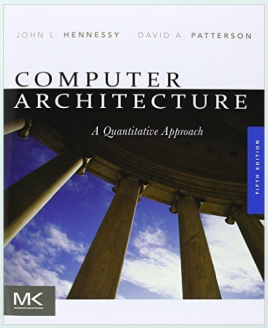


Technology Trends

Original slides from:
Computer Architecture
A Quantitative Approach
Hennessy, Patterson
Modified slides by Yashwant Malaiya
Colorado State University

Exponential Growth

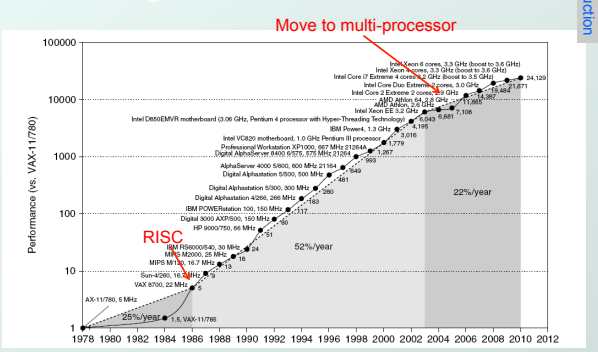
- Grows by a factor of (1+x) per year.
- By a factor of $(1+x)^n$ for n years.
- Example: An investment of $1000
  - 100% return in one year (i.e. doubles)
  - When will it become a million dollars?
  - Answer: 2^y=1000, y = ?

The computer industry has experienced exponential growth for decades: memory density, processor performance, circuit density, communications bandwidth, …

Computer Technology

- Performance improvements:
  - Improvements in semiconductor technology
    - Reduced feature (circuit) size
    - Higher clock speeds
  - Improvements in computer architectures
    - Enabled by HLL compilers, UNIX
    - Lead to RISC architectures
  - **Together have enabled:**
    - Lightweight, portable, cheap, fast computers
    - Productivity-based programming languages
    - Advanced development environments and tools

Single Processor Performance



Defining Computer Architecture

- "Classical" computer architecture:
  - Instruction Set Architecture (ISA) design
  - i.e. decisions regarding:
    - registers, memory addressing, addressing modes, instruction operands, available operations, control flow instructions, instruction encoding
- "New" computer architecture:
  - Specific requirements of the target machine
  - Design to maximize performance within constraints: - **cost, power, and availability**
  - Includes ISA, microarchitecture, hardware

Trends in Technology

- Integrated circuit technology
  - Transistor density: 35%/year
  - Die size: 10-20%/year
  - Integration overall: 40-55%/year
- DRAM capacity: 25-40%/year (slowing)
- Flash capacity: 50-60%/year
  - 15-20X cheaper/bit than DRAM
- Magnetic disk technology: 40%/year
  - 15-25X cheaper/bit then Flash
  - 300-500X cheaper/bit than DRAM

Bandwidth and Latency

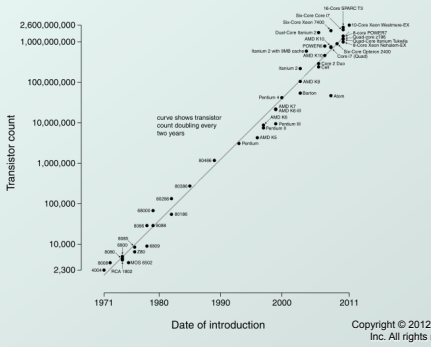
- Bandwidth or throughput
  - Total work done in a given time
  - 10,000-25,000X improvement for processors
  - 300-1200X improvement for memory and disks
- Latency or response time
  - Time between start and completion of an event
  - 30-80X improvement for processors
  - 6-8X improvement for memory and disks

Technology Laws

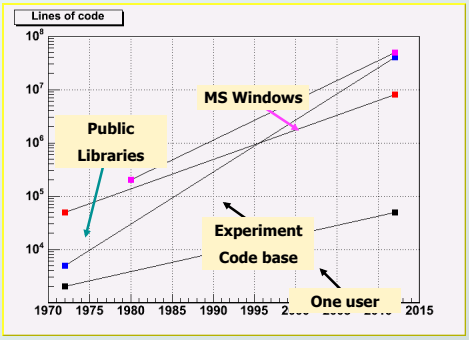
- **Moore's Law:** formulated by Gordon Moore of Intel in the early 70's - **the number of transistors on a chip doubles every 18 months**; corollary, computers become faster and the price of a given level of computing power halves every 18 months.
- **Gilder's Law:** proposed by George Gilder, prolific author and prophet of the new technology age - **the total bandwidth of communication systems triples every twelve months**. New developments seem to confirm that bandwidth availability will continue to expand at a rate that supports Gilder's Law.
- But no laws about Software (well, maybe Murphy's law!)

Moore's law

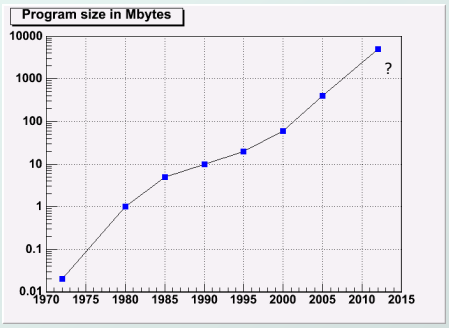
Microprocessor Transistor Counts 1971-2011 & Moore's Law



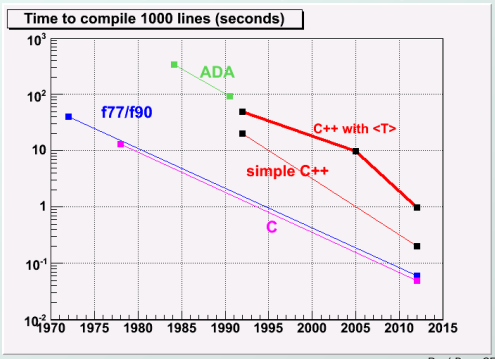
Program Size (lines of code)



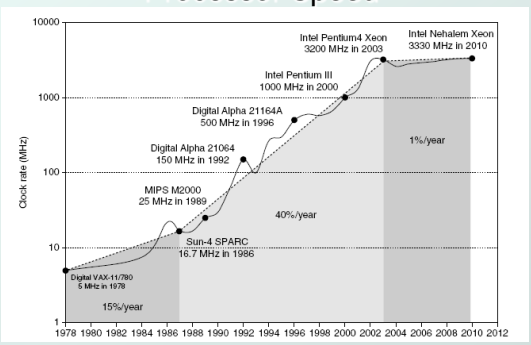
Program Size (RAM)



Compile Time (seconds)



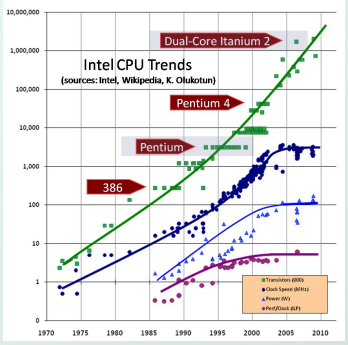
Processor Speed



Power Scaling

- Intel 80386 running at 16 Mhz consumed around 2 Watts, less than a LED light bulb.
- Intel Core i7 running at 3.3 GHz consumes 130 Watts, still less than a television.
- However, heat must be dissipated from 1.5 x 1.5 cm chip in a closed case.
- Even with aluminum cooling fins and a power fan, this is close the limit of what can be cooled.
- Furthermore, the power consumption (based on CMOS technology) scales faster than clock speed.
- So instead of increasing clock speed, CPU designers are adding multiple cores.

Power Wall



What would happen if clock speed and power consumption scaled as it did from the 1980's to 2000's?

Dr. Dobbs Journal, March 2003r