Semiconductor Trends 2005

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21 September 2005 Nick Tredennick
Overview

• Major trends affecting the microprocessor market
  – *Value PC*
  – *Value transistor*
  – *Emerging economies*

• Microprocessors
  – *Computer microprocessors*
  – *Embedded microprocessors*
  – *Configurable microprocessors*
  – *PLD microprocessors*
Moore’s Law

- **Cost of a transistor** decreases over time.
- **Number of transistors on a chip** increases over time.

Graph shows the relationship between the cost and the number of transistors over a 10-year period, with the cost decreasing and the number of transistors increasing exponentially.
Moore’s Law: Wafer Yield

- 37 die/wafer
- 28 good die
- Yield: 75%

- 177 die/wafer
- 167 good die
- Yield: 94%

Halving dimensions yields 6x good die!
Top View: Field-Effect Transistor

(Bacterium) | 1991 → 750 nm | (Visible light) | 370 nm | Channel

Gate

Transistor (top view)

4x

16x

64x

1024x

2003

2016

90 nm

45 nm (Virus)

22 nm

180 nm

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The Microprocessor

- 10 years of Moore’s-law progress led to the microprocessor
- The second generic component
- Raised engineers’ productivity
- Problem-solving became programming
- Grew to billions of units/year
- Stalled progress in design methods for thirty years
The Personal Computer

• 10 years of microprocessor progress led to the PC
• Dominated the industry for 20 years
• Supply of performance grows with Moore’s law
• Demand grows more slowly
• Diverging growth in supply and demand leads to the value PC
The PC Is Good Enough

![Graph showing the performance of leading and trailing edges of demand over time, with early and late adopters, and supply following Moore's law.](image)
The Path To The Value Transistor

![Graph showing the path to the value transistor with curves for leading and trailing edges of demand, and supply following Moore's law.](image_url)
Electronic Systems Market Segments

Zero Cost
Zero Power
Zero Delay
Zero Volume
Microprocessor Markets

- Embedded
- PCs
- Servers

Millions of Units

- 0
- 1000
- 2000
- 3000
- 4000
- 5000
- 6000
- 7000
- 8000

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The Cost-Performance Segment

Zero Cost
Zero Power
Zero Delay
Zero Volume

The Desktop Computer Segment
Cost-Performance-Per-Watt

Zero Cost
Zero Power
Zero Delay
Zero Volume

The Leading-Edge Wedge
Microprocessors Are Unsuitable

- Bottleneck: Find and access instructions and data
- Bottleneck: Transport instructions and data
- Bottleneck: Interpret instructions, manipulate data

Memory

Bus

Central Processing Unit (CPU)
Programmers And Logic Designers

- Programmers optimize software
  - Languages
  - OS
  - Compilers
  - Applications

- Logic designers optimize hardware
  - Microprocessors
  - Memory

The Users Manual is the (problematic) bridge
Scenic View
Scenic View in Fog
Scenic View with Lens
Scenic View and Photoshop
Microprocessors and ASICs

- For the ultimate in flexibility, programmers map the application onto a general-purpose microprocessor.
- For the ultimate in performance, logic designers map the application into a custom circuit.
ASICs & Microprocessors

Performance

Problem Size

ASICs ($30 B)

Microprocessors ($40 B)
Microprocessor Evolution

- Microprocessor
- Design-time configurable microprocessor
- Run-time reconfigurable microprocessor
- Dynamically reconfigurable microprocessor

Programmers

- ASIC
- FPGA

Logic designers

- ARC
- MIPS
- Tensilica

Stretch
Design-Time Configurable Microprocessor

Most of the application runs as execution of general-purpose instructions.

Profile the application

Create custom hardware and instructions to accelerate critical application sections.

Design-time configurable microprocessor

Logic designers

Programmers

Application

Profile the application

Create custom hardware and instructions to accelerate critical application sections.

Most of the application runs as execution of general-purpose instructions.

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Design-Time Configurable Microprocessor

- Profile the application
- Create custom instructions for critical code sections
- Build specialized execution units
- Can be 10 to 100 times faster than a general-purpose microprocessor on the target algorithm
- Examples: ARC and Tensilica
- Customized microprocessor limitations
  - Requires logic designers
  - Creates an application-specific, limited-function microprocessor
  - Accelerates only critical sections
Run-Time Reconfigurable Microprocessor

- Profile the application
- Create custom instructions in an FPGA fabric to accelerate critical application sections
- Most of the application runs as execution of general-purpose instructions
- Run-time reconfigurable microprocessor

Professionals involved:
- Application Programmers
- Logic designers
Run-Time Reconfigurable Microprocessor

• Build a general-purpose microprocessor with integrated FPGA fabric
• Profile the application
• Create custom instructions for critical code sections
• Build custom execution units in FPGA fabric
• Can be 10 to 100 times faster than a general-purpose microprocessor on the target application
• Example: Stretch
• Run-time reconfigurable microprocessor limitations
  – Accelerates only statically identifiable critical sections
  – Limited to problems for which profiling works
  – Profiling is difficult
ASICs & Microprocessors

- **ASICs ($30 B)**
- **Configurable Microprocessors**
- **Microprocessors ($40 B)**

Performance vs. Problem Size graph.
Dynamically Reconfigurable Microprocessor

Create custom instructions in a custom fabric to accelerate the entire application

Dynamically reconfigurable microprocessor
Dynamically Reconfigurable Microprocessor

- Each cycle creates a new microprocessor implementation
  - *Each cycle creates a custom circuit (Ascenium instruction) representing hundreds to thousands of conventional instructions*
- Programmed using ANSI-standard programming languages (e.g., C/C++)
- Tens to 100s of times faster than a general-purpose microprocessor
- Dynamically reconfigurable microprocessor limitations
  - *There are none on the market today*
    - Until Ascenium, no one has figured out how to “program” a dynamically reconfigurable circuit
  - *VCs don’t understand it*
Reconfigurable Systems Emerge
## Situation

<table>
<thead>
<tr>
<th>What</th>
<th>Value</th>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLDs</td>
<td>$3B</td>
<td>logic designers</td>
</tr>
<tr>
<td>ASICs</td>
<td>$30B</td>
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<td>programmers</td>
</tr>
</tbody>
</table>

PLDs and microprocessors are usurping a declining ASIC market. Microprocessors (and their derivatives) will win.
Supply and Demand: ASICs & PLDs

![Graph showing supply and demand for ASICs and PLDs over time.](image-url)
Battles are fought at the leading edge; the war goes to what is good enough.

- RISC vs. CISC
  - Proving you can build a career on smoke and mirrors

- Assembler vs. High-level language

- Workstations vs. PCs
  - Build for volume and performance follows; build for performance and languish

- ASICs vs. PLDs
Semiconductor Development and The Value PC

194x

Fixed Resources
Fixed Algorithms

1971

Fixed Resources
Variable Algorithms

Instruction-based Implementation

Problem solving: becomes programming
Solutions: affordable, adequate, inefficient
Entrenched: chips, tools, manufacturers
Design Methods: 30-year stall

Tethered systems dominate volumes
PCs dominate chip development
Progress depends on Moore’s law

Cost Performance
The End of Design’s 30-Year Stall

Fixed Resources
Fixed Algorithms

Variable Resources
Variable Algorithms

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194x
1971
Microprocessor

Tethered systems dominate volumes
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Progress depends on Moore’s law

Cost Performance

Variable Resources
Variable Algorithms

Generic chips
New non-volatile memory, new PLDs
Instruction-based processing is inadequate

Power Efficiency
Mobile systems
Embedded chips

Cost Performance Per Watt
Consequences

• Rise of mobile applications
  – New non-volatile memories
• Rise of foundries
  – Rise of soft (IP) cores
  – Horizontal fragmentation of integrated device manufacturers
• Rise of non-volatile PLDs
• Rise of reconfigurable systems
• Growing market for embedded microprocessors
  – Tethered: traditional role
  – Mobile: supervisory role
Microprocessors

- x86: AMD, Intel, Via
- ARC: ARC
- ARM: ARM
- MicroBlaze: Xilinx
- MIPS: MIPS
- Nios: Altera
- PowerPC: IBM, Freescale
- SPARC: Sun
- Tensilica: Stretch, Tensilica
- Old stuff: Everyone
Microprocessor Applications

- Supercomputers
- Workstations and servers
- PCs
- Embedded systems
  - Automobiles
  - Cameras
  - Cell phones
  - Game players
  - MP3 players
  - Set-top boxes
Computer Microprocessors

• x86
  – AMD
  – Intel
  – Via

• Proprietary
  – IBM
  – Freescale
  – Sun
Embedded Microprocessors

• Microprocessor advantages
  – *Flexibility*
  – *High-volume production*
  – *Usable by programmers*

• Microprocessor limitations
  – *Too slow*
  – *Too much power*
Embedded Microprocessors

• x86 AMD, Intel, Via
• ARM ARM
• PowerPC IBM, Freescale
• Old stuff Everyone
  – *Triscend (Xilinx)*
Configurable Microprocessors

- ARC
- Ascenium
- MIPS
- Nios
- Tensilica

ARC
Ascenium
MIPS
Altera
Stretch, Tensilica
PLD Microprocessors

• Altera
  – Nios (soft)

• Xilinx
  – MicroBlaze (soft)
  – PicoBlaze (soft)
  – PowerPC (hard)