1DT157 Digitalteknik och datorarkitekt

Digital technology and computer architecture, 5p

This is 1DT157 Digitalteknik och datorarkitekt

- Instructor: Stefanos Kaxiras
  - Few things about me:
    - Visiting professor – Computer Architetcure
    - 2003– Prof. Univ. of Patras, Greece
    - 1998–2003 Bell Labs (Unix & C group),
    - Ph.D. Univ. of Wisconsin, 1998
- Don’t speak Swedish …
  - Course taught in English … with your participation!

What the course is about:

- Teach “computer organization”
  - Transistors ➔ digital circuits ➔ arithmetic logic units (adders) ➔ processors & memory ➔ computers
- Teach the basic interface to the bare H/W
  - Basic operations ➔ microprogramming / microarchitecture ➔instruction set architecture (ISA) ➔ Assembly

Grading, Labs, Etc.

- Final Grade: 0.8*exam + 0.2*homework
  - Final exam 0.8
  - Homework: 2 sets of problems: one on H/W the second on assembly language
  - Each due before the corresponding Lab
- Labs: 2 sets of lab exercises DATES TBA
  - H/W (digital design)
  - Assembly (MIPS assembly)
- Lab assistants:

Books

Recommend Text Book

- *Structured Computer Organisation* Andrew S. Tanenbaum, Prentice Hall Fifth Edition.

The Tanenbaum book does not contain much information on the. MIPS processor. There will be material in the lectures some people might find the following book useful:

- *Introduction to RISC Assembly Language Programming* John Waldron, Addison-Wesley.
- Many resources available in the Internet for Assembly programming: use them!

Overview of the Course

- Based on the Tanenbaum Book Chapters:
- Introduction, Ch. 1&2, Week 13
  - General overview
- Digital Logic, Ch. 3, W. 14 & 16
  - Learn how to make an ALU. Homework 1
- Microarchitecture, Ch.4 W. 17 & 18
  - Learn how to make a CPU
- ISA, Assembly, Ch. 5, W. 19 & 20
  - Learn how to make an ISA. Homework 2
- Assembly Ch. 7, W. 21
  - Learn how to program on an ISA. Will be adapted for the LAB.
- OS and bits and pieces, Ch. 6, W. 22
  - Learn a bit more on how to make a computer

Slides based on:

Tanenbaum, Structured Computer Organization, Fifth Edition, (c) 2006 Pearson Education, Inc. All rights reserved. 0-13-148521-0

And:

Justin Pearson's Slides

Dave Patterson's Slides

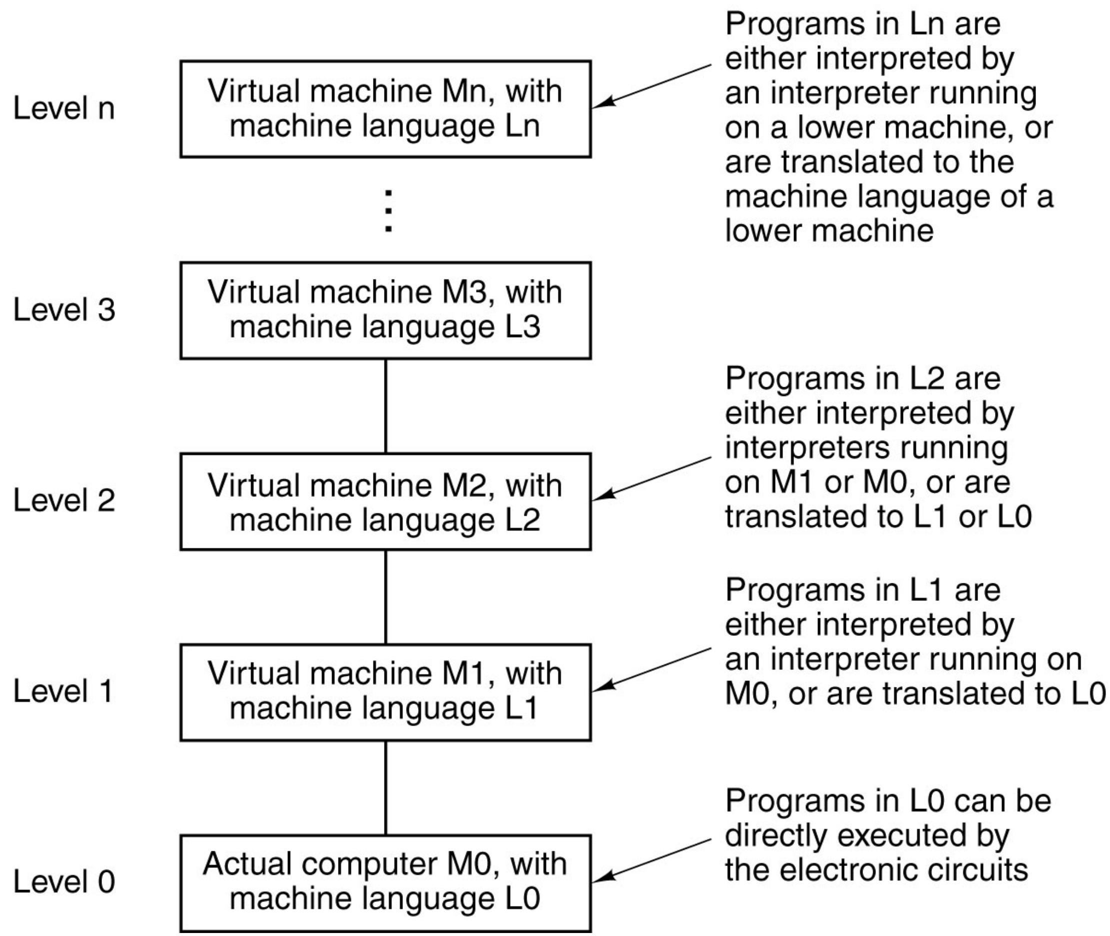
U. of Patras Slides

…

Introduction

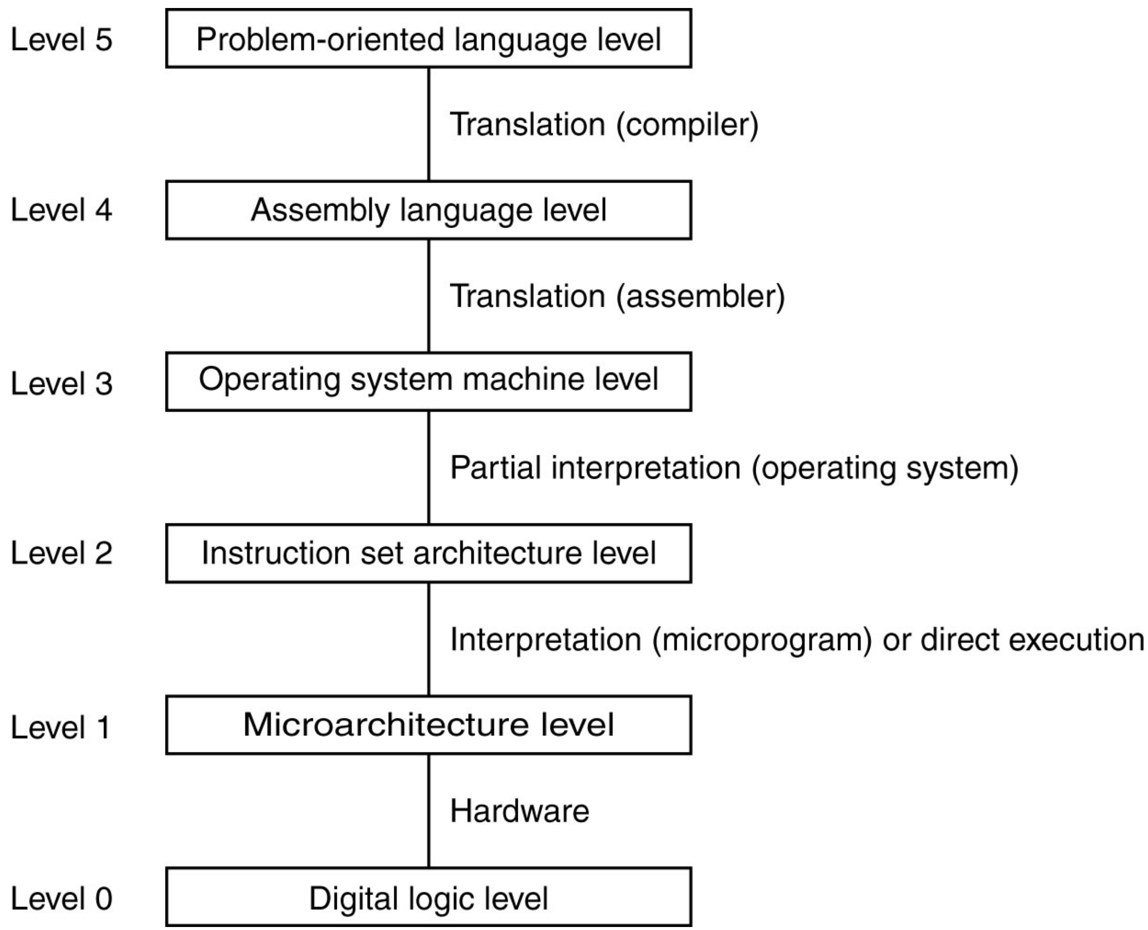
Chapter 1:
Some historical background and anecdotes

Book's angle: Languages, Levels, Virtual Machines



A multilevel machine

Book's angle (cont.): Contemporary Multilevel Machines



A six-level computer. The support method for each level is indicated below it .

Evolution of Multilevel Machines

- Invention of microprogramming
  - Wilkes 1950’s
- Invention of operating system
  - 1950’s
- Migration of functionality to microcode
  - 1970’s
- Elimination of microprogramming
  - 1980’s

Operating System Tasks

*JOB, 5494, BARBARA
*XEQ
*FORTRAN

FORTRAN program

*DATA

Data cards

*END

A sample job for the FMS operating system

Evolution of Operating Systems

- Batch job processing
  - Very early operating systems
- Interactive
  - Allows a programmer to interact with the computer (which cost $$$ to run)
- TIMESHARED systems
  - Allowed more than one user at the same time!
  - Thru teletypes!
- The most famous timeshared : MULTICS
  - so far ahead of its time that no computer could run it
  - Which gave birth to UNIX
- Microcomputers PC’s started with simple interatcive OS’s (DOS) which later became timeshared (Windows 3.5), eventually approached the functionality of UNIX
- Popularized the GUI

Milestones in Computer Architecture

Year	Name	Made by	Comments
1834	Analytical Engine	Babbage	First attempt to build a digital computer
1936	Z1	Zuse	First working relay calculating machine
1943	COLOSSUS	British gov't	First electronic computer
1944	Mark I	Aiken	First American general-purpose computer

PRE-HISTORY

Milestones in Computer Architecture

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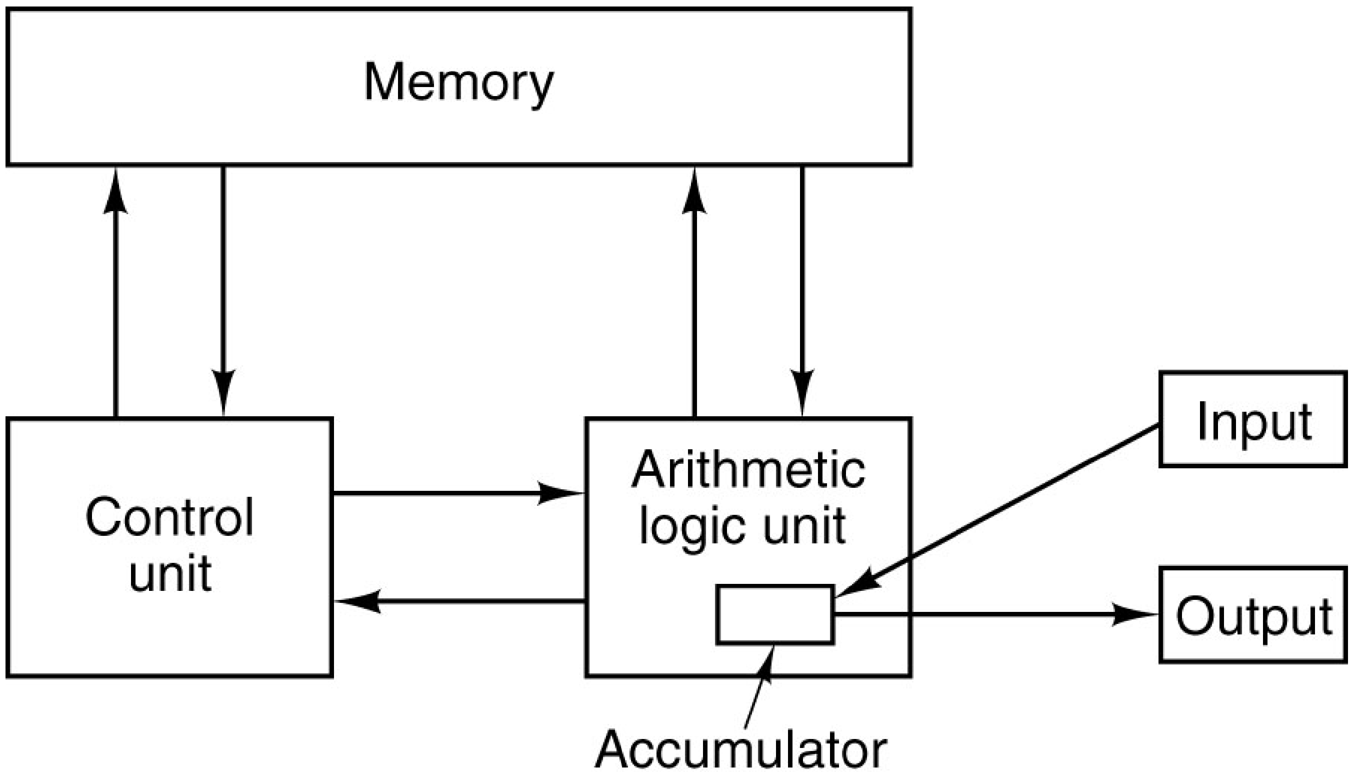
1944	Mark I	Aiken	First American general-purpose computer
1946	ENIAC I	Eckert/Mauchley	Modern computer history starts here
1949	EDSAC	Wilkes	First stored-program computer
1951	Whirlwind I	M.I.T.	First real-time computer
1952	IAS	Von Neumann	Most current machines use this design

EARLY-HISTORY

The birth of the Modern-era Computer

The concept of the Stored-Program Computer

Von Neumann Machine



The original Von Neumann machine.

Computer Generations

- Zeroth Generation
  Mechanical Computers (1642 – 1945)
- First Generation
  Vacuum Tubes (1945 – 1955)
- Second Generation
  Transistors (1955 – 1965)
- Third Generation
  Integrated Circuits (1965 – 1980)
- Fourth Generation
  Very Large Scale Integration (1980 – ?)

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1952	IAS	Von Neumann	Most current machines use this design
1960	PDP-1	DEC	First minicomputer (50 sold)
1961	1401	IBM	Enormously popular small business machine
1962	7094	IBM	Dominated scientific computing in the early 1960s
1963	B5000	Burroughs	First machine designed for a high-level language
1964	360	IBM	First product line designed as a family

The beginning of the Computer Age

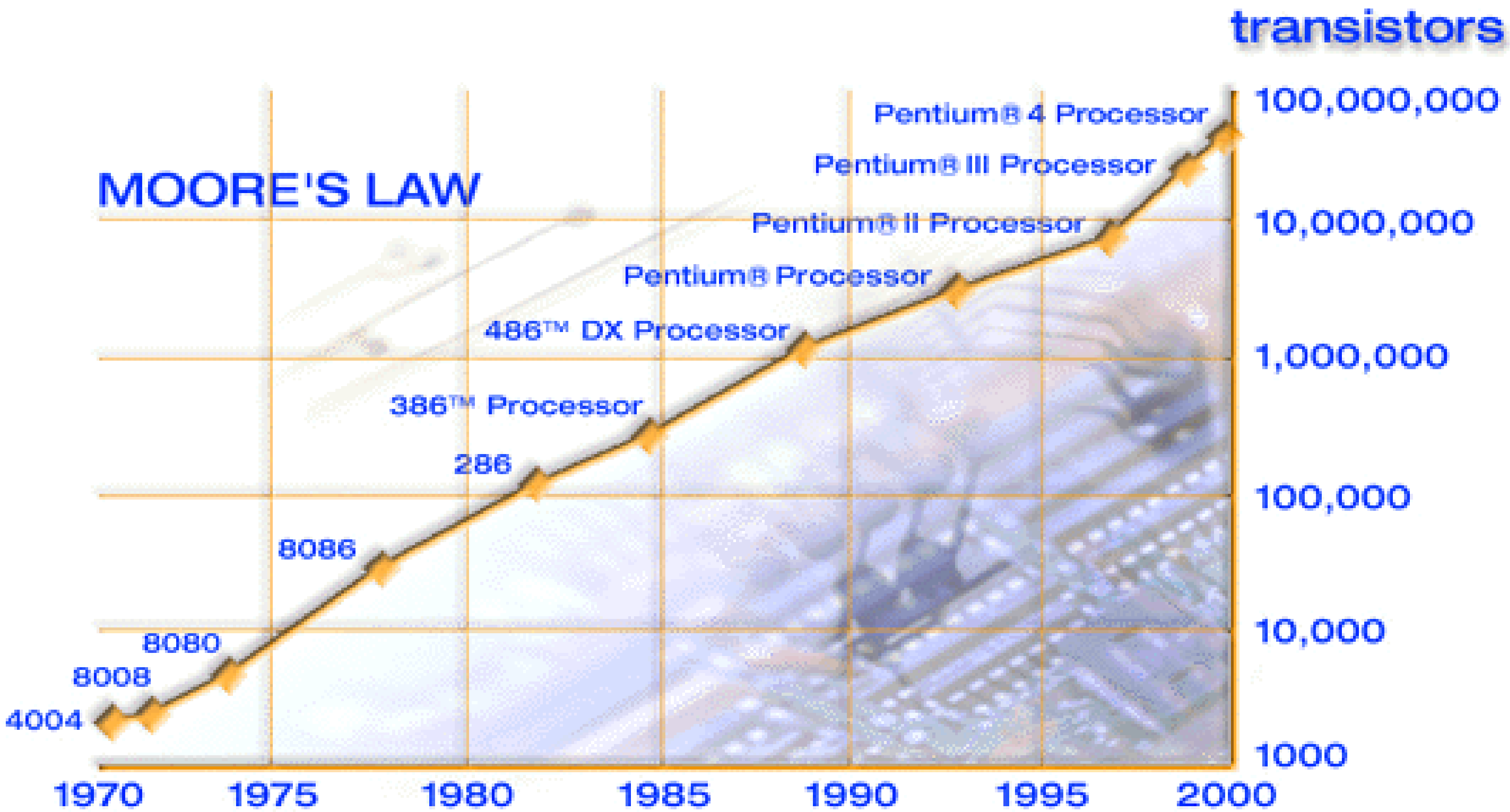
Milestones in Computer Architecture (2)

Year	Name	Made by	Comments
1965	PDP-8	DEC	First mass-market minicomputer (50,000 sold)
1970	PDP-11	DEC	Dominated minicomputers in the 1970s
1974	8080	Intel	First general-purpose 8-bit computer on a chip
1974	CRAY-1	Cray	First vector supercomputer
1978	VAX	DEC	First 32-bit superminicomputer
1981	IBM PC	IBM	Started the modern personal computer era
1981	Osborne-1	Osborne	First portable computer
1983	Lisa	Apple	First personal computer with a GUI
1985	386	Intel	First 32-bit ancestor of the Pentium line
1985	MIPS	MIPS	First commercial RISC machine
1987	SPARC	Sun	First SPARC-based RISC workstation
1990	RS6000	IBM	First superscalar machine
1992	Alpha	DEC	First 64-bit personal computer
1993	Newton	Apple	First palmtop computer

Evolution of the Computer:

Mainframes, Minis, Supercomputers, Workstations, and PCs (the Killer Micros)

Moore's LAW



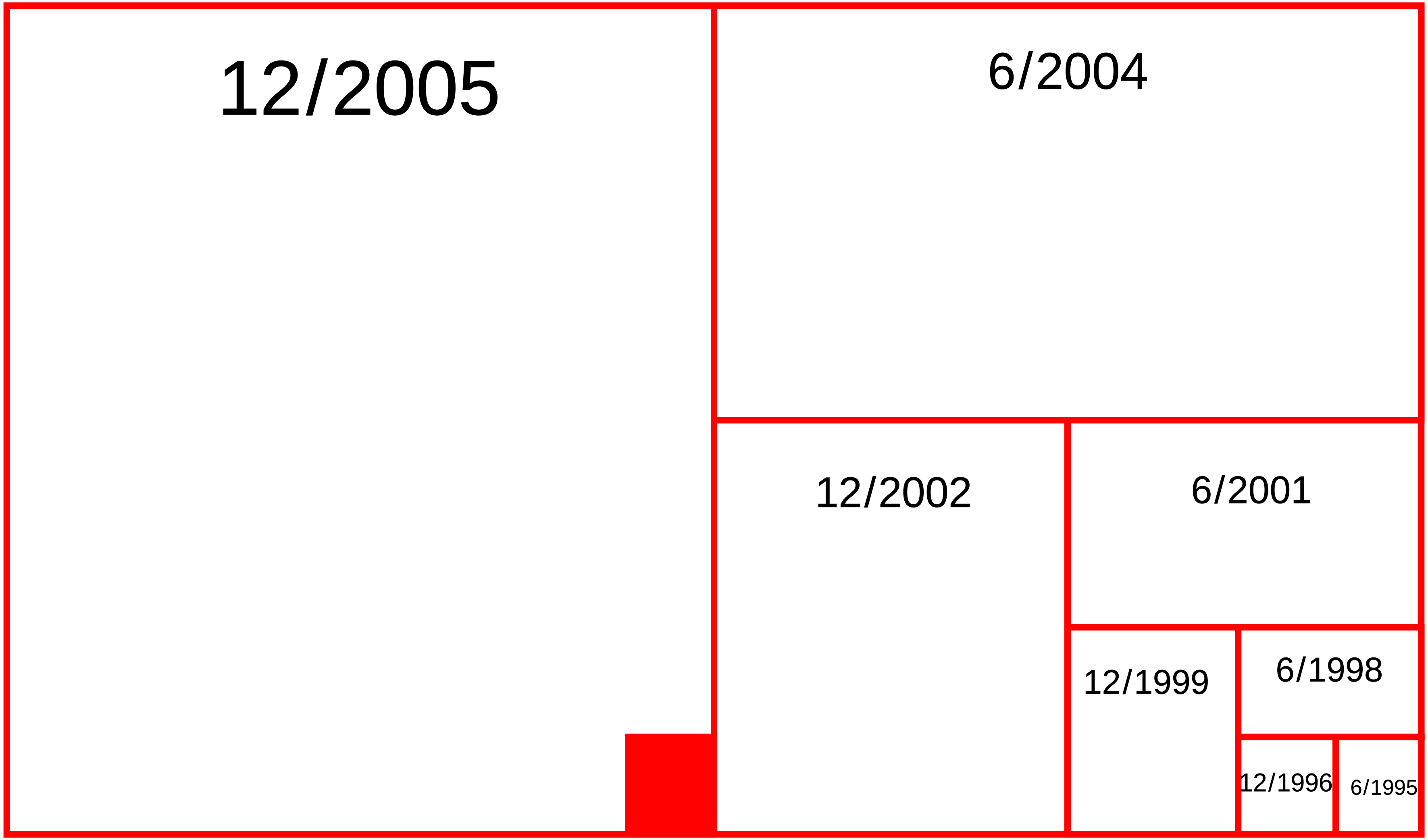
Moore said: every chip generation (3 years) # transistors double

Law: transistor # doubles every 18 months!

More on Moore's Law

- Corollary 1: speed of circuits (clock frequency, MHz or GHz) doubles every 18 months. Smaller transistors are also faster!
- Corollary 2: Performance doubles every 18 months!
  - BUT: ARCHITECTURE translates the increase in transistors to an increase in performance
    - Examples: add vs. memory access
    - Instructions per cycle: MAJOR ARCH. Contribution to Perf.
- Exponential increase in performance with every generation: What does it mean?

“Computing power” as area: what part of a 2005 processor corresponds to a 1995 processor?



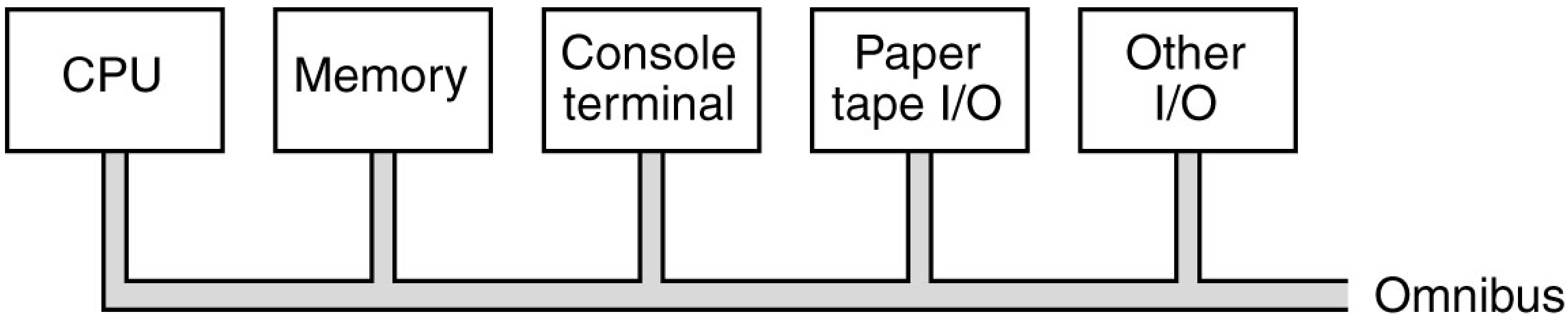
Is Moore's Law Still Alive?

- YES! Transistors will double for the next few generations: 65nano, 45, 32, 22, 16nano
  - Beyond that: transistors as we know them now don't work ➔ need new devices!!
- But FREQUENCY (speed) has stalled ~4GHz
- Power Consumption:
  - Power Density in chips would reach the surface of the sun if we continued
- Single-core (processor) performance also stalled
- Architectural implication: shift to MULTICORES ➔ use all these transistors for parallel performance

Some Important Computers

- DEC PDP-8
  - PDP-11
- VAX-11 the king of the minis
- IBM 360 the Mainframe
- The supercomputers: CDC 6600, CRAY-1
- The microprocessors: Intel 8086 …
- The RISCs: MIPS, SPARC, ALPHA, …
- Pentium 4, Core-2, …
- EXCELLENT resources on the Web for the history of these computers, especially wikipedia has great articles for all these

PDP-8 Innovation – Single Bus



The PDP-8 omnibus

- Primitive machine: 8 basic instructions! 4K to 32K word memory (12-bit words)

VAX-11

- VAX-11: Virtual Address eXtension to pdp 11
- Extremely popular university computer
  - Modern computer science developed on it
- One of the most complex machine instruction sets ever!
  - An Instruction could be a whole loop!
  - Studies showed that compilers could not use all these instructions …
- The nominal 1-MIPS machine
- BSD Unix, TCP/IP, …, took off on this machine

IBM 360

Property	Model 30	Model 40	Model 50	Model 65
Relative performance	1	3.5	10	21
Cycle time (in billionths of a sec)	1000	625	500	250
Maximum memory (bytes)	65,536	262,144	262,144	524,288
Bytes fetched per cycle	1	2	4	16
Maximum number of data channels	3	3	4	6

- Before 360: architecture == implementation
- 360 (Gene Amdahl): architecture independent of implementation!
- One ISA, multiple instantiations
- SAME Software runs on ALL! (Radical development)
- Backwards compatibility: crucial for an architecture
  - Intel
  - Apple !!!! Motorola 68000 ➔ PowerPC ➔ Intel and ALWAYS maintained software compatibility.
- IBM 360 also run (emulated) IBM 1401 and 7094

Supercomputers

- 1^{st} Supercomputer: CDC 6600 (Seymour Cray)
  - Could perform more than one instruction at the same time! (Superscalar -- Scoreboard)
  - Pipelined
  - Very fast cycle time
  - 10 Peripheral processors for I/O
  - No ECC or parity in memory
    - Correct answer?
- CRAY-1
  - First VECTOR supercomputer
  - Instructions could operate directly on vectors:
    - A[i] = B[i] + C[i], i=0,128

The dawn of the micros (mid 70's)

- Intel: 8051, 8080
- Motorola 6800
- Zilog Z80
- MOS 6502
- 8-bit micros, 8-bit words, 64K memory
- Invariably microprogrammed architectures running at about 1 – 2 MHz
- 80's: 16-bit micros: Intel 8086/8088, Motorola 68000
  - Up to 1 MB memory in 8086 via Segmentation
  - 16 MB in MC 68000
  - Precursors of the CISCs: 80386,486,Pentium,Pro,II,III,4,Core-2

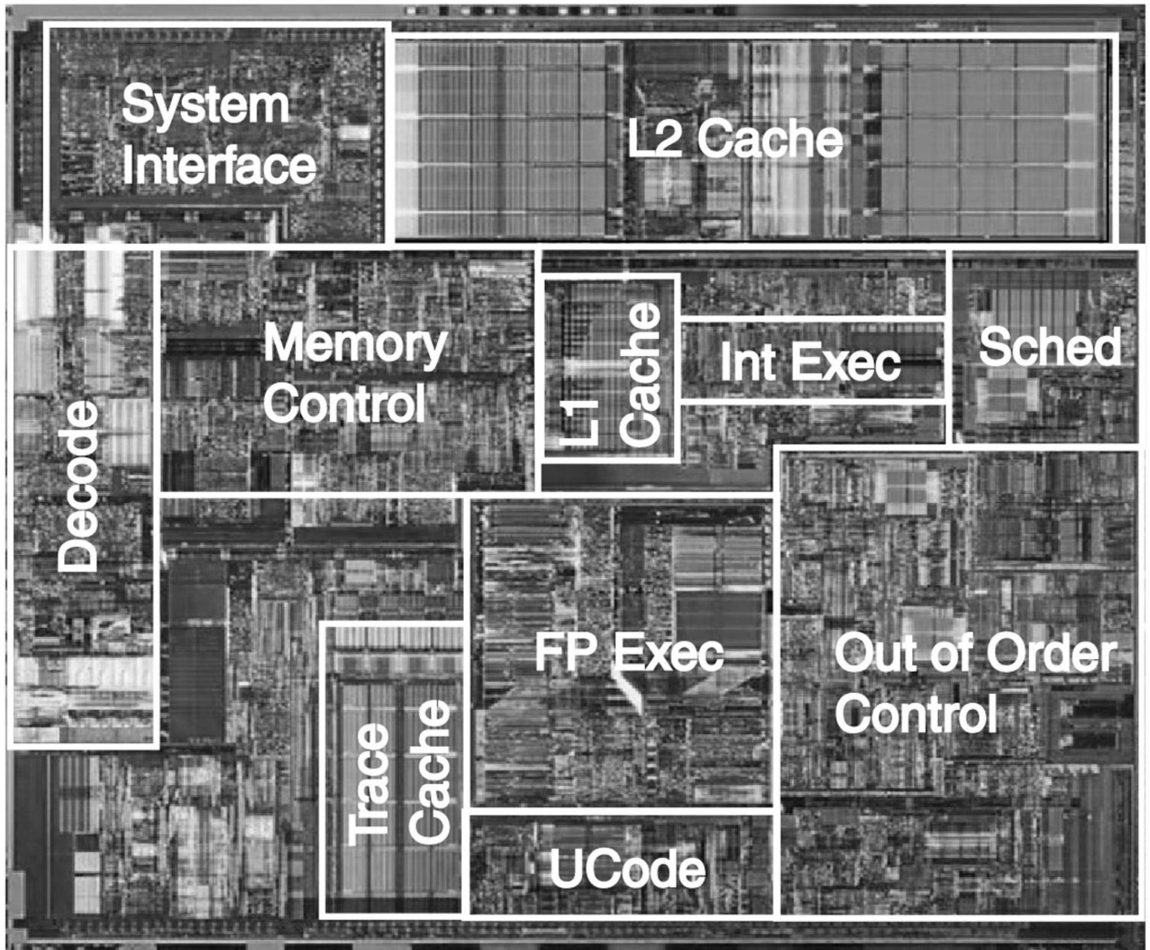
RISCs

- Introduced the concept of smaller (ISA) is better
- RISC: Reduced Instruction Set Computers
  - No microcore, all hardware, pipelined, many registers, very simple instructions
- Pioneered by:
  - Berkeley (Patterson) ➔ SPARC (SUN)
  - Stanford (Hennessy) ➔ MIPS (MIPS)
  - First RISC IBM 801,
  - First commercial RISC: ARM
- Others: HP PA-RISC, DEC ALPHA, IBM/Motorola PowerPC, IBM Power, …

Intel Computer Family (1)

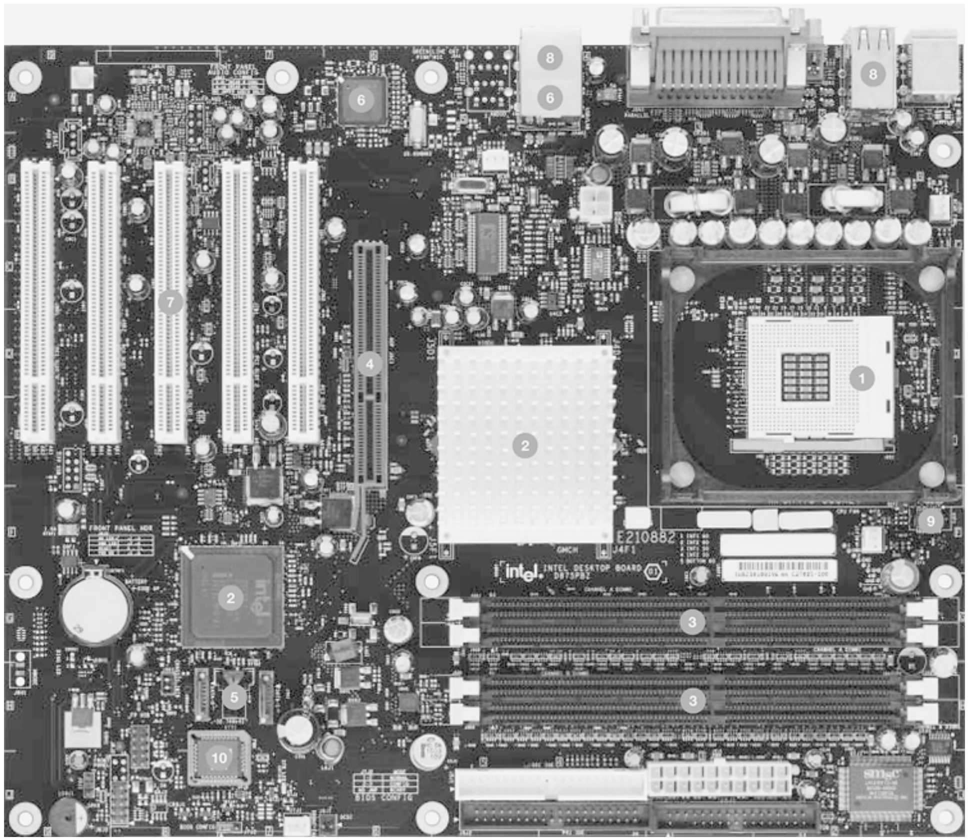
Chip	Date	MHz	Transistors	Memory	Notes
4004	4/1971	0.108	2300	640	First microprocessor on a chip
8008	4/1972	0.108	3500	16 KB	First 8-bit microprocessor
8080	4/1974	2	6000	64 KB	First general-purpose CPU on a chip
8086	6/1978	5–10	29,000	1 MB	First 16-bit CPU on a chip
8088	6/1979	5–8	29,000	1 MB	Used in IBM PC
80286	2/1982	8–12	134,000	16 MB	Memory protection present
80386	10/1985	16–33	275,000	4 GB	First 32-bit CPU
80486	4/1989	25–100	1.2M	4 GB	Built-in 8-KB cache memory
Pentium	3/1993	60–233	3.1M	4 GB	Two pipelines; later models had MMX
Pentium Pro	3/1995	150–200	5.5M	4 GB	Two levels of cache built in
Pentium II	5/1997	233–450	7.5M	4 GB	Pentium Pro plus MMX instructions
Pentium III	2/1999	650–1400	9.5M	4 GB	SSE Instructions for 3D graphics
Pentium 4	11/2000	1300–3800	42M	4 GB	Hyperthreading; more SSE instructions

Intel Computer Family (2)



The Pentium 4 chip. The photograph is copyrighted by the Intel Corporation, 2003 and is used by permission.

Personal Computer



1. Pentium 4 socket
2. 875P Support chip
3. Memory sockets
4. AGP connector
5. Disk interface
6. Gigabit Ethernet
7. Five PCI slots
8. USB 2.0 ports
9. Cooling technology
10. BIOS

A printed circuit board is at the heart of every personal computer. This figure is a photograph of the Intel D875PBZ board. The photograph is copyrighted by the Intel Corporation, 2003 and is used by permission.

The Computer Spectrum

Type	Price ($)	Example application
Disposable computer	0.5	Greeting cards
Microcontroller	5	Watches, cars, appliances
Game computer	50	Home video games
Personal computer	500	Desktop or notebook computer
Server	5K	Network server
Collection of Workstations	50–500K	Departmental minisupercomputer
Mainframe	5M	Batch data processing in a bank

The current spectrum of computers available. The prices should be taken with a grain (or better yet, a metric ton) of salt.

Example Computer Families in the Book

- Pentium 4 by Intel
- UltraSPARC III by Sun Microsystems
- The 8051 chip by Intel, used for embedded systems

- READ THEM for next class, to answer Qs