EECE 321: Computer Organization

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Lecture 2: History of Computers

Announcements

- Course webpage:

  http://webfea.fea.aub.edu.lb/mmansour/eece321/index.htm

- Follow the course calendar on the course web page.
- Homework:
  - HW1: Posted, Due Monday Feb. 22, class time
  - Submit using Moodle
- Reading assignment
  - Ch.1 P&H: Sections 1.1 – 1.4
- Modelsim for VHDL:
  - You need to download the student version and learn how to use it
  - See web page for details
- Project: The following is due by Wednesday Feb. 24:
  - Assemble a team of three members
  - I will circulate a paper in class to write down the group member names on it
  - Have "Modelsim" up and running
  - Document on a log-sheet, all project activities on a weekly basis, showing what each member has achieved throughout the semester.
    - Log-sheet to handed in and graded as part of the project

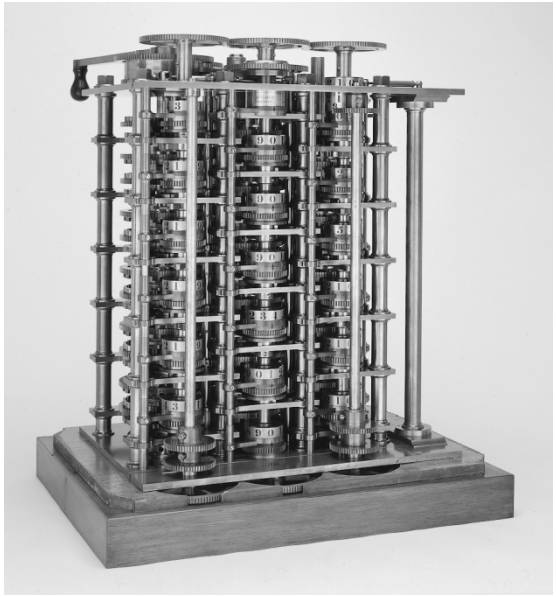
Computers: A Historical Perspective

- Early computers were mechanical/electromechanical in nature.
- Digital computer generations
  - Since early 50's, thousands of new computers have appeared using a wide range of technologies and offering wide range of capabilities.

Year	Technology	Relative performance/cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit (IC)	900
1995	Very large scale IC (VLSI)	2,400,000
2005	Ultra large scale IC	6,200,000,000

World's First 'Mechanical' Computer

- The Babbage Difference Engine (1832), by Charles Babbage
- Inspired by Jacquard's loom: Read the article "The Loom that Wove the Future" by James Essinger @ http://www.popularscience.co.uk/features/feat15.htm
  - Check also wiki page



Difference Engine, 1832

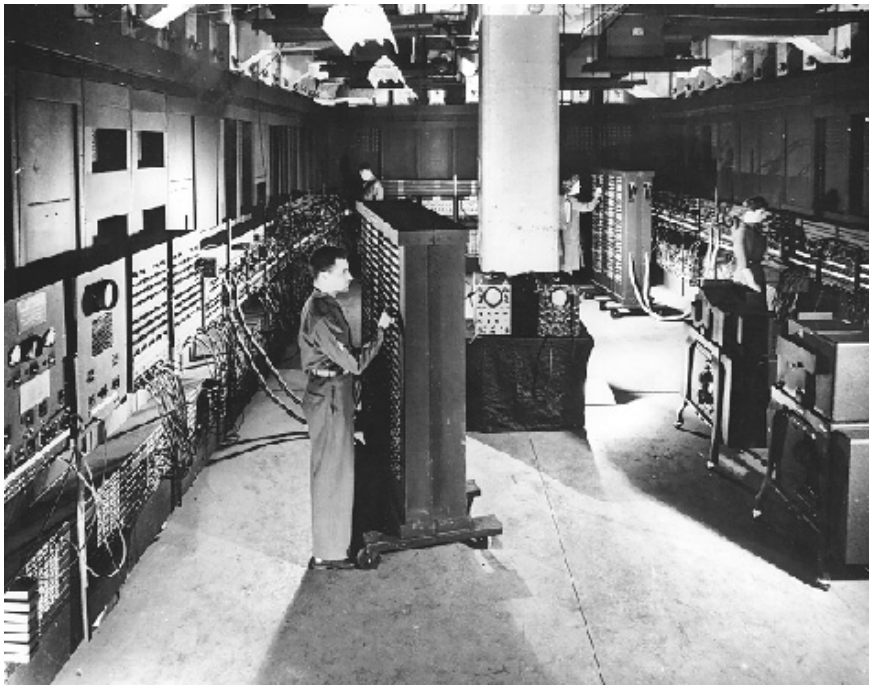
It included a pipelined-adder!

- Specs:
  - Based on mechanical gears that perform arithmetic
  - Uses the decimal number system
  - 25,000 parts
  - cost: £17,470

The photos in this lecture are adapted from the literature for teaching purposes.

World's First General-Purpose 'Electronic' Computer

- ENIAC: Built by Eckert & Mauchly at Univ. of Pennsylvania around World War II.



ENIAC, 1946

- Specs:
  - Weighed 30 tons
  - Occupied 1500 square feet
  - Used 18,000 vacuum tubes
  - Had 20 10-digit registers each 2 feet long
  - Consumed 140 KW of power
  - Performed 5000 additions/sec

The photos in this lecture are adapted from the literature for teaching purposes.

Commercial Developments: IBM System/360 Computers

- IBM introduced the System/360 models in 1964 after investing $5B.

- Four models were introduced:
  - Model 40 (shown above): 1.6 MHz, 32KB-256KB, $225,000
  - Model 50: 2.0 MHz, 128KB-256KB, $550,000
  - Model 65: 5.0 MHz, 256KB-1MB, $1,200,000
  - Model 75: 5.1 MHz, 256KB-1MB, $1,900,000

Minicomputers: DEC PDP-8

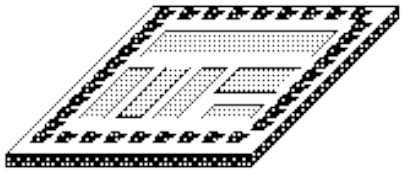
- Digital Equipment Corporation (DEC) introduced the first commercial minicomputer in 1965.
- Cost: $20,000
- Minicomputers were forerunners of microprocessors.

Computers Today: Overview of Physical Implementations

- The hardware out of which we make systems.
- Integrated Circuits (ICs)
  - Combinational logic circuits, memory elements, analog interfaces (CPU)
- Printed Circuits (PC) boards
  - Substrate for ICs and interconnection, distribution of CLK, Vdd, and GND signals, heat dissipation.
- Power Supplies
  - Converts line AC voltage to regulated DC low voltage levels.
- Chassis (rack, card case, ...)
  - holds boards, power supply, provides physical interface to user or other systems.
- Connectors and cables

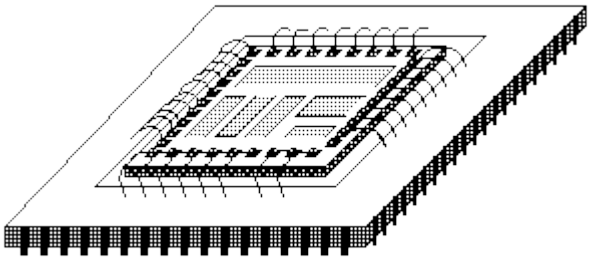
Integrated Circuits (2009 ~ state-of-the-art)

Bare Die



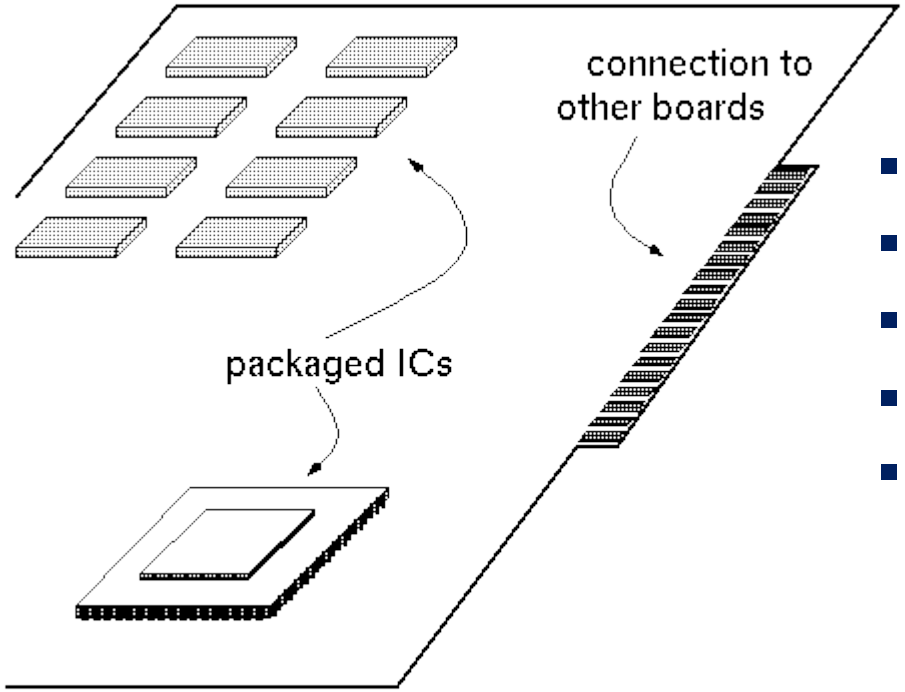
- Primarily Crystalline Silicon
- 1mm - 25mm on a side
- 2009 feature size ~ 45 nm = 45 x 10^{-9} m (then 32, 22, and 16 [by yr 2013])
- 100 - 1000M transistors
- (25 - 100M "logic gates")
- 3 - 10 conductive layers
- "CMOS" (complementary metal oxide semiconductor) - most common.

Chip in Package



- **Package provides:**
  - **spreading of chip-level signal paths to board-level**
  - **heat dissipation.**
- **Ceramic or plastic with gold wires.**

Printed Circuit Boards



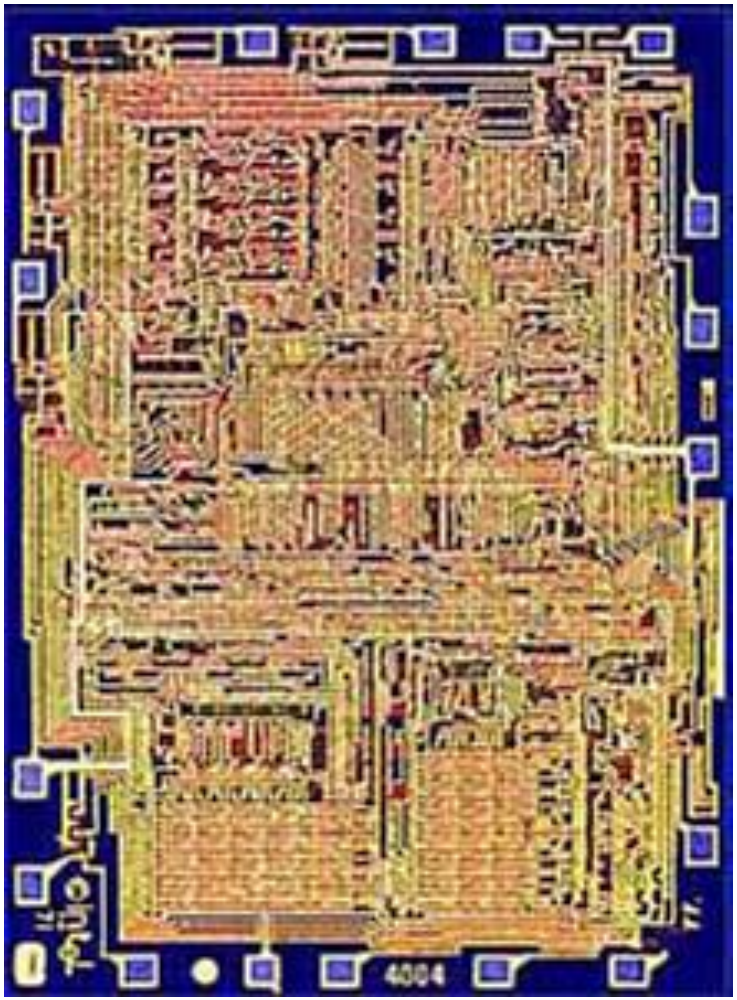
- fiberglass or ceramic
- 1-20 conductive layers
- 1-20 inches on a side
- IC packages are soldered down.
- Provides:
  - Mechanical support
  - Distribution of power and heat.

How did all that start?

The *Microprocessor*

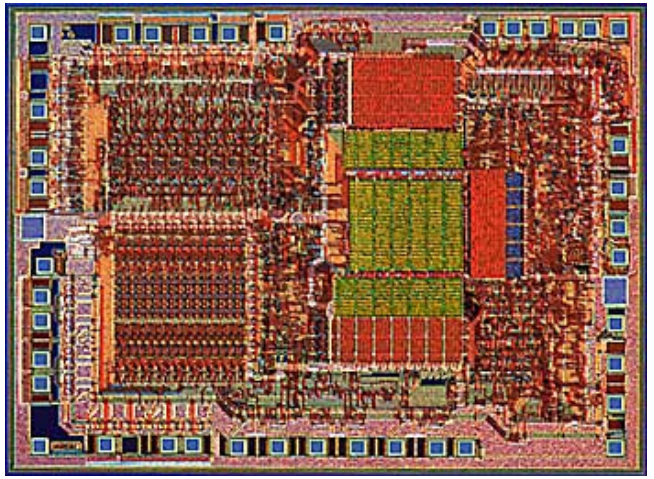
Microprocessors: The Intel 4004

- Intel introduced the world's first general purpose, single-chip microprocessor in 1971.
- 8-bit architecture, 4-bit implementation
- 2,300 transistors
- All transistors were hand-crafted on the die.
- Performance < 0.1 MIPS
  (Million Instructions Per Second)
- Intel 8008: 8-bit implementation in 1972
  - 3,500 transistors
  - First microprocessor-based computer (Micral)
    - Targeted at laboratory instrumentation
    - Mostly sold in Europe
- Also, 1971 featured the introduction of the first integrated memory chip (4-Kbit) using MOS.



Intel 80x86 ISAs and Microprocessors

- Introduced 8086 in 1978
  - Performance < 0.5 MIPS
- New 16-bit architecture
  - "Assembly language" compatible with 8080
  - 29,000 transistors
  - Includes memory protection, support for Floating Point coprocessor
- In 1981, IBM introduces PC
  - Based on 8088--8-bit bus version of 8086
- Intel processor family:
  - 80286 (1982)
  - 80386 (1985)
  - 80486 (1989)
  - Pentium (1992)
  - Pentium Pro (1995)
  - Pentium II (1997)
  - Pentium III (1999)
  - Pentium IV (2000)
  - Intel Core (2006)

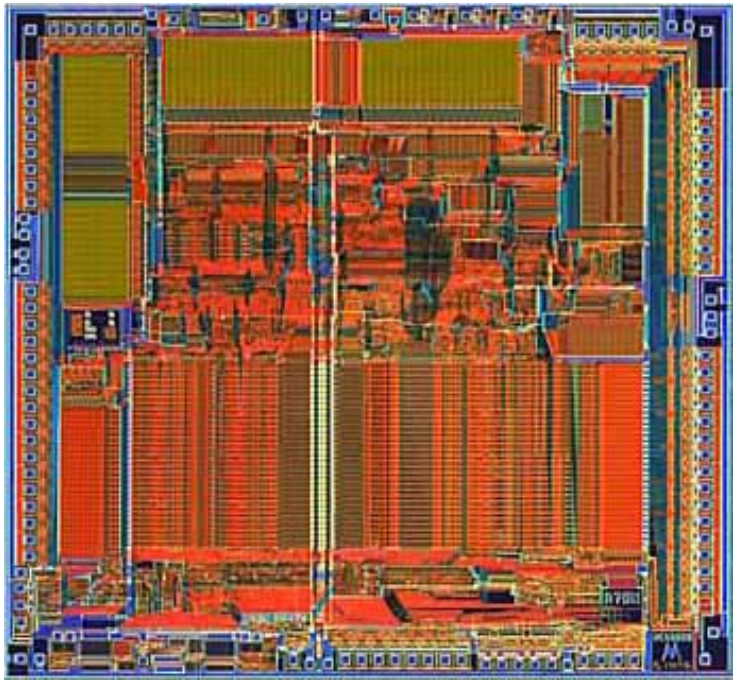


Pentium IV: 42M transistors

- Each release featured an expansion of the 8086 ISA
- All future processors are backward compatible

Motorola 68000 Family

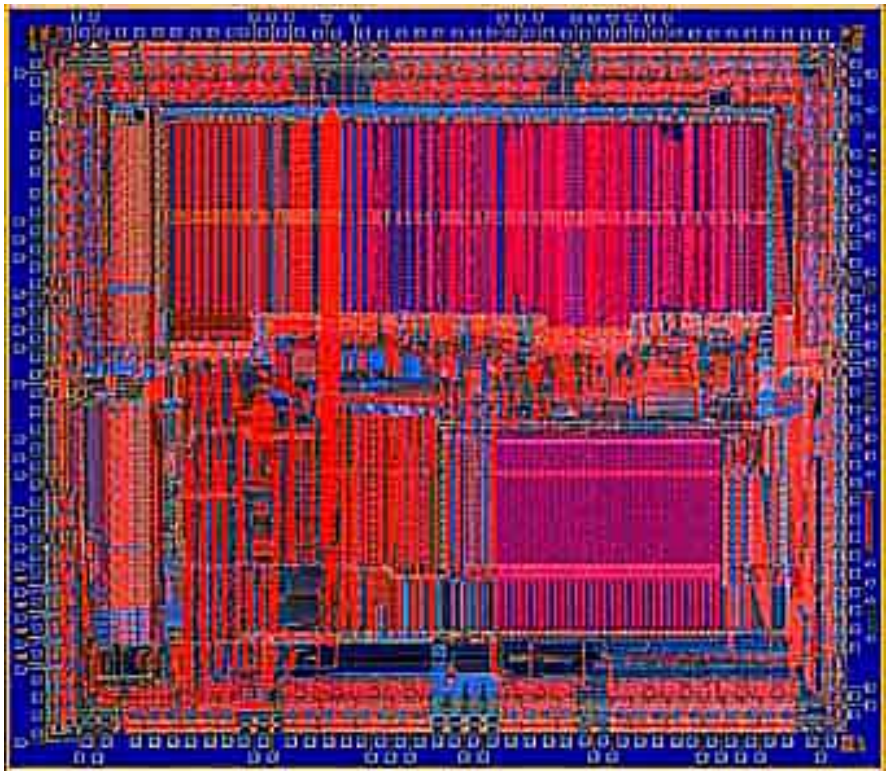
- Major architectural step in microprocessors:
  - First 32-bit architecture
    - initial 16-bit implementation
  - First flat 32-bit address



- First implementation in 1979
  - 68,000 transistors
  - < 1 MIPS
  - Used in
    - Apple Mac
    - Sun, Silicon Graphics, & Apollo workstations
- Motorola 680X0 processors
  - 68000
  - 68020
  - 68030
  - 68040
  - 68050
  - 68060
  - ColdFire

MIPS Processors

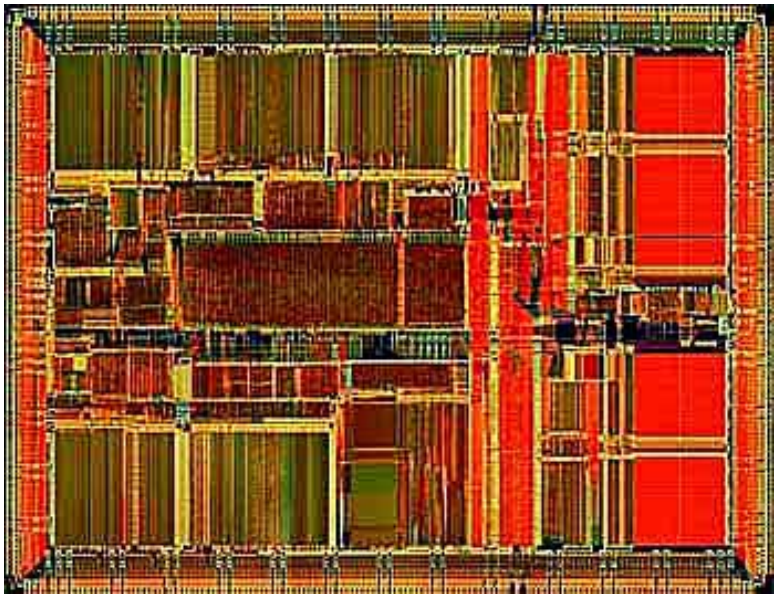
- The MIPS project was started at Stanford University in 1981 by Hennessy with a handful of grad students.
- MIPS stands for *Microprocessor without Interlocked Pipe-Stages*
- In 1984 he co-founded MIPS computer systems (merged with Silicon Graphics).
- Several firsts:
  - First (commercial) RISC microprocessor
  - First microprocessor to provide integrated support for instruction & data cache
  - First pipelined microprocessor (sustains 1 instruction/clock)
- Implemented in 1985
  - 125,000 transistors
  - Sustained 5-8 MIPS (millions of instructions per second)



MIPS R2000

MIPS R4000: 64-Bit Processor

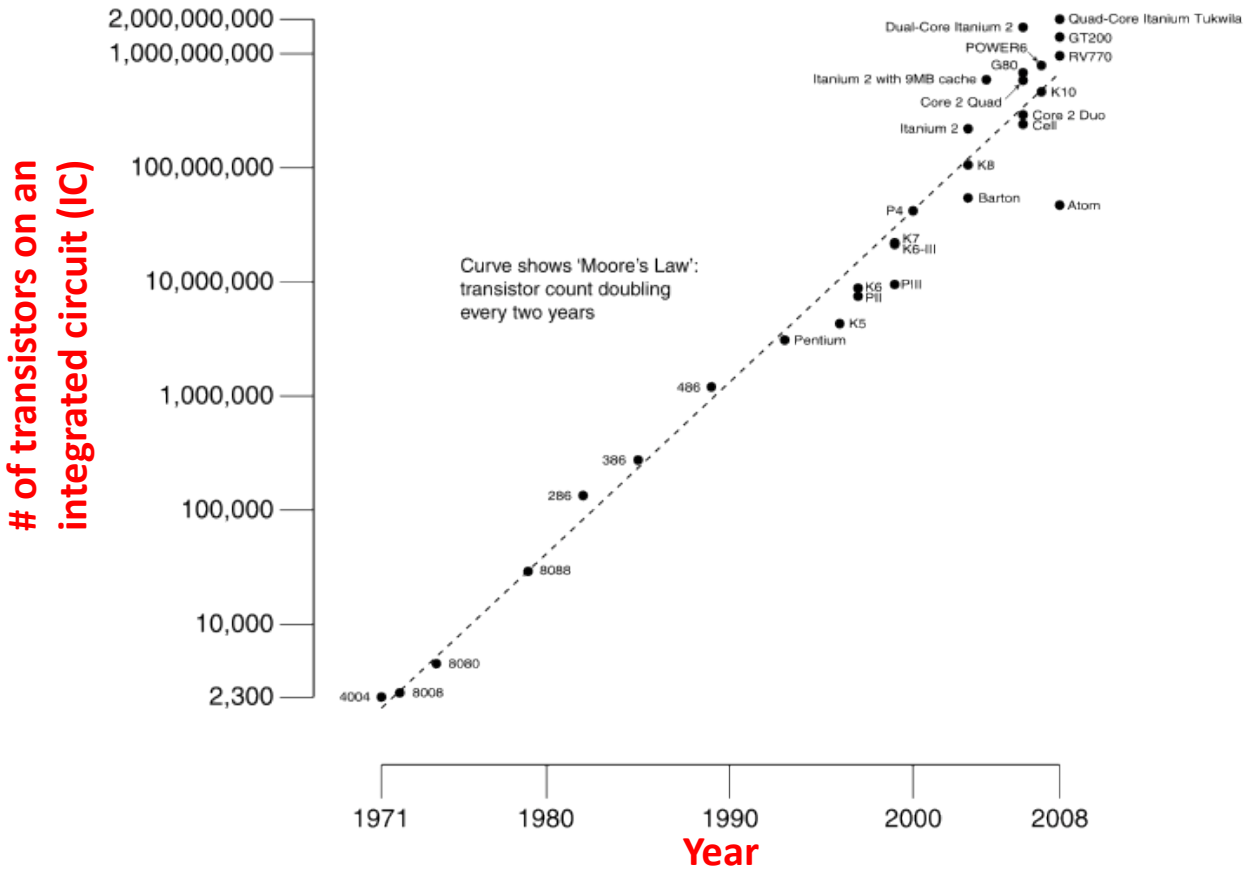
- First 64-bit architecture
- Integrated caches
  - On-chip
  - Support for off-chip, secondary cache
- Integrated floating point
- Implemented in 1991:
  - Deep pipeline
  - 1.4M transistors
  - Initially 100MHz
  - > 50 MIPS



Technology Trends: Microprocessor Complexity

- Moore's Law: Transistors per chip double every 18 to 24 months

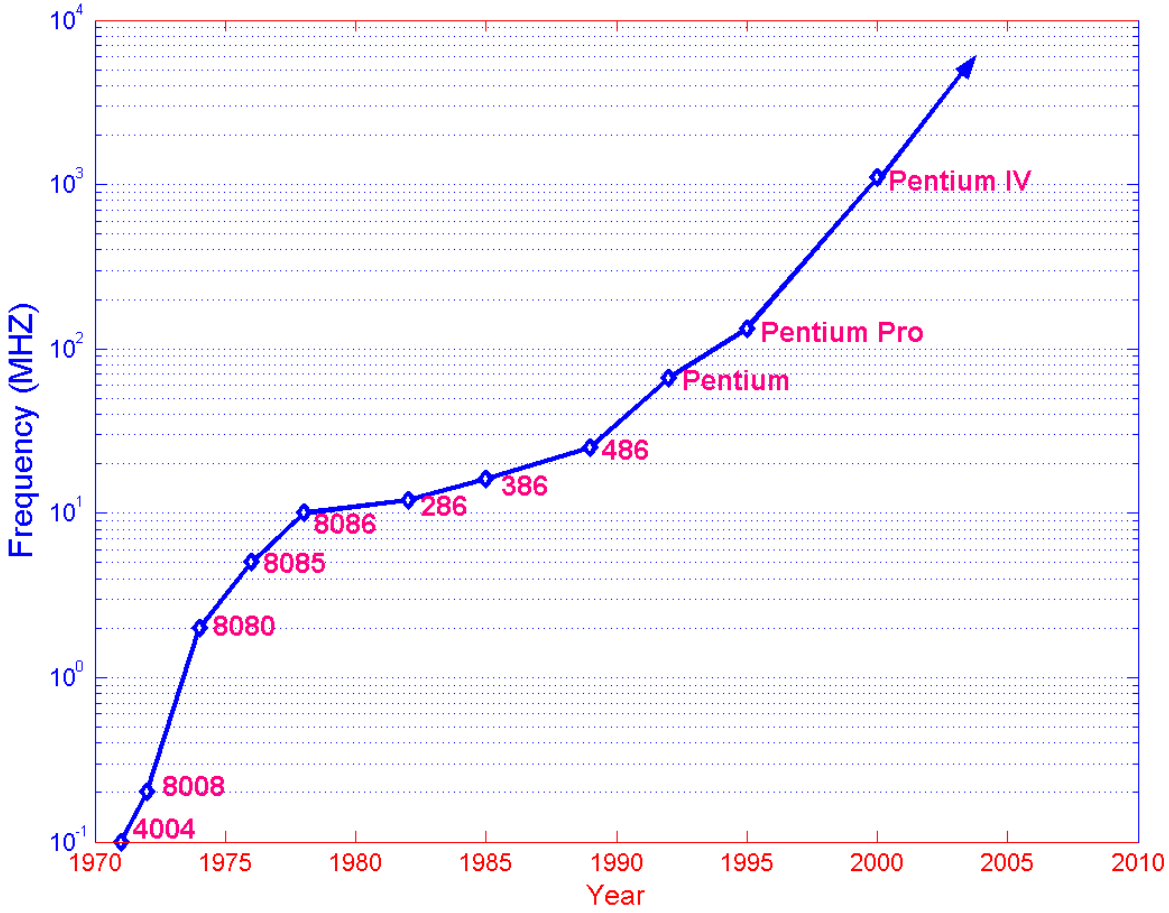
Predicts: 2X Transistors / chip every 2 years



en.wikipedia.org/wiki/Moore's_law

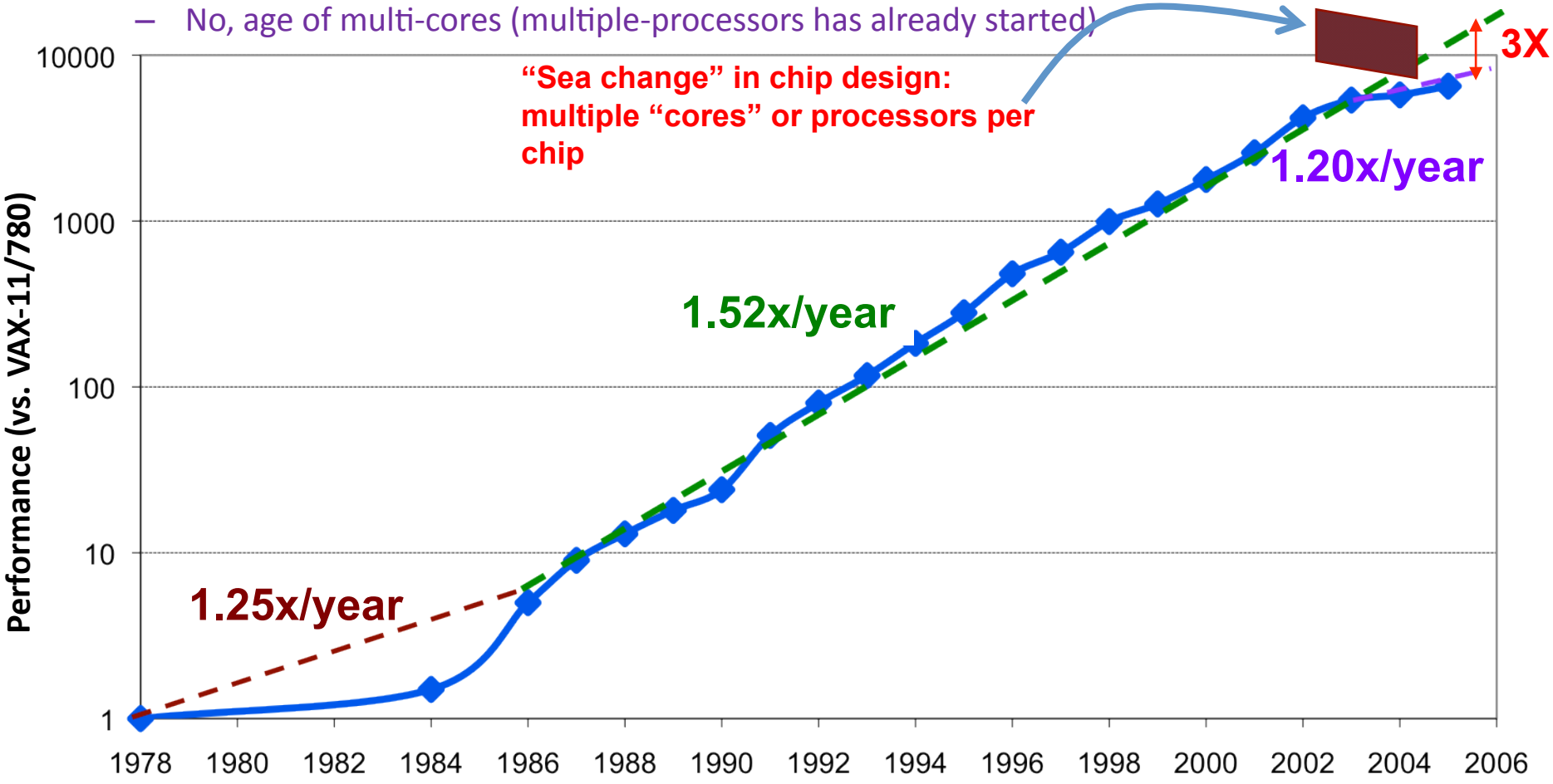
Technology Trends: Microprocessor Performance (Frequency)

- Processor frequency performance doubles every two years (since 1990's)



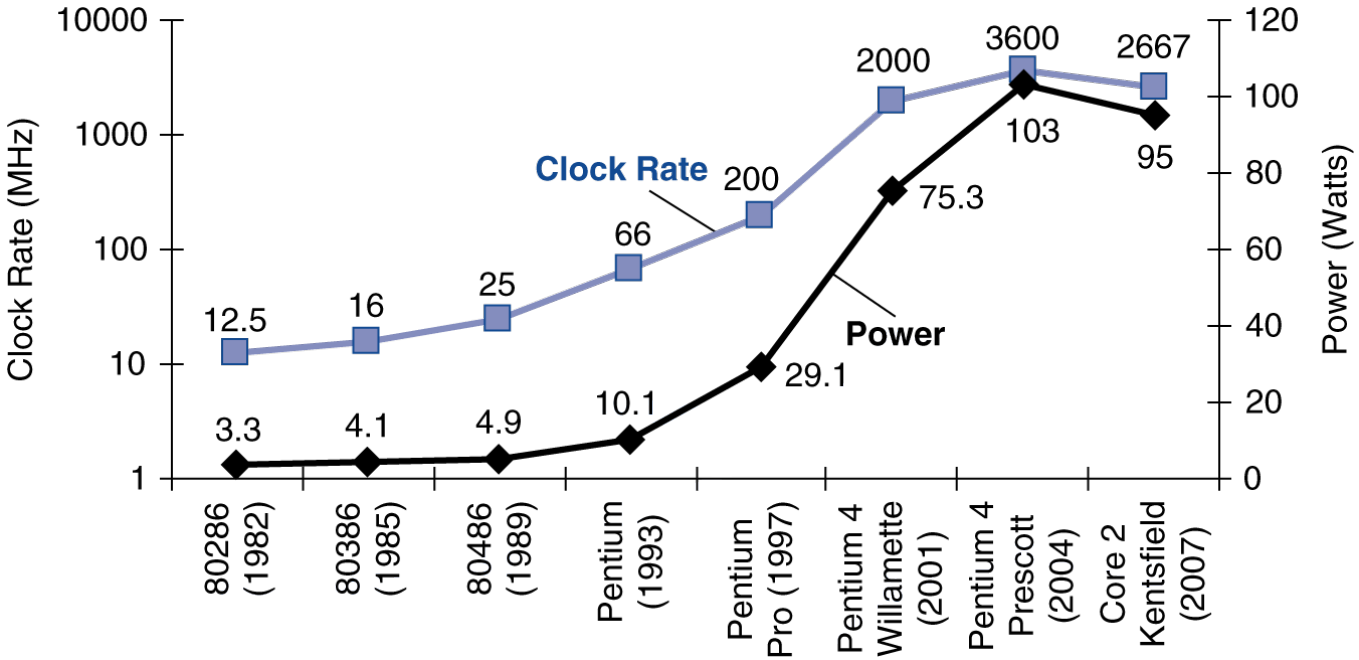
Technology Trends: Uniprocessor Performance on Benchmarks

- Is one processor enough?
  - No, age of multi-cores (multiple-processors has already started)



- **VAX : 1.25x/year 1978 to 1986**
- **RISC + x86: 1.52x/year 1986 to 2002**
- **RISC + x86: 1.20x/year 2002 to present**

Power Trends



- In CMOS IC technology:

$$\text{Power} = \text{Capacitive load} \times \text{Voltage}^2 \times \text{Frequency}$$

×30 | 5V → 1V | ×1000

Dramatic Changes in Computer Technology

- Processor
  - Speed 2x / 1.5 years (since ‘85) (now slowing down!)
  - 100X performance in last decade.
  - Prediction: When you graduate: 4 GHz, 32 Cores
- Memory
  - DRAM capacity: 2x / 2 years (since ‘96)
  - 64x size improvement in last decade.
  - Prediction: When you graduate: 128 GibiBytes
- Disk
  - Capacity: 2x / 1 year (since ‘97)
  - 250X size in last decade.
  - Prediction: When you graduate: 8 TeraBytes
- New units

Kilo (10^3)	Kibi (2^{10})	Ki
Mega (10^6)	Mebi (2^{20})	Mi
Giga (10^9)	Gibi (2^{30})	Gi
Tera (10^{12})	Tebi (2^{40})	Ti
Peta (10^{15})	Pebi (2^{50})	Pi
Exa (10^{18})	Exbi (2^{60})	Ei
Zetta (10^{21})	Zebi (2^{70})	Zi
Yotta (10^{24})	Yobi (2^{80})	Yi

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

The Processor Market