Survey of new trends in Industry for Programmable hardware: FPGAs, MPPAs, MPSoCs, Structured ASICs, eFPGAs and new wave of innovation in FPGAs

Syed Zahid Ahmed1, 2, Gilles Sassatelli2, Lionel Torres2, Laurent Rougé1
1 (Menta, France), 2 (University of Montpellier, UMR CNRS 5506, LIRMM, France)
1 (ahmed, rouge@menta.fr), 2 (ahmed, sassatelli, torres @lirmm.fr)
Outline

- **Introduction**
  - Semiconductor Industry
  - Makimoto’s wave
  - The Ring of Power & birth of MPSoC

- **FPGAs & vs FPGAs**
  - History of PLD startups
  - FPGAs Dominance: Fundamental Pros & Cons
  - MPPAs & Survey of vs FPGAs companies
  - Why coarse grain mostly failed/fail
  - Survey of new FPGA startups

- **New Trends among FPGAs**
  - Enhanced Customization, Wave of ESL
  - View point: historic success and failure: Processor inside FPGA vs FPGA inside Processor

- **Conclusions & Cloudy Future**
Outline

**Introduction**
- Semiconductor Industry
- Makimoto’s wave
- The Ring of Power & birth of MPSoC

**FPGAs & vs FPGAs**
- History of PLD startups
- FPGAs Dominance: Fundamental Pros & Cons
- MPPAs & Survey of vs FPGAs companies
- Why coarse grain mostly failed/fail
- Survey of new FPGA startups

**New Trends among FPGAs**
- Enhanced Customization, Wave of ESL
- View point: historic success and failure: Processor inside FPGA vs FPGA inside Processor

**Conclusions & Cloudy Future**
Semiconductor Industry Empire 2009-2010

2009 Semiconductor Revenue Distribution (230 B$)

Computers and Communications Account for >64%

Main Markets of FPGAs

~85% PLDs (Xilinx+Altera)

47% Communications
31% Industrial & Other
15% Consumer & Auto
7% Data Processing

http://www.latticesemi.com/corporate/about/pldmarketbackground.cfm?source=topnav
http://www.eetimes.com/electronics-news/4088277/Viewpoint-Is-semiconductor-industry-consolidation-inevitable-
The Versatility and dominance of Microprocessors and FPGAs in Industry

Pre. Silicon Era Iconic Mathematician
Credited for the von-Neumann architecture. The foundation of modern Computers is based on the 1945 incomplete 101 pages draft report written by Neumann famously known as “First Draft of a Report on the EDVAC”
http://qss.stanford.edu/~godfrey/vonNeumann

John von Neumann
1903-1957

Sadly both Neumann and Freeman died of illness at a young age without seeing tremendous boom of their basic concepts in Industry

Sequential Arch.
Parallel Arch.
Transistor Technology

Among 2009 Inductees of Hall of Fame

Gordon E. Moore
Born January 3, 1929
Method for Fabricating Transistors
Inducted 2009
As a cofounder of both Fairchild Semiconductor and Intel, Gordon Moore set the pace and standards for Silicon Valley’s chip manufacturing methods.

Ross Freeman (XILINX Co-founder)
Born July 26, 1948 - Died October 22, 1989
Configurable electrical circuit having configurable logic elements and configurable interconnects
Patent #: 4,870,302
Inducted 2009
Ross Freeman invented the field programmable gate array (FPGA), a computer chip full of "open gates" that engineers can reprogram ....
Makimoto’s Wave
Cyclic nature of Industry discovered in late 80s by Makimoto

Dr. Tsugio Makimoto
Hitachi: 1959-2000
Sony: 2000-2005

Speech at FPT 2002 Hong Kong
“The hot decade of field programmable technologies”
http://www.sony.net/Products/SC-HP/cx_news/vol33/sideview.html
https://www.doc.ic.ac.uk/~wl/teachlocal/cuscomp/k01_makimoto.pdf

Reconfigurable Computing
In Education

Prof. Reiner Hartenstein
http://xputers.informatik.uni-kl.de/staff/hartenstein/lot/invited.html
Gordon Moore ISSCC 50th Anniversary 2003

Power becoming Challenge

STATIC Power:
Leakage power getting Significant

Dynamic Power:
Voltage Scaling Flattening around 1V

http://sscs.org/History/MooresLaw.htm
POWER CONSUMPTION!

Around Mid 2000 (Finding of the Ring of Power 😊)

One element has shaken
almost 4 decades of research, technology and business legacy!
Move to von Neumann's
(The industry’s one true love, can’t live without you 😊)

Power Wall forced Industry to Multicore

Around mid 2000s
Birth of MPSoCs
2X Cores with Moore Law! *(has it really happened?)*
High end, Fat Cores
*Intel, AMD, ARM...*
High end market. Legacy code issues!
Parallel Software challenges

New Portal opens: MPPAs
Thin Cores in large quantity
FPGA/Coarse grain like Computing style
*We consider this class in this work*

NoC Research Boom
Outline

- Introduction
  - Semiconductor Industry
  - Makimoto’s wave
  - The Ring of Power & birth of MPSoC

- FPGAs & vs FPGAs
  - History of PLD startups
  - FPGAs Dominance: Fundamental Pros & Cons
  - MPPAs & Survey of vs FPGAs companies
  - Why coarse grain mostly failed/fail
  - Survey of new FPGA startups

- New Trends among FPGAs
  - Enhanced Customization, Wave of ESL
  - View point: historic success and failure: Processor inside FPGA vs FPGA inside Processor

- Conclusions & Cloudy Future
# The History of PLD startups

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Xilinx</td>
<td>1</td>
<td>1</td>
<td>1,809</td>
<td>1,906</td>
<td>5.4%</td>
<td>51.2%</td>
</tr>
<tr>
<td>Altera</td>
<td>2</td>
<td>2</td>
<td>1,216</td>
<td>1,323</td>
<td>8.8%</td>
<td>35.5%</td>
</tr>
<tr>
<td>Lattice Semiconductor</td>
<td>3</td>
<td>3</td>
<td>229</td>
<td>222</td>
<td>-3.1%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Actel</td>
<td>4</td>
<td>4</td>
<td>196</td>
<td>216</td>
<td>11.2%</td>
<td>5.9%</td>
</tr>
<tr>
<td>QuickLogic</td>
<td>5</td>
<td>5</td>
<td>28</td>
<td>23</td>
<td>-17.9%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Cypress Semiconductor</td>
<td>6</td>
<td>6</td>
<td>32</td>
<td>21</td>
<td>-34.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Atmel</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>9</td>
<td>-35.7%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Chengdu Sino Microelectronics System</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>-25.0%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total Market</td>
<td></td>
<td></td>
<td>3,528</td>
<td>3,725</td>
<td>-5.6%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

SOURCE: EE Times

The Dominance of FPGAs
Fundamental **pros** and cons

**RTL Programming**
- Language of Silicon
- Highly mature Tools
- Path to ASICs/ASSPs, across FPGAs
- No programming crisis (rising issue is compile time not programming!)

**Universal Nature/Prototype Power**
- In theory can implement anything
- Relative ease to Absorb functionalities to Hard blocks and go Heterogeneous

**IP eco-system leverage**
- IP ecosystem is RTL dominated
- Attractive target for IP providers

**Have become Programmable Platform**
It is becoming unfair to use term Field Programmable *Gate arrays* for modern FPGAs. They are not just GA anymore!, have become complex heterogeneous mixed grain devices

Example: Altera 40nm Stratix IV
The Dominance of FPGAs
Fundamental pros and cons

Structured ASICs
One time programmable with Mask (Chip solution)
FPGA vendors: Hard Copy, Easy Path (from Altera, Xilinx)
Others: e.g. eASIC

COARSER GRAIN
ALUs based
Processors+Coarse grain mix
(Chip + IP solutions)

MPPAs (mostly chip)

Large Silicon Gap
FPGAs vs ASICs

Will Power Kill FPGAs?
FPGA 2006 Panel

Dr. I. Kuon Prof. J. Rose
Measuring the Gap between FPGAs and ASICs
30-40X Area,
12-14X Power,
3-5X Speed
http://www.eecg.toronto.edu/~jayar

Worst enemy: Power

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>PRODUCT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambric</td>
<td>AM2000 family-344 Processors</td>
<td>Was shipping video chips, but backing dried up</td>
</tr>
<tr>
<td>Aspex Semiconductor (U.K.)</td>
<td>Linedancer 4,096 Processors</td>
<td>Silicon killed; now marketing IP for video</td>
</tr>
<tr>
<td>BrightScale</td>
<td>BA 1024 Video Processor</td>
<td>Was Connex Technology; now marketing IP</td>
</tr>
<tr>
<td>ClearSpeed Technologies</td>
<td>Multithread 96-element array processor</td>
<td>Now selling as subsystems</td>
</tr>
<tr>
<td>Coherent Logix, Inc.</td>
<td>hx2100 HyperX-based DSP</td>
<td>Still in development</td>
</tr>
<tr>
<td>CPU Technology, Inc.</td>
<td>Acalis7 Field-Programmable MultiCores</td>
<td>Actively marketing</td>
</tr>
<tr>
<td>Element CXI</td>
<td>Reconfigurable Array</td>
<td>Showing silicon-actively marketing</td>
</tr>
<tr>
<td>Elixent/Panasonic (U.K.)</td>
<td>D-Fabrix Array</td>
<td>Now Captive; status unknown</td>
</tr>
<tr>
<td>IMEC (Belgium)</td>
<td>ADRES: Coarse Grain Array for VLIW's</td>
<td>Licensable IP, actively marketing</td>
</tr>
<tr>
<td>Intellasys</td>
<td>Scalable Embedded Array 24 processors</td>
<td>Actively marketing</td>
</tr>
<tr>
<td>IP Flex (Japan)</td>
<td>DAP/DNA-955 16-bit processors</td>
<td>Now shipping for video</td>
</tr>
<tr>
<td>MathStar</td>
<td>Field Programmable Object Array</td>
<td>Out of business</td>
</tr>
<tr>
<td>Motorola Labs</td>
<td>Reconfig. Streaming Vector Processor</td>
<td>Development ceased</td>
</tr>
<tr>
<td>NEC (Japan)</td>
<td>Dynamically Reconfigurable Logic Engine</td>
<td>Development appears to have ceased</td>
</tr>
<tr>
<td>PACT XPP Technologies</td>
<td>XPP 3C-64 processors</td>
<td>Actively marketing IP</td>
</tr>
<tr>
<td>PicoChip Designs (U.K.)</td>
<td>picoArray Massively Parallel Array</td>
<td>Shipping in volume</td>
</tr>
<tr>
<td>Plurality (Israel)</td>
<td>Hypercore Processor: 16-256 cores</td>
<td>In Development</td>
</tr>
<tr>
<td>Rapport Inc.</td>
<td>Kilocore KC-256 with 256 processors</td>
<td>Appears to have folded</td>
</tr>
<tr>
<td>Recore (Netherlands)</td>
<td>Montium Tile Processors</td>
<td>Licensable IP-status unknown</td>
</tr>
<tr>
<td>Silicon Hive (Netherlands)</td>
<td>Moustique Block Accelerators</td>
<td>Licensable IP-actively marketing</td>
</tr>
<tr>
<td>Stream Processors Inc.</td>
<td>Storm-1 Family-80 32-bit ALUs</td>
<td>Surveillance Video-actively marketing</td>
</tr>
<tr>
<td>Tabula</td>
<td>Unannounced</td>
<td>In Stealth Mode** (starts shipping in 2010)</td>
</tr>
<tr>
<td>Tilera</td>
<td>TilePro36 &amp; 64</td>
<td>1st generation now shipping</td>
</tr>
</tbody>
</table>

---

FPGAs vs Coarse Grain Story

Setting aside inevitable Business duopoly of THE 2
It is interesting to note from technology perspective

“Fundamental Pros of FPGAs have usually been
the Fundamental Cons of Coarse Grain”

FPGAs have enjoyed: Nice party Scenario

Coarse Grains suffered: Solo Adventure in Desert

Simultaneous War at 3 frontiers
New hardware, new Language, no IP

Diverse solutions of coarse grain makes/have kept them difficult to be widely adapted by Industry

No/partial reuse of designs, scarce IP leverage, non standard programming makes them risky investment option by companies compared to FPGAs
New FPGA Startups, their differentiations

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>Low cost ultra high density SRAM FPGAs (700K+ LUTs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>Prototype, high performance computing, telecom</td>
</tr>
<tr>
<td>Technology</td>
<td>TSMC 65nm</td>
</tr>
</tbody>
</table>

Abound Logic (Former M2000)

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>Low power, small and medium size SRAM FPGAs (1200-16000 LUTs). Single Chip Solution with NVM. Die Solution for SiP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>Battery based Portable devices</td>
</tr>
<tr>
<td>Technology</td>
<td>TSMC 65nm</td>
</tr>
</tbody>
</table>

SiliconBlue

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>Very high speed Asynchronous SRAM FPGAs (up to 164K LUTs). Standard RTL flow! Using their CAD tools suite ACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>Networking, Telecom, DSP, High performance computing, military, aerospace</td>
</tr>
<tr>
<td>Technology</td>
<td>TSMC 65nm</td>
</tr>
</tbody>
</table>

Achronix

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>3D device with configuration SRAM on top of device using TFT (Thin Film Transistor), Easy path to ASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>General</td>
</tr>
<tr>
<td>Technology</td>
<td>Toshiba</td>
</tr>
</tbody>
</table>

**bad News: Company has Folded in July 2010!**

Tier Logic

http://www.eetimes.com/electronics-news/4331423/FPGA-startup-Tier-Logic-folds
New FPGA Startups, their differentiations

**Tabula**
- **Differentiation**: Extreme Dynamic Reconfiguration architecture. Usual RTL Programming flow!
- **Market**: General FPGAs market
- **Technology**: TSMC 40nm

**Menta**
- **Differentiation**: Customizable Domain specific soft eFPGAs of small size (100-3000 LUTs). Interest in MRAMs technology. Standard RTL programming
- **Market**: ASICs/ASSPs, Aerospace, Defense, Automotive
- **Technology**: Tech. Independent!, Current Focus ST 65nm, future TSMC, UMC, Samsung

What is Common in all of These Startups:
- RTL flow***(even if un-conventional device)***
- In most cases TSMC fab, 65nm
Outline

- Introduction
  - Semiconductor Industry
  - Makimoto’s wave
  - The Ring of Power & birth of MPSoC

- FPGAs & vs FPGAs
  - History of PLD startups
  - FPGAs Dominance: Fundamental Pros & Cons
  - MPPAs & Survey of vs FPGAs companies
  - Why coarse grain mostly failed/fail
  - Survey of new FPGA startups

- New Trends among FPGAs
  - Enhanced Customization, Wave of ESL
  - View point: historic success and failure: Processor inside FPGA vs FPGA inside Processor

- Conclusions & Cloudy Future
New Trends in FPGAs
Makimoto’s Customization cycle: Domain Specific FPGAs

Dr. Steve Trimberger
XILINX

The Four Ages of FPGAs

- **1984-1991 Invention**
- **1992-1999 Expansion**
- **2000-2007 Accumulation**
- **2008-2015 Specialization**


Makimoto’s **Customization** Cycle begins
More domain specific and Heterogeneous solutions (FPGAs and ASSPs)

*Power* will further force customization

```latex
\begin{itemize}
  \item Mask-Less Technology
  \item Super Connect
  \item e-Business
\end{itemize}
```
Xilinx 28nm Extensible Processing Platform with Hard ARM

Software-centric development flow

Altera’s 28nm Stratix V with embedded HardCopy blocks

Actel’s Mixed Signal Smart Fusion with Hard ARM

ESL wave:
- Using HLL to program FPGAs
- Leading EDA vendors (Synopsys, Mentor…) providing tools
**Processor Inside FPGA vs FPGA inside Processor**

**view point (Problem of Reconf. Functional unit)**

<table>
<thead>
<tr>
<th>What is right with this one?</th>
<th>What is wrong with this one? (Almost always fail/failed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processor</strong></td>
<td><strong>Fine/Coarse Grain rec. Unit</strong></td>
</tr>
<tr>
<td>Soft/Hard</td>
<td>Processor</td>
</tr>
</tbody>
</table>

**Huge Commercial Success**

Hard: PPC, ARM
Soft: Microblaze, Nios...

Effectively preserves Processor Integrity.
both FPGA and Processor Company concentrate on their product differentiation

**What is better with this one? (example: Servers, MCUs)**

<table>
<thead>
<tr>
<th></th>
<th><strong>Pros:</strong> Similar more independent modal like FPGAs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processor</strong></td>
<td><strong>Fine/Coarse Grain rec. Unit</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Cons:</strong> More cycle waste in communication</td>
</tr>
</tbody>
</table>

**Pros:** Best Performance

**Cons:** Which Processor???
Processor/SoC vendor, end customer ok with it?
Programming challenge?
Who is end provider?

*End result: often Chaos*
Outline

- **Introduction**
  - Semiconductor Industry
  - Makimoto’s wave
  - The Ring of Power & birth of MPSoC

- **FPGAs & vs FPGAs**
  - History of PLD startups
  - FPGAs Dominance: Fundamental Pros & Cons
  - MPPAs & Survey of vs FPGAs companies
  - Why coarse grain mostly failed/fail
  - Survey of new FPGA startups

- **New Trends among FPGAs**
  - Enhanced Customization, Wave of ESL
  - View point: historic success and failure: Processor inside FPGA vs FPGA inside Processor

- **Conclusions & Cloudy Future**
"No one knows how to design a 15GHz processor, so the other option is to re-train all the software developers,"

Every startup that has tackled the problem over the last forty years has failed. Nevertheless, "The whole IT industry has bet its future on figuring out the problem of parallel programming, and I am still astonished about that,"


**Industry faces 'platform collision'**

Which platform technology will win in the long run? And will it be the ASIC, ASSP, FPGA, MCU or IP core? And which company will be left standing? "It's not clear, and all may coexist," Howe said. "The value propositions are different."


FPGA architecture: Survey and Challenges (2008)

“FPGA architecture has many degrees of freedom which have only been partially explored by vendors and researchers over the past 20 years”

http://www.eecg.toronto.edu/~jayar

[Diagram of Dark Silicon]


**The End of Denial Architecture and the Rise of Throughput Computing**

“All performance in the future will come from parallelism”


Conclusions & Cloudy Future
Industry is heading for Platform Collision

Far Future is Cloudy!
Battles will get further interesting if/when the parallel programming crisis is over

FPGAs Continued Heterogeneity
- Hard Embedded Processors
- Hard custom blocks (hard accelerators/IOs, Mem Controller …)
- Fine Grain LUTs (soft/custom accelerators)

ASSPs (SoC Platforms, MCUs…), IPs dominance
- At present Single/Multicore CPU with numerous HW accelerators, DSPs...
- Big Players (Intel, AMD) also preparing! (Atom, BobCat)
- In future added Programmable IPs (eFPGAs, Coarse/Mix Grain IPs…)

MPPAs/Coarse Grain/Mixed Grain
- Parallel Processing using arrays of CPUs/ALUs/Hard blocks
- Big Players (Intel, AMD) also preparing! (Atom, BobCat)

* Programming challenges

Collisions in Future
who will win????

vs FPGAs
GPGPUs?
Tough roads ahead, new dawn and decade of **The Ring** begins
Competitors will quest for **the Precious to rule**

One Ring will rule them all
One Ring will bring them all
One Ring will force them all
and in the new innovations bind them

In the industry of Semiconductor where **THE LAW**
is expected for another decade and 3D is on the move

**The Ring of POWER** is our worst enemy and best hope for new innovations

Sadly we lost **Freeman** and **Neumann** at their young age!, Long will their legacy live in Industry & Academics
Education Challenge: Our Student is getting Overburdened!

We need the fellowship of Industry and academics to redefine our curriculum

*We need and depend on him/her, We are not the only choice he/she has!*

---

**Prof. Gandalf**

Our Student 2010
(Ring bearer)

---

**Prof. Oogway**

Promise me you will believe

---

**Prof. Yoda**

Contribute you must Education
Prof. you are, If not of what good you are, Worried I am for young Jedi

---

**Prof. Dumbledore**

Students must be trained for defense against dark challenges coming ahead

---

**Prof. Saruman**

More fame is in research than education. Strengthen Impact factors, let fools waste time on education

---

**Prof. Internet**

We are in 21st Century you must collaborate with me

---

I wish the ring had never come to me, I wish none of this would have happened

---

C, C++, VHDL, Verilog, System Verilog, SystemC, ESL, Matlab ...

---

Single Core, Multicore, Many Core, FPGAs, Coarse grain, SoC, Homo/Hetero MPSoC ...

---

chip design challenges, DFM, DFT, DRC ...

---

Software, Hardware, Firmware, Configware, Flexware, Morphware, ...

---

Economic Crisis Jobs demands

---

Who will be the Dragon Hardware?
Thanks for watching, hope you enjoyed
EXTRA SLIDES
Outline

Semiconductor Industry Empire
Semiconductor Industry Empire

Top 25 Semiconductor Giants (Foundries excluded)

<table>
<thead>
<tr>
<th>Rank</th>
<th>2008 Rank</th>
<th>Company Name</th>
<th>2008 Revenue</th>
<th>2009 Revenue</th>
<th>Percent Change</th>
<th>Percent of Total</th>
<th>Cumulative Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Intel</td>
<td>33,757</td>
<td>32,410</td>
<td>-4.2%</td>
<td>14.1%</td>
<td>14.1%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Samsung</td>
<td>18,902</td>
<td>17,400</td>
<td>-7.5%</td>
<td>7.6%</td>
<td>21.7%</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Toshiba</td>
<td>11,081</td>
<td>10,319</td>
<td>-6.3%</td>
<td>5.8%</td>
<td>27.5%</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Texas</td>
<td>11,098</td>
<td>8,671</td>
<td>-22.9%</td>
<td>3.7%</td>
<td>31.2%</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>STMicroelectronics</td>
<td>10,358</td>
<td>8,510</td>
<td>-17.7%</td>
<td>3.4%</td>
<td>34.6%</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Qualcomm</td>
<td>8,477</td>
<td>6,685</td>
<td>-17%</td>
<td>2.6%</td>
<td>37.2%</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Samsung</td>
<td>6,105</td>
<td>5,361</td>
<td>-12.3%</td>
<td>2.3%</td>
<td>39.5%</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Advanced Micro Devices (AMD)</td>
<td>5,455</td>
<td>5,207</td>
<td>-4.6%</td>
<td>2.3%</td>
<td>41.8%</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Renesas</td>
<td>7,017</td>
<td>5,153</td>
<td>-29.6%</td>
<td>2.2%</td>
<td>44.0%</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Sony</td>
<td>6,969</td>
<td>4,832</td>
<td>-32.7%</td>
<td>1.9%</td>
<td>45.9%</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>Infineon</td>
<td>9,954</td>
<td>4,496</td>
<td>-54.9%</td>
<td>1.9%</td>
<td>47.8%</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>NEC Electronics</td>
<td>5,828</td>
<td>4,384</td>
<td>-25.5%</td>
<td>1.9%</td>
<td>49.7%</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>Micron</td>
<td>4,435</td>
<td>4,293</td>
<td>-3.2%</td>
<td>1.9%</td>
<td>51.6%</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>Broadcom</td>
<td>4,840</td>
<td>4,273</td>
<td>-12.5%</td>
<td>1.9%</td>
<td>53.5%</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>Epix Memory</td>
<td>3,588</td>
<td>3,948</td>
<td>10.1%</td>
<td>1.7%</td>
<td>55.2%</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>MediaTek</td>
<td>2,634</td>
<td>3,581</td>
<td>37.7%</td>
<td>1.6%</td>
<td>56.9%</td>
</tr>
<tr>
<td>17</td>
<td>17</td>
<td>Freescale</td>
<td>4,966</td>
<td>3,402</td>
<td>-31.5%</td>
<td>1.5%</td>
<td>58.4%</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>Panasonic</td>
<td>4,473</td>
<td>3,124</td>
<td>-29.9%</td>
<td>1.4%</td>
<td>60.0%</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>Nexx</td>
<td>4,055</td>
<td>2,920</td>
<td>-27.5%</td>
<td>1.4%</td>
<td>61.4%</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>Sharp Electronics</td>
<td>3,807</td>
<td>2,977</td>
<td>-27.5%</td>
<td>1.3%</td>
<td>62.7%</td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>nvidia</td>
<td>3,241</td>
<td>2,822</td>
<td>-12.9%</td>
<td>1.2%</td>
<td>63.9%</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>Rambus</td>
<td>3,340</td>
<td>2,585</td>
<td>-24.7%</td>
<td>1.1%</td>
<td>65.0%</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>Fujitsu Microelectronics</td>
<td>2,978</td>
<td>2,574</td>
<td>-13.8%</td>
<td>1.1%</td>
<td>66.1%</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>Marvell Technology Group</td>
<td>3,059</td>
<td>2,672</td>
<td>-12.9%</td>
<td>1.1%</td>
<td>67.2%</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>IBM Microelectronics</td>
<td>2,473</td>
<td>2,283</td>
<td>-7.9%</td>
<td>1.0%</td>
<td>68.2%</td>
</tr>
</tbody>
</table>

Total Revenue: 709,237,229,917

Top Semiconductor OEM Spenders

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hewlett-Packard</td>
<td>10,985</td>
<td>12,613</td>
</tr>
<tr>
<td>2</td>
<td>Samsung Electronics</td>
<td>10,252</td>
<td>12,458</td>
</tr>
<tr>
<td>3</td>
<td>Intel</td>
<td>9,003</td>
<td>9,700</td>
</tr>
<tr>
<td>4</td>
<td>Apple</td>
<td>7,000</td>
<td>8,448</td>
</tr>
<tr>
<td>5</td>
<td>Dell</td>
<td>7,186</td>
<td>7,736</td>
</tr>
<tr>
<td>6</td>
<td>Panasonic</td>
<td>5,711</td>
<td>6,325</td>
</tr>
<tr>
<td>7</td>
<td>Sony</td>
<td>4,492</td>
<td>5,277</td>
</tr>
<tr>
<td>8</td>
<td>Motorola</td>
<td>4,227</td>
<td>4,535</td>
</tr>
<tr>
<td>9</td>
<td>US Electronics</td>
<td>3,920</td>
<td>4,291</td>
</tr>
<tr>
<td>10</td>
<td>Kingston Technology</td>
<td>3,319</td>
<td>4,102</td>
</tr>
<tr>
<td>11</td>
<td>Acer</td>
<td>3,272</td>
<td>3,754</td>
</tr>
<tr>
<td>12</td>
<td>Toshiba</td>
<td>3,209</td>
<td>3,745</td>
</tr>
<tr>
<td>13</td>
<td>Hitachi</td>
<td>2,961</td>
<td>3,333</td>
</tr>
<tr>
<td>14</td>
<td>Lenovo</td>
<td>2,881</td>
<td>3,115</td>
</tr>
<tr>
<td>15</td>
<td>Cisco Systems</td>
<td>2,628</td>
<td>3,133</td>
</tr>
<tr>
<td>16</td>
<td>Fujitsu</td>
<td>2,285</td>
<td>2,785</td>
</tr>
<tr>
<td>17</td>
<td>NEC</td>
<td>2,725</td>
<td>3,081</td>
</tr>
<tr>
<td>18</td>
<td>NTT</td>
<td>2,601</td>
<td>2,780</td>
</tr>
<tr>
<td>19</td>
<td>Nintendo</td>
<td>3,081</td>
<td>2,406</td>
</tr>
<tr>
<td>20</td>
<td>Sony-Ericsson</td>
<td>2,038</td>
<td>2,206</td>
</tr>
</tbody>
</table>

Source: iSuppli Corporation, March 2010

Top Semiconductor OEM Spenders

Biggest Stand alone FAB
TSMC: ~10,000 Million $

~ 85% of FPGA market
Xilinx: ~1,900 Million $
Altera: ~ 1,400 Million $

iSuppli: 2010 forecast, highest growth year ever in history

Annual Global Semiconductor Revenue:

Worldwide Semiconductor Revenues

Source: iSuppli, Top 10 semiconductor company list

Semiconductor Industry Empire

**2009 Semiconductor Revenue Distribution**

Computers and Communications Account for >64%

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td>13%</td>
</tr>
<tr>
<td>Notebook/Netbook</td>
<td>15%</td>
</tr>
<tr>
<td>Notebooks</td>
<td>15%</td>
</tr>
<tr>
<td>Servers</td>
<td>14%</td>
</tr>
<tr>
<td>Military</td>
<td>1%</td>
</tr>
<tr>
<td>Computer Other</td>
<td>1%</td>
</tr>
<tr>
<td>Military Other</td>
<td>2%</td>
</tr>
<tr>
<td>Industrial</td>
<td>1%</td>
</tr>
<tr>
<td>Automotive</td>
<td>8%</td>
</tr>
<tr>
<td>Consumer Other</td>
<td>3%</td>
</tr>
<tr>
<td>DVD Player/Recorder</td>
<td>4%</td>
</tr>
<tr>
<td>Video Game Console</td>
<td>4%</td>
</tr>
<tr>
<td>MP3/Digital Media Player</td>
<td>3%</td>
</tr>
<tr>
<td>Digital Still/Video Camera</td>
<td>3%</td>
</tr>
<tr>
<td>DTV</td>
<td>3%</td>
</tr>
<tr>
<td>Mobile Phones</td>
<td>16%</td>
</tr>
<tr>
<td>Cellular Infrastructure</td>
<td>1%</td>
</tr>
<tr>
<td>Communications Other</td>
<td>2%</td>
</tr>
</tbody>
</table>

**Main Markets of FPGAs**

- **Revenue by End Market**
  - Data Processing: 47%
  - Communications: 31%
  - Consumer & Auto: 15%
  - Industrial & Other: 7%

**2010 Revenue Breakdown**

- **ATSC/ASSP Semiconductor Revenue Forecast for Major Markets, 2013**

ASPs focused on markets where FPGAs don’t compete

Source: Xilinx Corporate Backgrounder [http://www.xilinx.com/company/about.htm](http://www.xilinx.com/company/about.htm)

[http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9NDg3MzR8Q2hpbGRJRD0tMXxUeXBlPTM=&t=1](http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9NDg3MzR8Q2hpbGRJRD0tMXxUeXBlPTM=&t=1)

http://www.eetimes.com/electronics-news/4088277/Viewpoint-Is-semiconductor-industry-consolidation-inevitable-

http://en.wikipedia.org/wiki/Semiconductor_sales_leaders_by_year

http://www.eetimes.com/electronics-news/4088113/Who-is-largest-buyer-of-chips-


According to some experts, PLDs is a stuck <4B$ niche for last 10 years and has not grown.

According to some: FPGAs vendors claim amazing victory, Where is the money?

Some believe after 2001 dotcom bust it is gradually increasing steadily.

http://www.latticesemi.com/corporate/about/pldmarketbackground.cfm?source=topnav
**Why the Semiconductor Market is Unique**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes</td>
<td>Texas Instrument</td>
<td>Texas Instrument</td>
<td>NEC</td>
<td>Intel</td>
<td>Intel</td>
<td></td>
</tr>
<tr>
<td>Transistor</td>
<td>Fairchild</td>
<td>Motorola</td>
<td>Toshiba</td>
<td>NEC</td>
<td>Samsung</td>
<td></td>
</tr>
<tr>
<td>Philips</td>
<td>Motorola</td>
<td>NEC</td>
<td>Hitachi</td>
<td>Motorola</td>
<td>Toshiba</td>
<td></td>
</tr>
<tr>
<td>Siemens</td>
<td>General Instruments</td>
<td>Hitachi</td>
<td>Motorola</td>
<td>Texas Instrument</td>
<td>Texas Instrument</td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>GE</td>
<td>Philips</td>
<td>Texas Instrument</td>
<td>Toshiba</td>
<td>STMicroelectronics</td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>RCA</td>
<td>National Semiconductor</td>
<td>Fujitsu</td>
<td>Hitachi</td>
<td>Infineon</td>
<td></td>
</tr>
<tr>
<td>RCA</td>
<td>Sprague</td>
<td>Toshiba</td>
<td>Philips</td>
<td>Samsung</td>
<td>HPix</td>
<td></td>
</tr>
<tr>
<td>Westinghouse</td>
<td>Philips</td>
<td>Fairchild</td>
<td>Intel</td>
<td>Fujitsu</td>
<td>Renesas</td>
<td></td>
</tr>
<tr>
<td>Motorola</td>
<td>Transistor</td>
<td>Intel</td>
<td>National Semiconductor</td>
<td>Philips</td>
<td>NXP</td>
<td></td>
</tr>
<tr>
<td>Clevite</td>
<td>Raytheon</td>
<td>Siemens</td>
<td>Matsushita</td>
<td>STMicroelectronics</td>
<td>NEC</td>
<td></td>
</tr>
</tbody>
</table>

Retrieved from [Top 10 semiconductor company list](http://www.eetimes.com/electronics-news/4088277/Viewpoint-Is-semiconductor-industry-consolidation-inevitable-)

---

**Viewpoint: Is semiconductor industry consolidation inevitable?**

http://www.eetimes.com/electronics-news/4088277/Viewpoint-Is-semiconductor-industry-consolidation-inevitable-

---

**Reduced Memory Cost Drives New Architecture and Applications**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage Technology</strong></td>
<td>Cassette Tape</td>
<td>CD</td>
<td>Hard Drive</td>
<td>Flash</td>
<td>Flash</td>
</tr>
<tr>
<td><strong>Storage Size</strong></td>
<td>60 MB (20 nugs)</td>
<td>700 MB (26 nugs)</td>
<td>5 GB (5,000 nugs)</td>
<td>4 GB (4,096 nugs)</td>
<td>16 GB (1,024 GB)</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$200</td>
<td>$299</td>
<td>$400</td>
<td>$249</td>
<td>$399</td>
</tr>
<tr>
<td><strong>Device Cost per Sng</strong></td>
<td>$10</td>
<td>$11.50</td>
<td>$0.40</td>
<td>$0.31</td>
<td>$0.13</td>
</tr>
</tbody>
</table>

---

**Semiconductor Industry Empire**

Interesting article by Dr. Walden C. Rhines, CEO Mentor Graphics

---

**Growth in Unit Volume Distinguishes Semiconductors from Other Industries**

1. Automotive: 0.1%
2. Crude Oil: 1.0%
3. Cotton: 2.2%
4. Aluminum: 2.5%
5. Steel: 5.3%
6. Computer: 9.3%
7. Semiconductor: 49% (trend 13% units)**
Dear Gilles,

nice to hear from you again.

here the ReCoSoC talk may be downloaded:  
http://hartenstein.de/Hartenstein-ReCoSoC-KA-2010.pdf

Your Ph. D. students may download several other papers or presentations. For instance:

http://helios.informatik.uni-kl.de/staff/hartenstein/lot/HartensteinWRCE06.pdf
http://hartenstein.de/Hartenstein-SPL-2010.pdf
http://hartenstein.de/NEMA-2010-DA-keynote.pdf
http://hartenstein.de/Savannah.pdf
http://hartenstein.de/vNsyndrome.pdf
http://hartenstein.de/Hartenstein-SEMISH-2010.pdf
State of Art in NoC

NoC Research world-wide

- More than 60 projects
  - Universities and Industries

- Convergent Technique choices
  - 2-D topology
  - Deterministic routing
  - Packet commutation

- Best Effort NoC
- NoC with QoS
- Asynchronous NoC
- NoC on FPGA
- NoC start-up
- Industrial products

Structured ASICs

- Configuration by a via mask in very small time by their patented technology
- Good industrial solution having positive market potentials between FPGAs and ASIC (Area, Power, Performance)
- Drawback: One time programmable only! (but in many applications it can be a good choice compared to full ASICs)
New Trends in FPGAs
Makimoto’s Customization cycle: Domain Specific FPGAs

Industry is moving to Makimoto’s **Customization** Cycle
More domain specific and Heterogeneous FPGAs and ASSPs will come In coming years and **Power** will further force that
New Trends in FPGAs (2010-2011)
Hard embedded Processors, Enhanced Customization

Xilinx 28nm Extensible Processing Platform
Software-centric development flow

Altera’s 28nm Stratix V

Actel’s Mixed Signal Smart Fusion


New Trends in FPGAs
Wave of ESL (Create ease of Programming)

ESL tools to auto generate RTL from High Level Language (HLL)

HLSTs Usability — Key Findings

AutoESL and Synfora HLSTs did a good job generating quality RTL implementations from user-modified C code

- Significant vendor support was required for ramp-up
- After initial user ramp-up, both tools are very usable by a hardware-aware DSP software engineer
- Similar total effort required for DSP and HLST+FPGA implementations
- HLSTs required less code restructuring than the optimized DSP processor implementation

The HLSTs do not insulate the user from RTL tool flow

- Weaknesses in RTL tools prevent HLSTs from fully delivering on their promise
- Different skills required
  - Processor users get stuck after generating RTL, need an experienced FPGA designer to manage the “back end”
  - For FPGA users, HLSTs accelerate only a portion of the flow

For Portions of the Workload, a Conventional Processor is Typically a Good Fit

- User interfaces
- Device drivers
- Network stacks
- High-level decision processing
- Supervisory control
- Other stuff with modest performance requirements

Throughput on a Heavy, Parallel DSP Workload
BDTI Communications Benchmark (OFDM)™

http://www.eetimes.com/virtualshows/FPGAProgramSchedule
Gordon Moore at ISSCC 50th Anniversary 2003

http://sscs.org/History/MooresLaw.htm

Now, we get some problems coming along here .... and that is what is happening to the power?

Those of you have heard Moore’s law quoted as doubling every 18 months, notice I never said 18 months, I said one year and two years...

I suspect something around 1 volt is going to be a limit... you folks probably know that a lot better than I do. We chemists don’t understand this kind of stuff...

But there’s still a lot to do ..... I am certainly honored to have be part of it. Thank-you. (applause)
Victory near, Von Neumann end near, The era of FPL to begin. FPGAs will rule the planet. Excitement of Students: Shame on slow Processors/DSPs, Wow Wow FPGAs 😊, the Fastest growing Industry!

But Something terrible was also on way which will soon shake industry & academics

Prof. Jonathan Rose
Father of FPGAs in Academics
http://www.eecg.toronto.edu/~jayar

Prof. Reiner Hartenstein
Credited Father of Reconfigurable Computing

http://www.cs.tut.fi/soc/hartenstein/tampere01course4.ppt
http://xputers.informatik.uni-kl.de/staff/hartenstein/lot/invited.html
Heterogeneous MPSoCs
High end ASSPs

Will FPGAs reach this one day
Should FPGAs reach this one day

Source: All images (TI’s OMAP, Samsung S3C6400) openly available on companies websites and/or web
Despite numerous failures, and still being a small niche, Reconfigurable Computing will continue inspiring researchers and industry and will play important role in dark challenges ahead.
MPPAs (Massively Parallel Processor Arrays)
Further Info.

- Please Visit following document for more details (like IBM cell, picochip, SMP, SIMD, ...)

Tech Papers
ESC-SV Special: Multicore and Massively Parallel Platforms and Moore's Law Scalability
Embedded Systems Conference (ESC)
Mike Butts
Conference Paper
December 2008


http://www.techonline.com/learning/techpaper/212202148
Future of FPGAs beyond CMOS

Evening Panel
International Symposium on FPGAs, 2009

CMOS vs. NANO
Comrades or Rivals?

Monterey, California
February 23, 2009

Co-chairs
Deming Chen
Russell Tessier

Experts in the panel

- Prof. Kaustav Banerjee
  - University of California, Santa Barbara
- Dr. Moji C. Chian
  - Technology Development, Altera
- Prof. André DeHon
  - University of Pennsylvania
- Dr. Shinobu Fujita
  - Corporate R&D Center, Toshiba
- Dr. James Hutchby
  - Semiconductor Research Corporation (SRC)
- Dr. Steve Trimberger
  - Xilinx Research Labs, Xilinx

http://www.ece.wisc.edu/~kati/fpga2009/FPGA2009panel-CMOSvsNANO.pdf
John von Neumann (1903 – 1957)

First Draft of a Report on the EDVAC
by John von Neumann,
Contract No. W-670-ORD-4926,
Between the United States Army Ordnance Department
and the University of Pennsylvania Moore School of Electrical Engineering
University of Pennsylvania
June 30, 1945

John Von Neumann appears on the television program "America's Youth Wants To Know". He made this appearance when he was the Commissioner of the Atomic Energy Commission.

IEEE John von Neumann Medal

Quotations
If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is.
Anyone who considers arithmetical methods of producing random numbers is, of course, in a state of sin. (Quoted in Knuth, 1968, Vol. 2, also in Goldstine, 1972, p. 297.)

http://www.youtube.com/watch?v=vLblFHBQM4&feature=related
http://qss.stanford.edu/~godfrey/vonNeumann
http://en.wikipedia.org/wiki/Von_Neumann_architecture
http://ei.cs.vt.edu/~history/VonNeumann.html
2009 Hall of fame Inventors


Martin (John) M. Atalla
Semiconductor Devices Having Dielectric Coatings

Alfred Y. Cho
Optical Devices Utilizing Single Crystal GaP or GaAs Films Epitaxially Grown on CaF Substrates and Method of Fabricating Same

Ross Freeman
Configurable electrical circuit having configurable logic elements and configurable interconnects

Dov Frohman-Bentchkowsky
Erasable programmable read only memory array

George H. Heilmeier
Electro-Optic Liquid Crystal Device

Jean A. Hoerni
Method of Manufacturing Semiconductor Devices

Larry J. Hornbeck
Spatial Light Modulator and Method

Dawon Kahng
Electric Field Controlled Semiconductor Device

John D. Macdougall
Method of Making Insulated Gate Field Effect Transistor with Controlled Threshold Voltage

Kenneth E. Manchester
Method of Making Insulated Gate Field Effect Transistor with Controlled Threshold Voltage

Carver A. Mead
Processor Which Sequences Externally of a Central Processor

Gordon E. Moore
Method for Fabricating Transistors

Gordon Kidd Teal
Method of producing a semiconductor element

Frank Wanlass
Low stand-by power complementary field effect circuitry

Robert J. Widlar
Biasing scheme especially suited for integrated circuits