>High-speed I/O interface: PCI-X, USB 1.1 Transceiver, SSTL-2, PECLR, HSTL, LVPECL</td>
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<tr>
<td></td>
<td>Mixed signal: PLL, ADC, Crystal Oscillator, Voltage Regulator</td>
</tr>
<tr>
<td>0.16μm</td>
<td>High-speed I/O interface: USB2.0 PHY, USB2.0 OTG PHY</td>
</tr>
<tr>
<td></td>
<td>Embedded processor: ARM926EJ, ARM7TDMI, ARM922T, C210, C310, C340, MIPS 4KC, CK510, ZSP400, MeP</td>
</tr>
<tr>
<td>0.18μm</td>
<td>Mixed signal: PLL, DAC, Audio DAC, ADC, Codec, Band Gap Reference, Voltage Regulator, VCO, USB 1.1/OTG, USB 2.0/OTG, POR, Crystal Oscillator, Class D Amp, Ring Oscillator, DC-DC, Video AFE, Class-D Audio</td>
</tr>
</tbody>
</table>
Other major institutions conducting EDA research in China

- Chinese University of Hong Kong
- Hong Kong University of Science and Technology
- Hong Kong Polytechnic University
- Harbin Institute of Technology
- University of Electronic Science and Technology of China
- Zhejiang University
- Peking University
Government Programs (1/3)

- NSFC started a Major Scientific Research Program
  “Basic Research of Semiconductor Integrated System-On-a-Chip” (2002-2010)

- Granted in total 55 million yuan
- 13 key projects and 83 general projects
- 8 years’ efforts with 1200 researchers involved,
- Fruitful results: 1161 published papers and 340 applied or granted patents
Government Programs (2/3)
Major Science & Technology Project

- Ministry of Science and Technology sets up 16 National Science and Technology Major Projects.
- Each project is funded by 10-50 billion yuan.
- “CPU & EDA” are the key parts of the first project.
  - Godson (Loongson) processor series, ICT, CAS
  - YHFT processor series, NUDT
  - Panda (EDA) System, Empyrean
Empyrean Company (Panda EDA System)

- Investment: 299 M Yuan
  - Center Gov.: 159M
  - Beijing: 70M
  - Market: 70M
- 3 Years
- Target a series of tools covering physical and post silicon flow

Source: Empyrean 2009/12
The National Basic Research Program of China (973) granted 30 million yuan to the project

“Research of new principles, architectures and methodologies of microprocessor design to extend Moore’s Law” (2005-2010)

- 6 sub-projects, microprocessor design, testing, EDA algorithms issues.
- Major participants, Institute of Computing Technology, Tsinghua University, the University of Science and Technology of China.
- High performance many-core processor Godson-T with single chip tera-scale computing capability.
- The 3S fault tolerance technique, (self-test, self-diagnosis, self-repair)
Welcome to China!

China Space

China High-speed Railway Network

China Supercomputing
Welcome to China!

Tourism

Foods

Jiangsu
High cutting techniques
large meatball

Anhui
Nutritious food

Sichuan
Spicy-hot