Computer Science 703

Advance Computer Architecture

2010 Semester 1

Lecture Notes
2Mar10
Moore's Law

James Goodman

Department of Computer Science

CS703

- Meets Tuesday, Thursday, Friday 3pm
- Web page information in usual place
  - Don't believe anything past Home page (yet)
- Readings will be provided or on-line.
- Some lectures by Fuad Tabba
- Evaluation
  - Final exam is worth 60%.
  - Assignments, including a project, are worth 25%.
  - A test, to be given in-class on (Thursday 29Apr??), is worth 10%.
  - Class participation is worth 5%.

Do I belong in this course?

You will need to know about

- Low-level hardware concepts
  - Logic design
  - Basic processor organization
  - Cache memory
- Virtual memory
- Pipelining, out-of-order execution

Standard reference book(CS313): Patterson & Hennessy, Computer Organization and Design, Fourth Edition: The Hardware/Software Interface

- This is overkill, but a useful reference

Assignment 1 for Thursday

E-mail to goodman@cs.auckland.ac.nz before class

- What previous courses have you taken that prepared you for this paper? (Computer organization, operating systems, database, etc.)
- What are you hoping to get out of this paper? (Knowledge about multiprocessors/multicore architectures? Transactional memory? Traditional advanced architecture topics?)
- Other topics you would like to see covered

Not taking class for credit? This assignment is still optional!

Assignment 2 for Thursday

Read: Olukotun & Hammond, "The future of microprocessors", *ACM Queue*, September 2005 (available on course website).

Not taking class for credit? This assignment is still optional!

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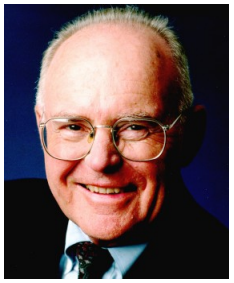
Dr. Gordon Moore

1965



2003

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Moore's Data: 1965

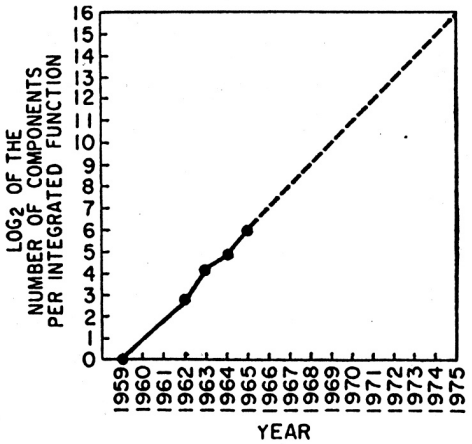

Fig. 3.

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Moore's Observation

"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year.... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least ten years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65 000."

— Gordon E. Moore
"Cramming more components onto integrated circuits,"
Electronics, pp. 114-117, Apr. 1965.

Moore's Prediction

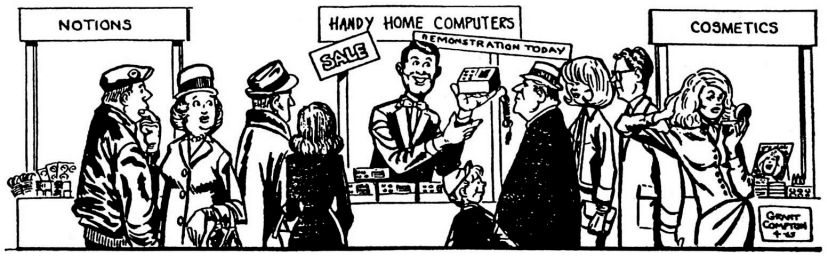

Fig. 2.

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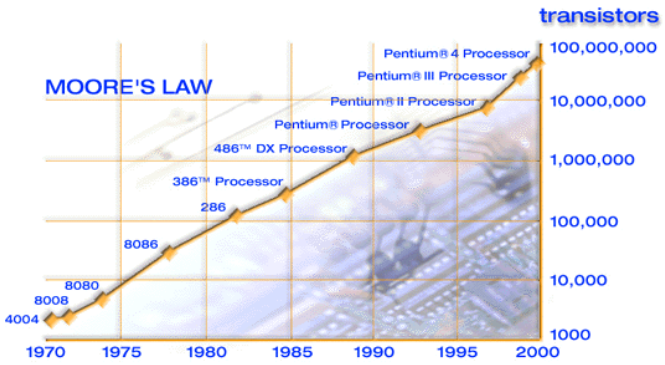
Moore's Company



http://www.intel.com/research/silicon/mooreslaw.htm

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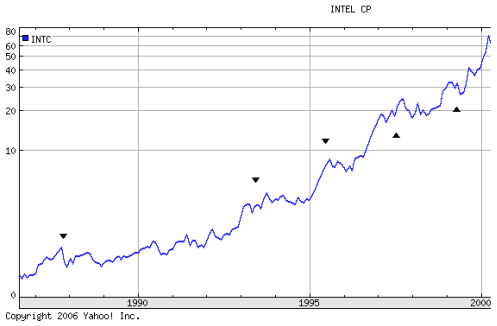
Moore's Motivation



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Moore's Formula

Minimum cost # of components/chip

$$N = 2^{(year - 1959)}$$

Extrapolating to 2010,

$$N = 2^{(2010 - 1959)} = 2.25 * 10^{15}$$

= 2.25 *Quadrillion transistors*

= 2.25 *Million Billion transistors*

Moore's Correction: 1975

"There is no room left to squeeze anything out by being clever. Going forward from here we have to depend on the two size factors – bigger dice and finer dimensions."

— Gordon E. Moore
Electronic Devices Meeting, 1975.

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Moore's Corrected Formula

Minimum cost # of components

$$N = 2^{(\text{year} - 1959)/1.5} = 1.59^{(\text{year} - 1959)}$$

Extrapolating to 2010,

$$N = 1.59^{(2010 - 1959)} = 1.72 * 10^{10}$$

= 17 *billion transistors*

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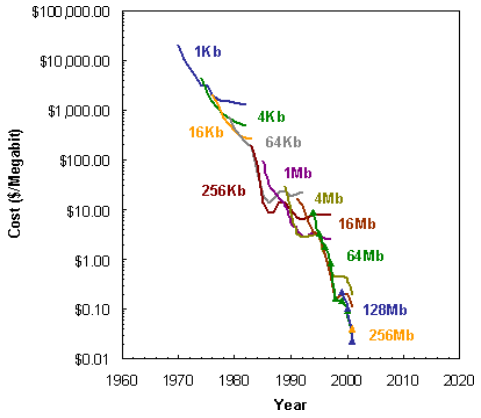
Drop in DRAM Cost per Bit



http://www.icknowledge.com/economics/dramcosts.html
IC Knowledge, 2001

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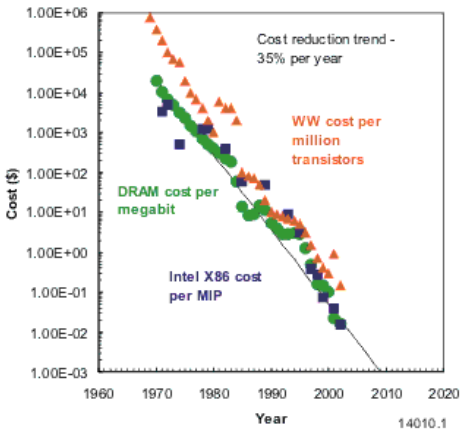
Other Measures of Cost Reduction



http://www.icknowledge.com/economics/productscostscosts2.html
IC Knowledge, 2001

Total Transistor Production

- Reduction in cost: 35%/year
- Increase in sales volume: 15%/year
- Increase in transistor production:

1.15/.65 = 77%/year

My estimate for 2010: ~5,900,000,000,000,000,000,000
i.e., 5.9 sextillion = 5,900 billion billion transistors!

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Transistors ≠ Performance

- Limited gain in performance derives directly from semiconductor gains
- The rest comes from better architecture

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Performance Gains from Physics

Smaller transistors are closer together
- switch faster
- communicate faster
- require less energy

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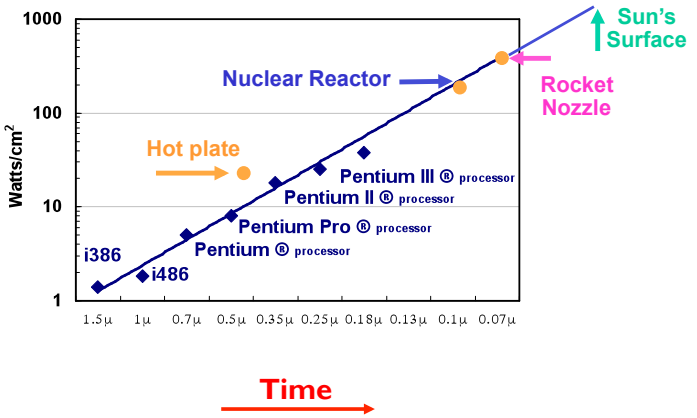
A Different Exponential Law



Fred Pollack, Intel Corp. 2000

Joy's Law

"PERFORMANCE of a microprocessors doubles every three years."

—William Joy, 1980

Also known as "Popular Moore's Law"

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Joy's Law

Relative Performance of Microprocessor

$$P = 2^{(\text{year} - 1980)/3} = 1.26^{(\text{year} - 1980)}$$

Extrapolating to 2010 relative to 1980,

$$P = 1.26^{(2010 - 1980)} = 1{,}026x$$

Realistic rate to 2010 was closer to 40%/year:

$$P = 1.40^{(2010 - 1980)} = 6300x$$

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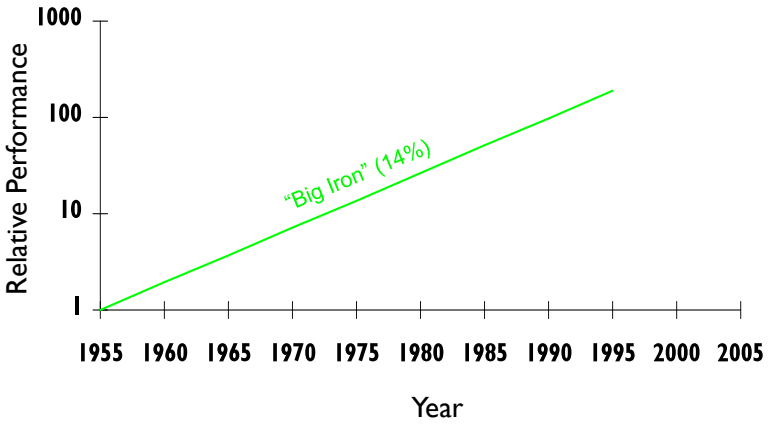
Best Uniprocessor Performance 1955-1995



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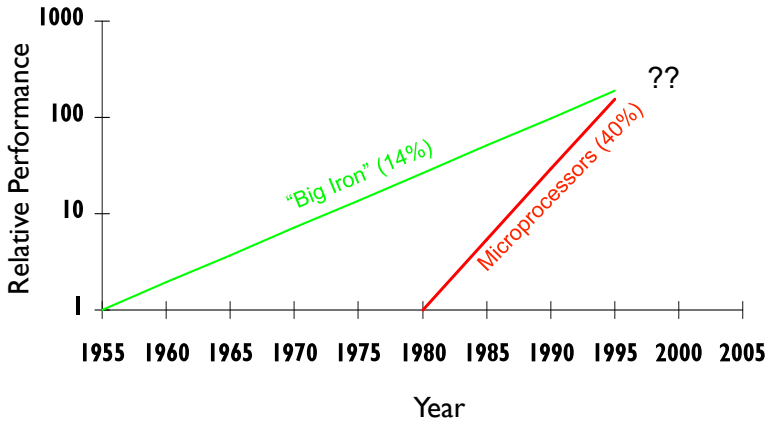
Best Uniprocessor Performance 1955-1995



News [Processors]

Friday 15th October 2004

Intel abandons clock speed chase and drops 4GHz Pentium 9:31AM

In another embarrassing admission in a year scattered with them, Intel has announced that it is to cease development of the 4GHz Pentium processor. For now the 3.8GHz part will remain the highest clock speed. Instead, the company says that it will be transferring its engineers to work on the dual core designs demonstrated at the recent Developer's Forum.

The unexpected announcement marks the end of an era for Intel. Ever since the launch of the 4.77MHz 8088 around which the original IBM PC was designed, the company has largely depended on ever increasing clock speeds to boost performance. However, recently Intel and arch-rival AMD have been having greater problems in producing reliable parts that could cope with the amount of heat generated by these clock speeds.

First AMD and now Intel have changed tack away from raw clock speed towards

Source: http://www.comp-buyer.co.uk/buyer/processors/news/64478/intel-abandons-clock-speed-chase-and-drops-4ghz-pentium.html

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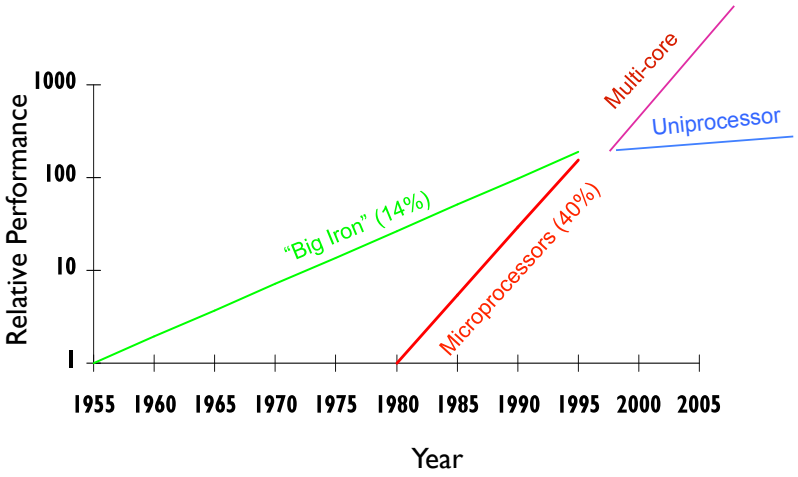
Multi-cores!



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Microprocessor Improvements

- Microprocessors are a good match for Moore's Law: single-chip processors
- Previous technology created a "bag of tricks" to be exploited

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Architectural Advances 1950-1990

- Branch prediction: 1995 (1959)
- Out-of-order issue: 1993 (1963)
- Multi-threading: 1995 (1963)
- Cache memories: 1985 (1965)
- Superscalar Processing (mult instrs/cycle): ~1990 (1960s)
- Register renaming: ~1992 (1967)
- Deep pipelining: ~1993 (1976)
- Speculative execution: ~1995 (1983)