Computer Systems are Different!

6.033 Spring 2008

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Static discipline

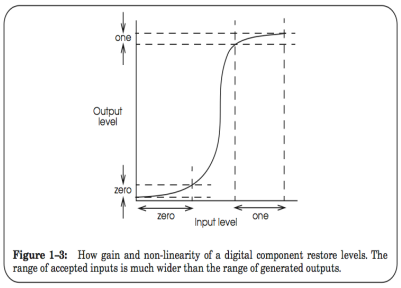
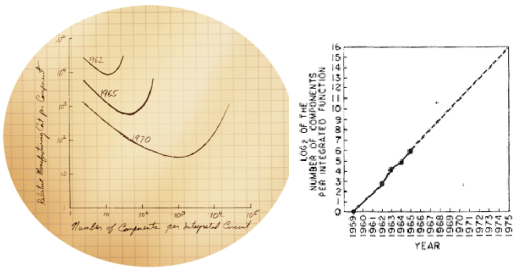


Figure 1–3: How gain and non-linearity of a digital component restore levels. The range of accepted inputs is much wider than the range of generated outputs.

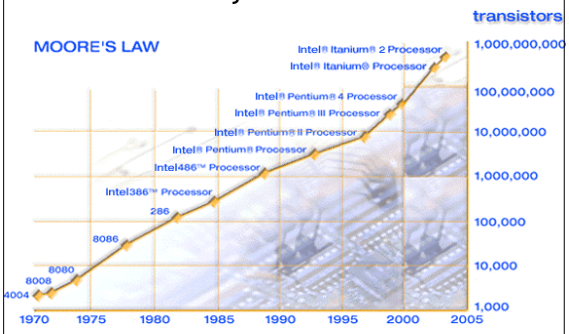
- Be tolerant of inputs and strict on outputs

Moore's law

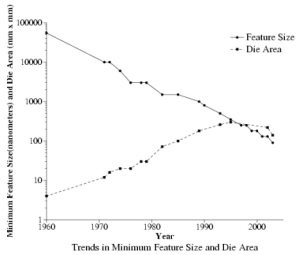


"Cramming More Components Onto Integrated Circuits", *Electronics*, April 1965

Moore's Law: # transistors/die doubles every ~18 months

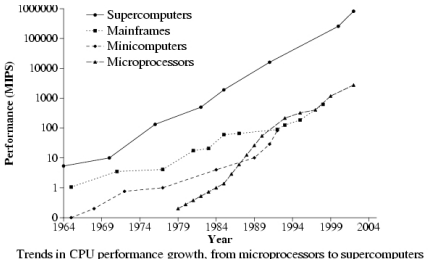


Lithography: the driver behind transistor count



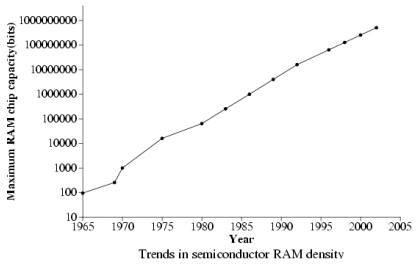
- Components/area O(x^2) with feature size
- Total components O(a) with die area
- Switching rate O(x) with feature size

CPU performance



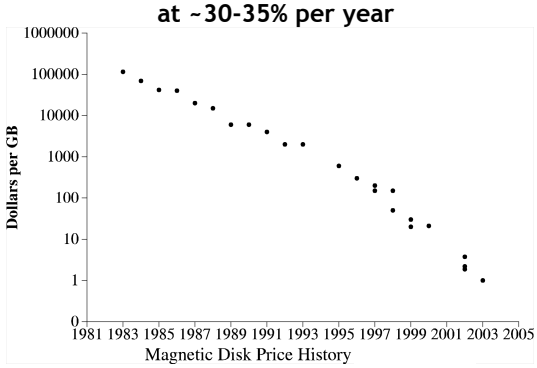
Trends in CPU performance growth, from microprocessors to supercomputers

RAM density



Trends in semiconductor RAM density

Disk: Price per GByte drops at ~30-35% per year



Magnetic Disk Price History

ENIAC

- 1946
- Only one
- 5000 adds/sec
- 20 10-digit registers
- 18,000 vacuum tubes
- 124,500 watts
- Not really stored program

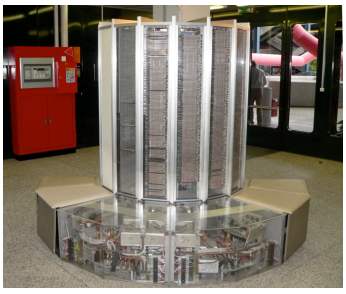
UNIVAC (Universal Automatic Computer)

- 1951
- 46 sold
- 2000 ops/sec
- 1,000 12-digit words (mercury)
- 5000 tubes
- $1.5 million

IBM System/360-40

- 1964
- 1.6 MHz
- 16-256 KB core
- $225,000
- Family of six
- 32-bit
- Time-sharing

Cray 1: supercomputer



- 1976
- 80 sold
- 80 MHz
- 8 Mbyte SRAM
- 230,000 gates
- $5 million

DEC PDP-8 (1964)

- 60,000 sold
- 330,000 adds/sec
- 4096 12-bit words
- $18,000

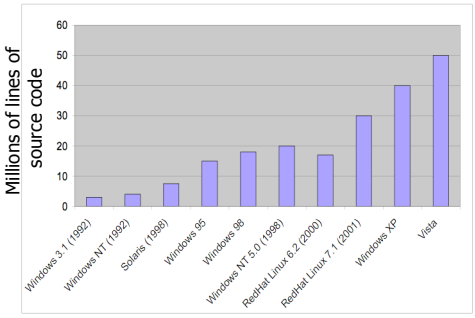
Apple II

- 1977
- 1 MHz
- 6502 microprocessor
- 4 to 48 Kilobytes
- $1300
- Basic, Visicalc

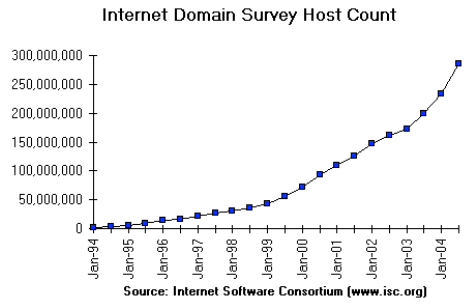
IBM's wrist watch

- 2001
- Linux and X11
- 74 Mhz CPU
- 8 Megabyte flash
- 8 Megabyte DRAM
- Wireless

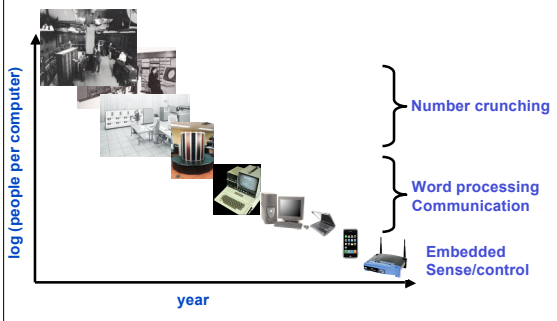
Software follows hardware



Cheap → Pervasive

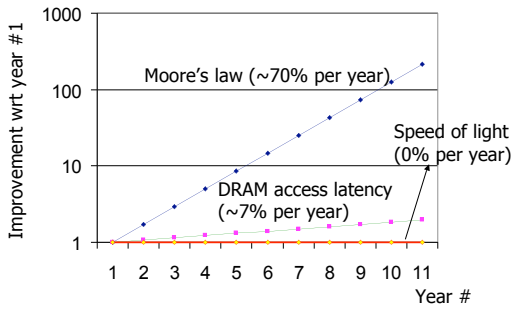


Pervasive → qualitative change

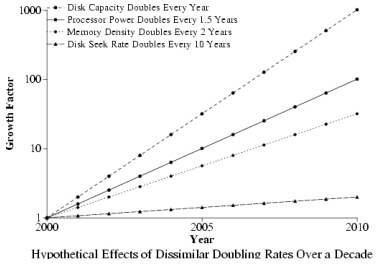


Slide from David Culler, UC Berkeley

Latency improves slowly

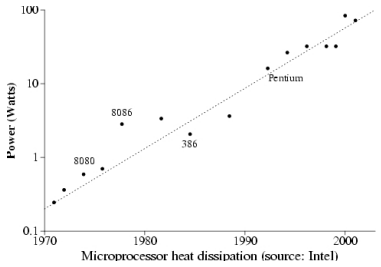


Incommensurate doubling



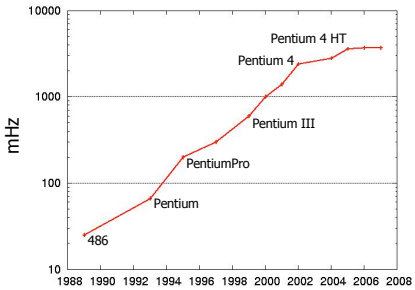
Hypothetical Effects of Dissimilar Doubling Rates Over a Decade

Heat is a problem

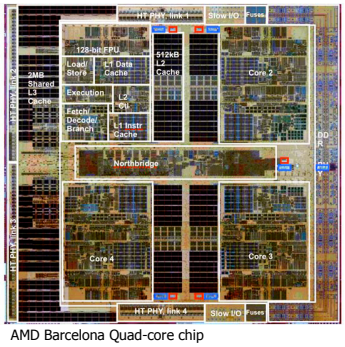


Microprocessor heat dissipation (source: Intel)

Recent Intel CPU Clock Rates



The Future: will it be painful?



AMD Barcelona Quad-core chip

What went right?

- Unbounded composability
- General-purpose computers
  - Only need to make one thing fast
  - Simple interface, complex implementation
  - Decouple software from CPU
- Cumulative improvement over years