Computer System Design

Instructor: Saraju P Mohanty

Text: "Logic and Computer Design Fundamentals", 3rd Edition, by M. M. Mano and C. R. Kime,

Prentice Hall

Note

The course material presented by the instructor is mainly based on the text and the reference books.

All figures are the book authors' property, provided in the course companion information available through their respective web sites.

Course Summary

The course covers logic circuits and design; combinatorial design; sequential circuits; registers and counters; programmable logic devices; registers; sequencing and control; instruction set architecture (and introduction to RISC); CPU design; I/O and memory systems; timing.

Course Homepage
http://www.csee.usf.edu/~smohanty/teaching/ComputerSystemDesignFall2003/

Digital computer is the best example of a digital system.

Lecture Outline

- Historical development of computers
- Introduction to a basic digital computer
- Software / Hardware Hierarchy in a computer
- Five classic components of a computer
- Microprocessor
- IC design abstraction level
- Intel processor family
- Developmental trends of ICs

What is a digital Computer ?

A fast electronic machine that accepts digitized input information, processes it according to a list of internally stored instruction, and produces the resulting output information.

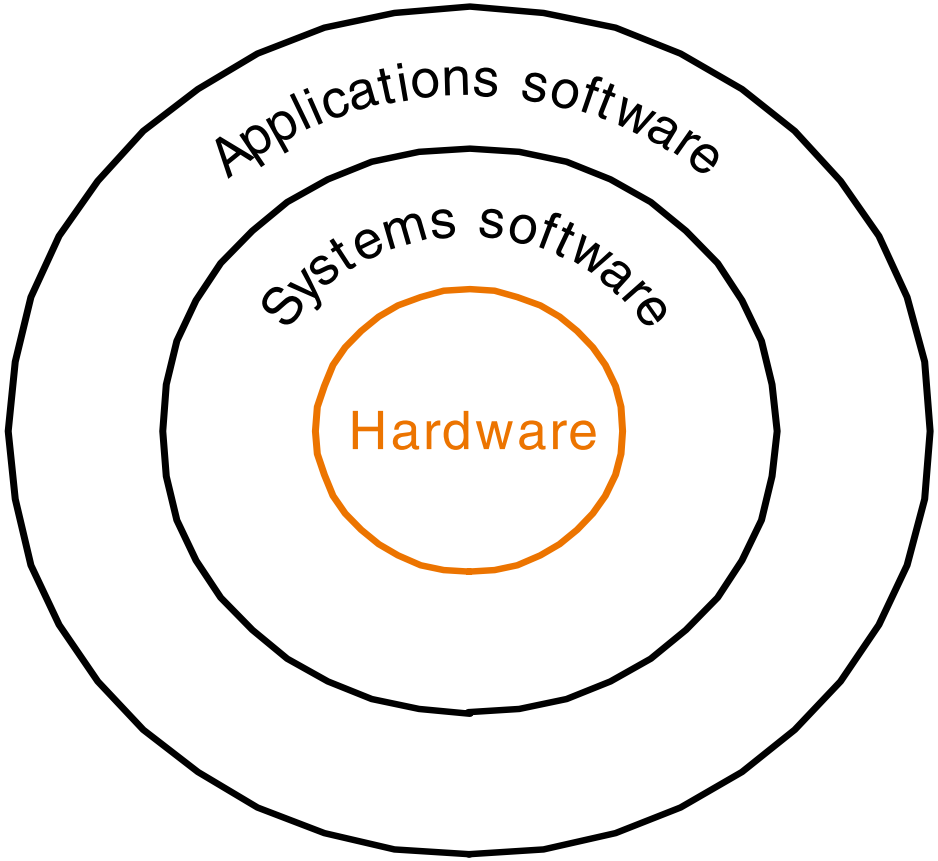
List of instructions → Computer program

Internal storage → Memory

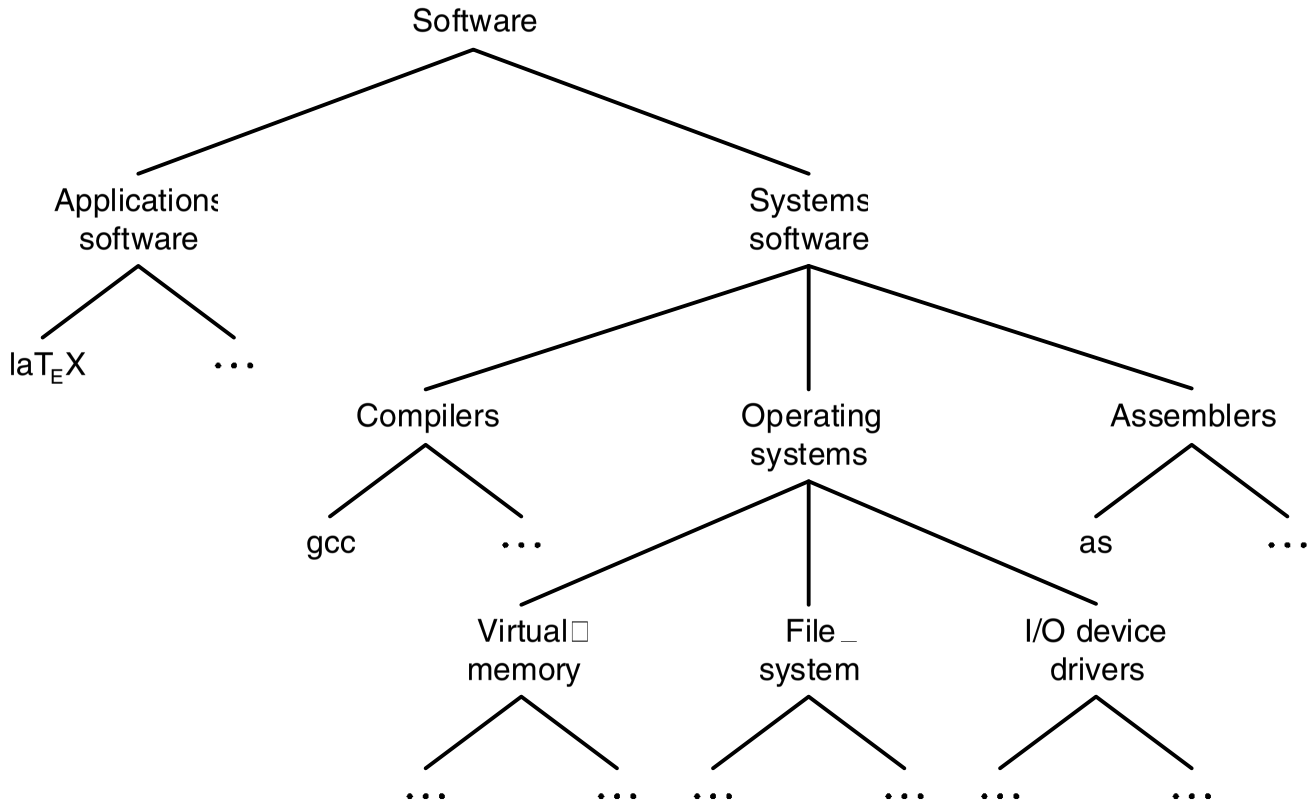
Different Types and Forms of Computer

- Personal Computers (Desktop PCs)
- Notebook computers (Laptop computers)
- Handheld PCs
- Pocket PCs
- Simputers (Simple + Computer) [Handheld with Linux]
- Workstations (SGI, HP, IBM, SUN)
- ATM (Embedded systems)
- Supercomputers

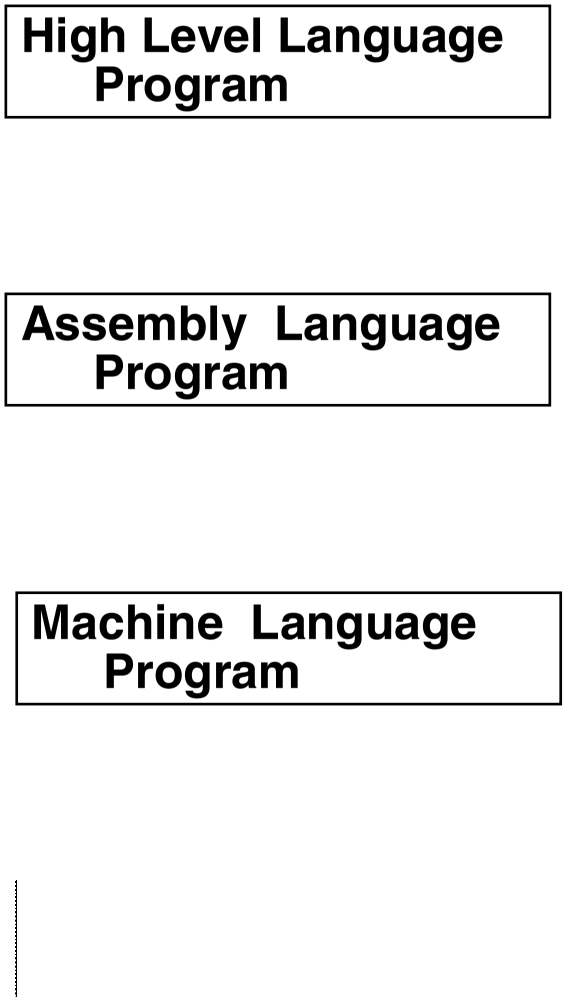
Software-Hardware Hierarchy in a Digital Computer



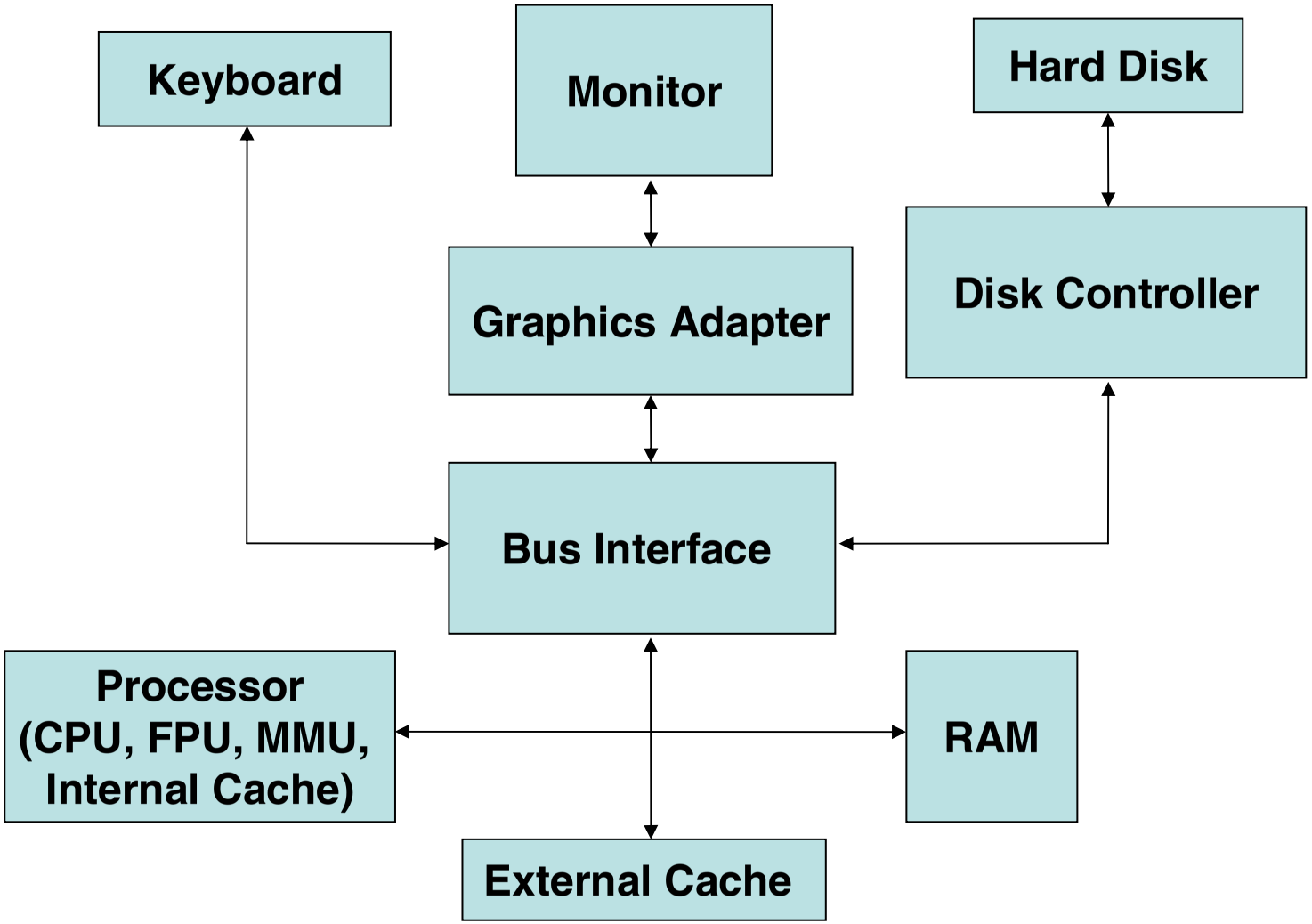
Digital Computer : Software Types



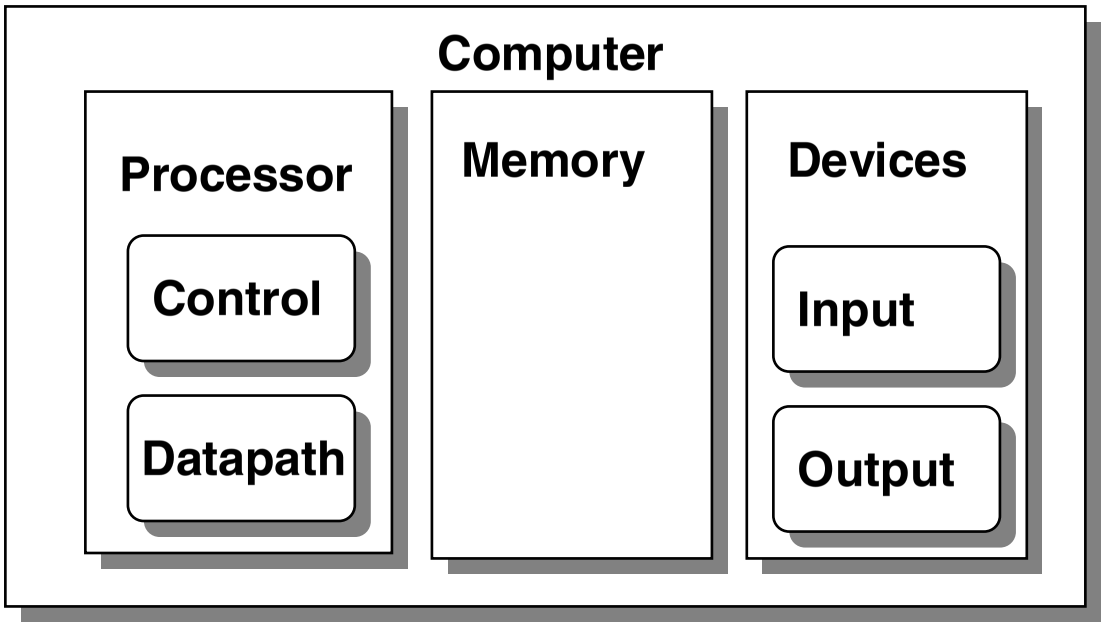
Digital Computer : Program Execution Flow



A Personal Computer System : Hardware



Five classic components of a Computer



(1) Input, (2) Output, (3) Datapath, (4) Controller, and (5) Memory

History of Computers

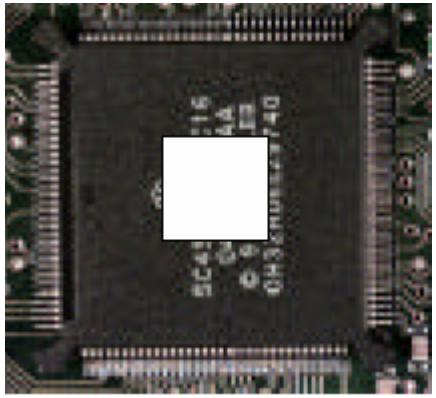
Year	Name	Made by	Comments
1834	Analytical Engine	Babbage	First attempt to build a digital computer
1936	Z1	Zuse	First working relay calculating machine
1943	COLOSSUS	British gov't	First electronic computer
1944	Mark I	Aiken	First American general-purpose computer
1946	ENIAC I	Eckert/Mauchley	Modern 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
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
1964	6600	CDC	First scientific supercomputer
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
1985	MIPS	MIPS	First commercial RISC machine
1987	SPARC	Sun	First SPARC-based RISC workstation
1990	RS6000	IBM	First superscalar machine

What is a microprocessor ?

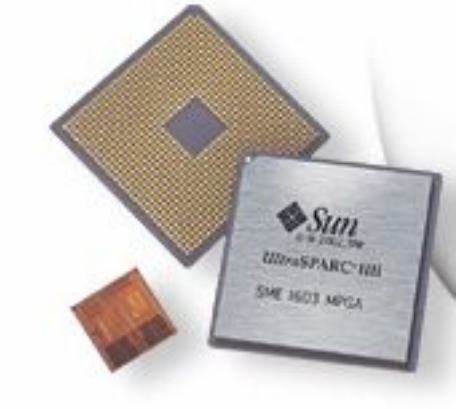
- A microprocessor is an integrated circuit (IC) built on a tiny piece of silicon. It contains thousands, or even millions, of transistors, which are interconnected via superfine traces of aluminum. The transistors work together to store and manipulate data so that the microprocessor can perform a wide variety of useful functions. The particular functions a microprocessor performs are dictated by software. (source : Intel)
- Simply speaking, microprocessor is the CPU on a single chip. CPU stands for "central processing unit" also known as processor.
- Processor can be "general purpose" or "special purpose". A special purpose processor is also known as "application specific integrated circuit" (ASIC).

The terms have become more or less fuzzy at present.

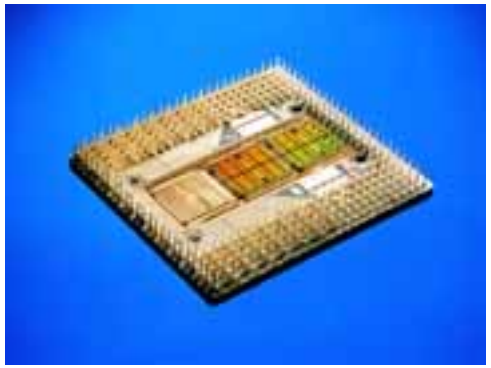
How does a microprocessor look like ?



(1) ASIC

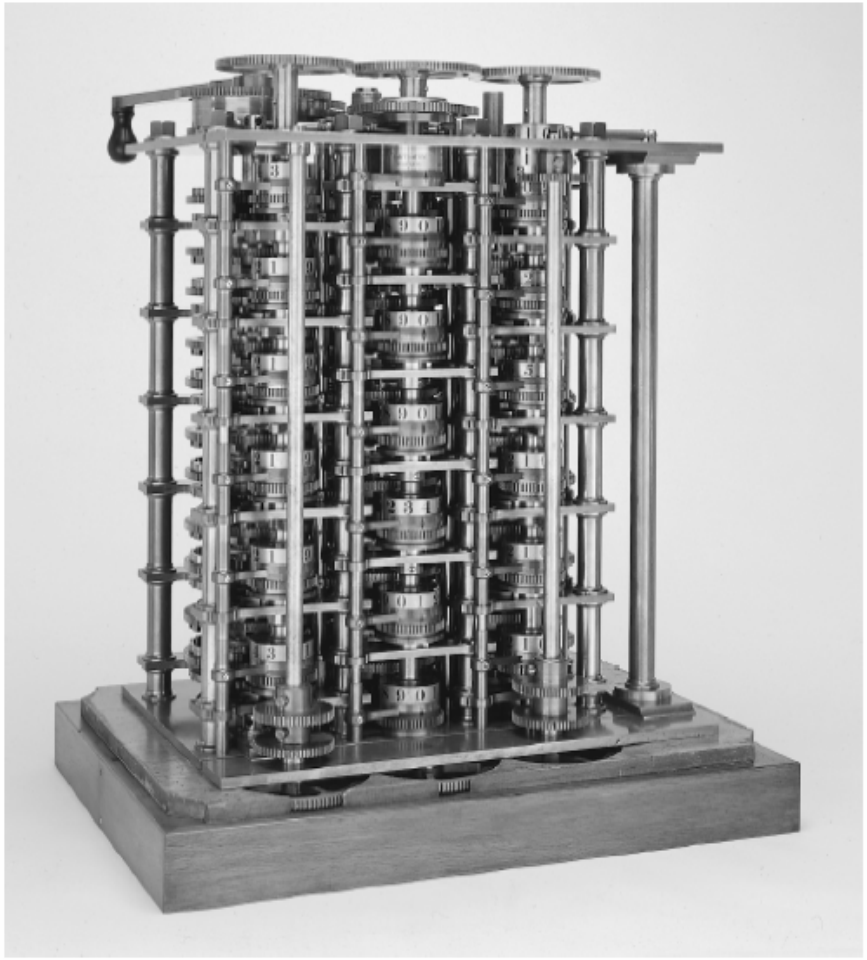


(2) Sun UltraSparc

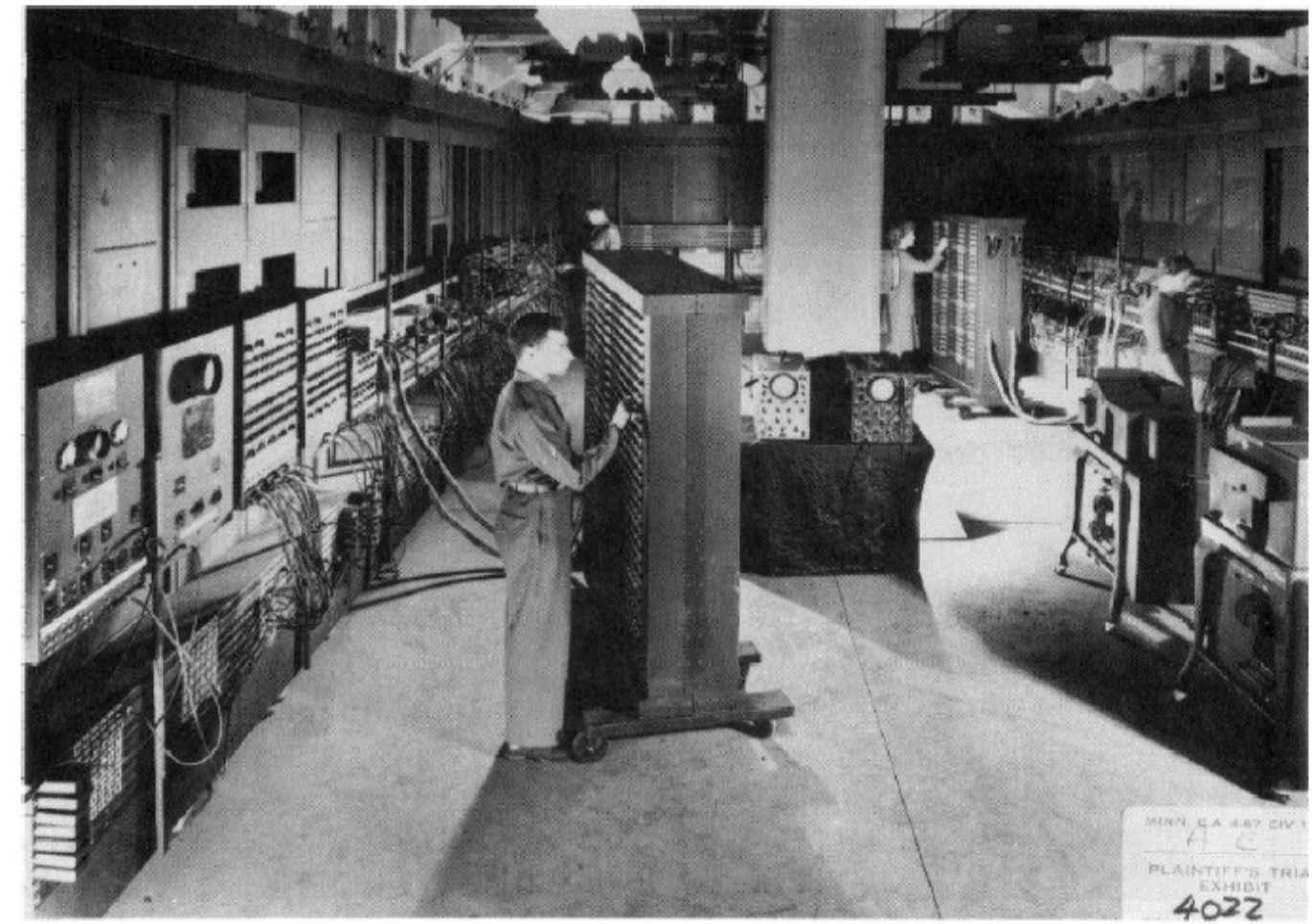


(3) PentiumPro

The Babbage Difference Machine in 1832



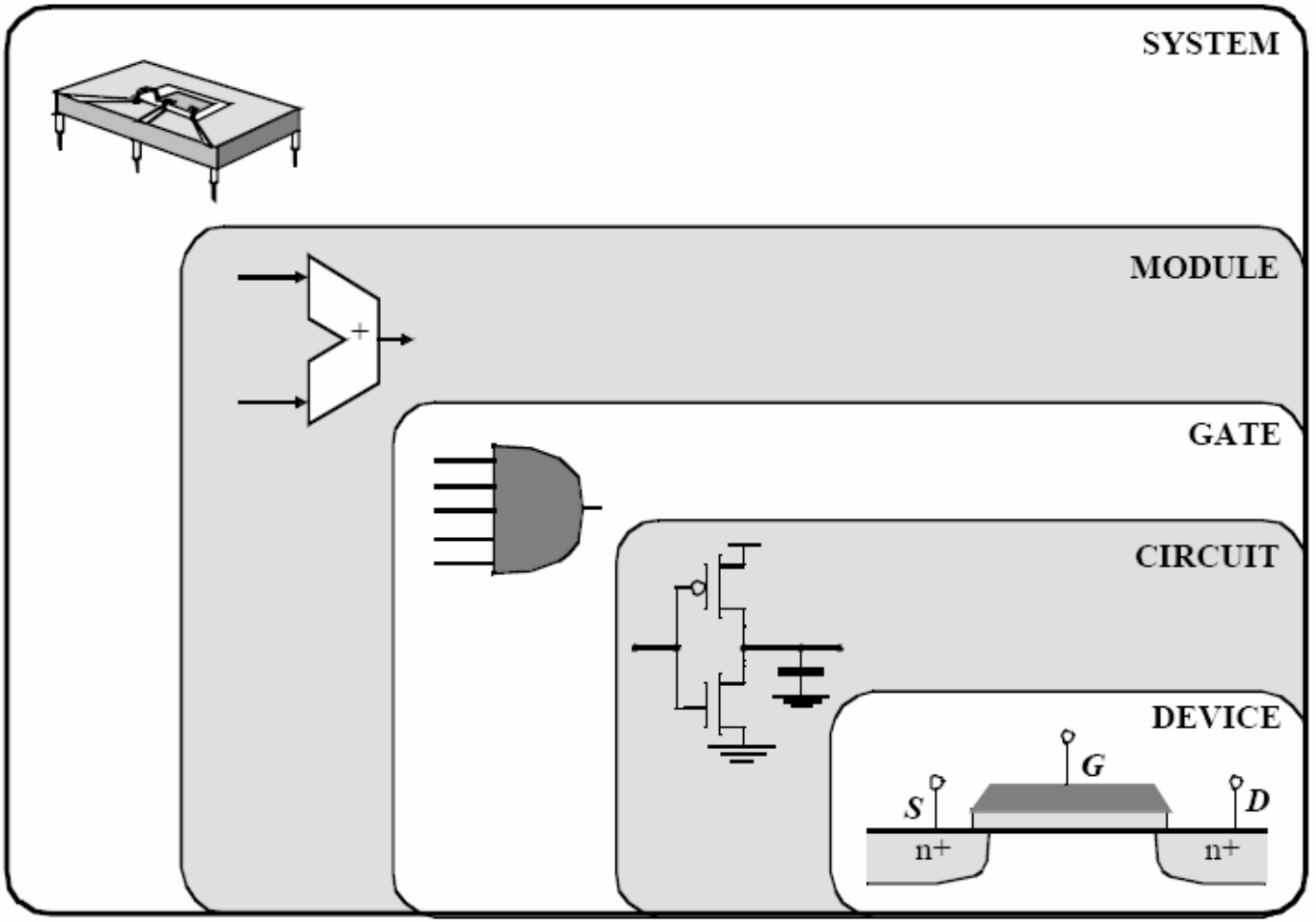
The First Electronic Computer in 1946 (ENIAC)



The Intel CPU family

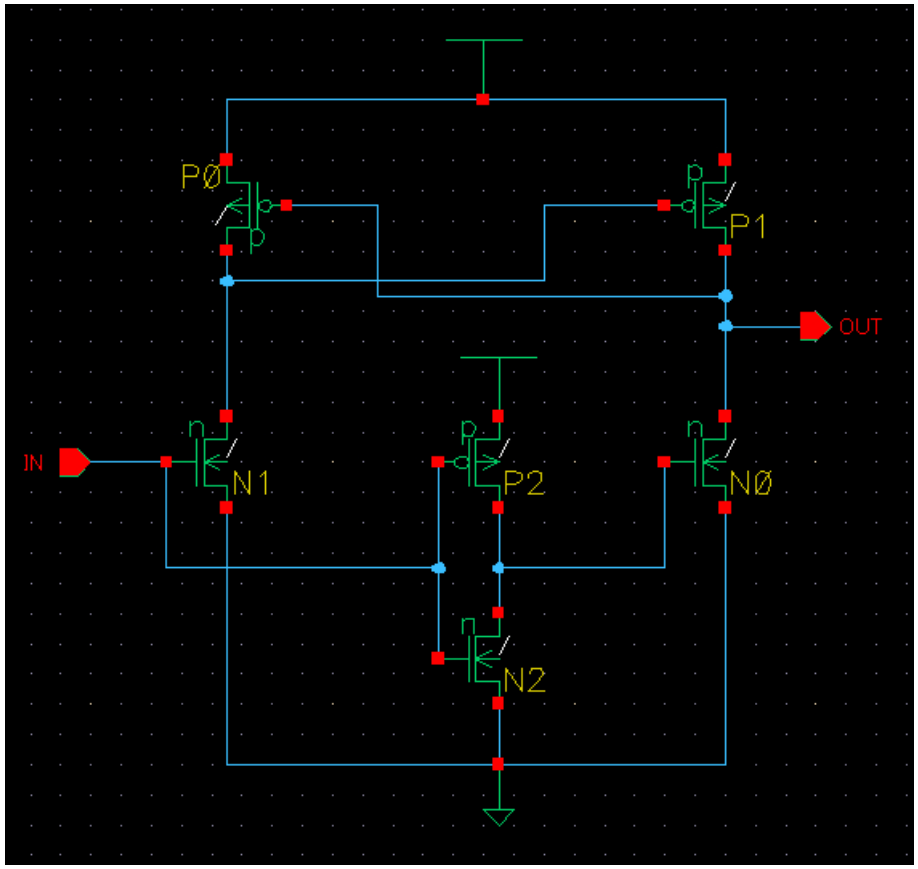
Chip	Date	MHz	Transistors	Notes
4004	4/1971	0.108	2,300	First microprocessor on a chip
8008	4/1972	0.108	3,500	First 8-bit microprocessor
8080	4/1974	2	6,000	First general-purpose CPU on a chip
8086	6/1978	5-10	29,000	First 16-bit CPU on a chip
8088	6/1979	5-8	29,000	Used in IBM PC
80286	2/1982	8-12	134,000	Memory protection present
80386	10/1985	16-33	275,000	First 32-bit CPU
80486	4/1989	25-100	1.2M	Built-in 8K cache memory
Pentium	3/1993	60-233	3.1M	Two pipelines; later models had MMX
Pentium Pro	3/1995	150-200	5.5M	Two levels of cache built in
Pentium II	5/1997	233-400	7.5M	Pentium Pro plus MMX
Pentium III	1999	450-1400	28.1M	0.18 micron, 6-layer metal
Pentium IV	2000	1300-3200	42-55M	0.13 micron technology

Digital Circuits : Design Abstraction Levels

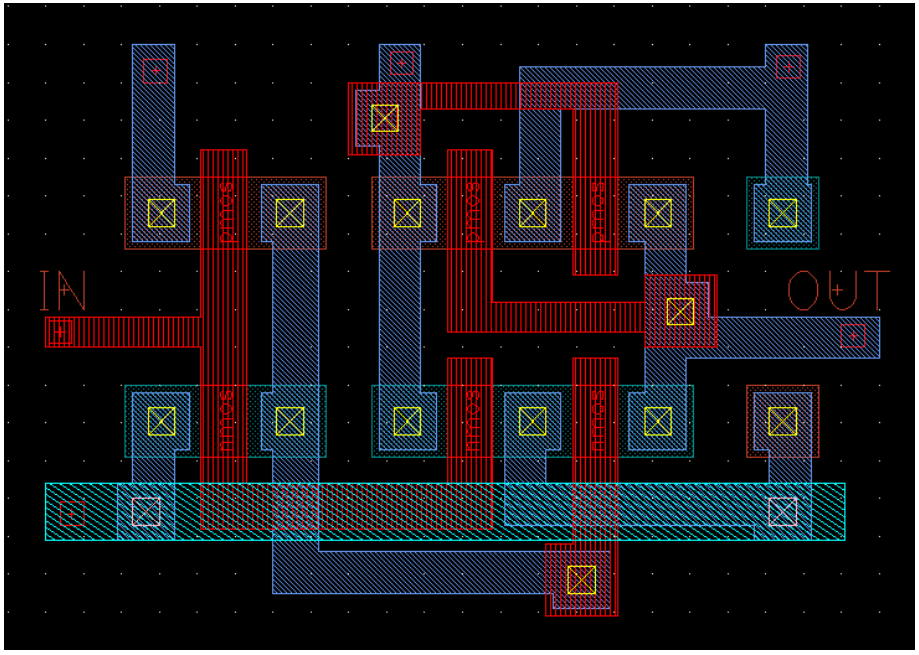


In this Course

Digital Circuits : Transistor Vs Device

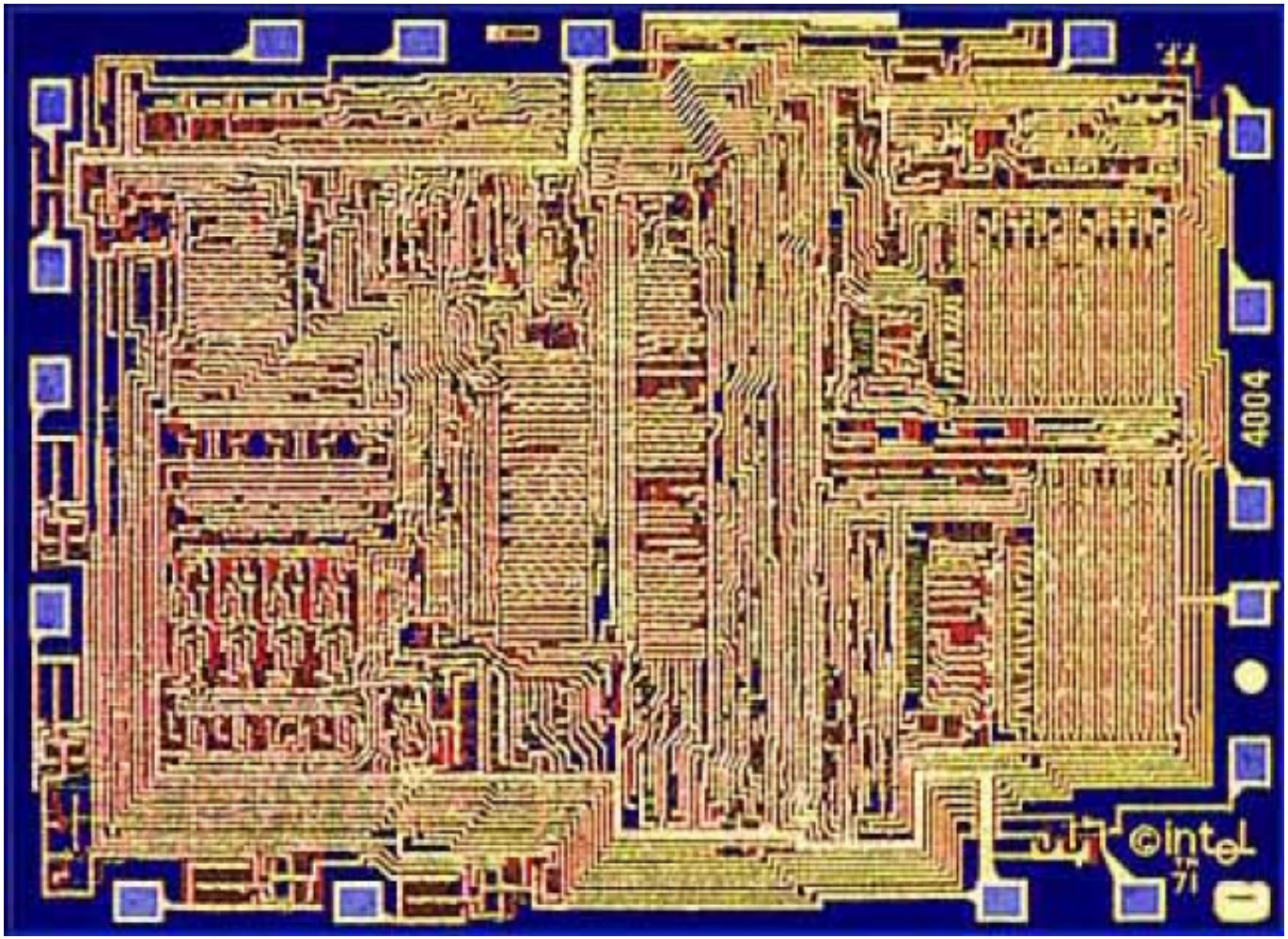


(Transistor Diagram)

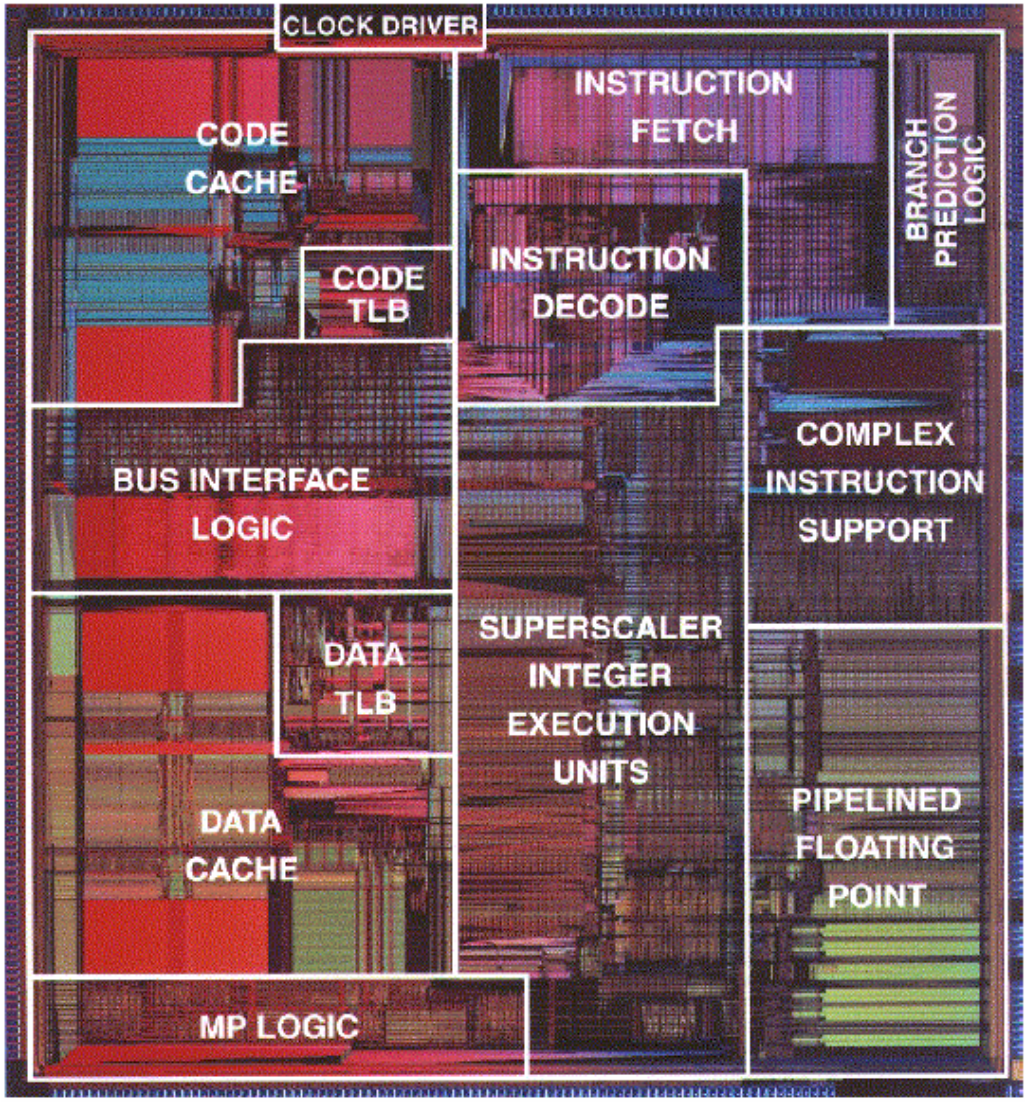


(Device Layout Diagram)

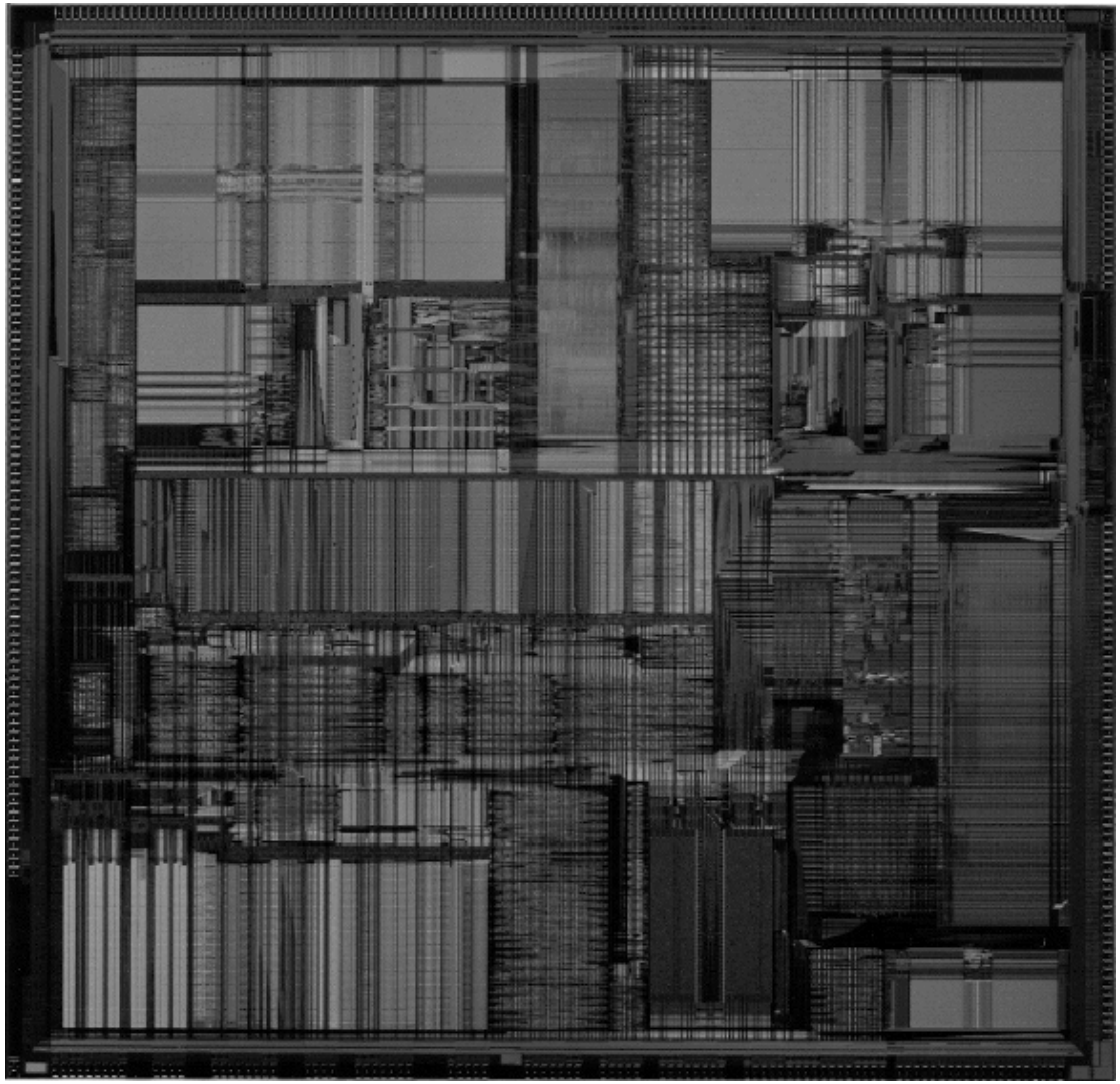
Intel 4004 : 2.3K Transistor (1971)



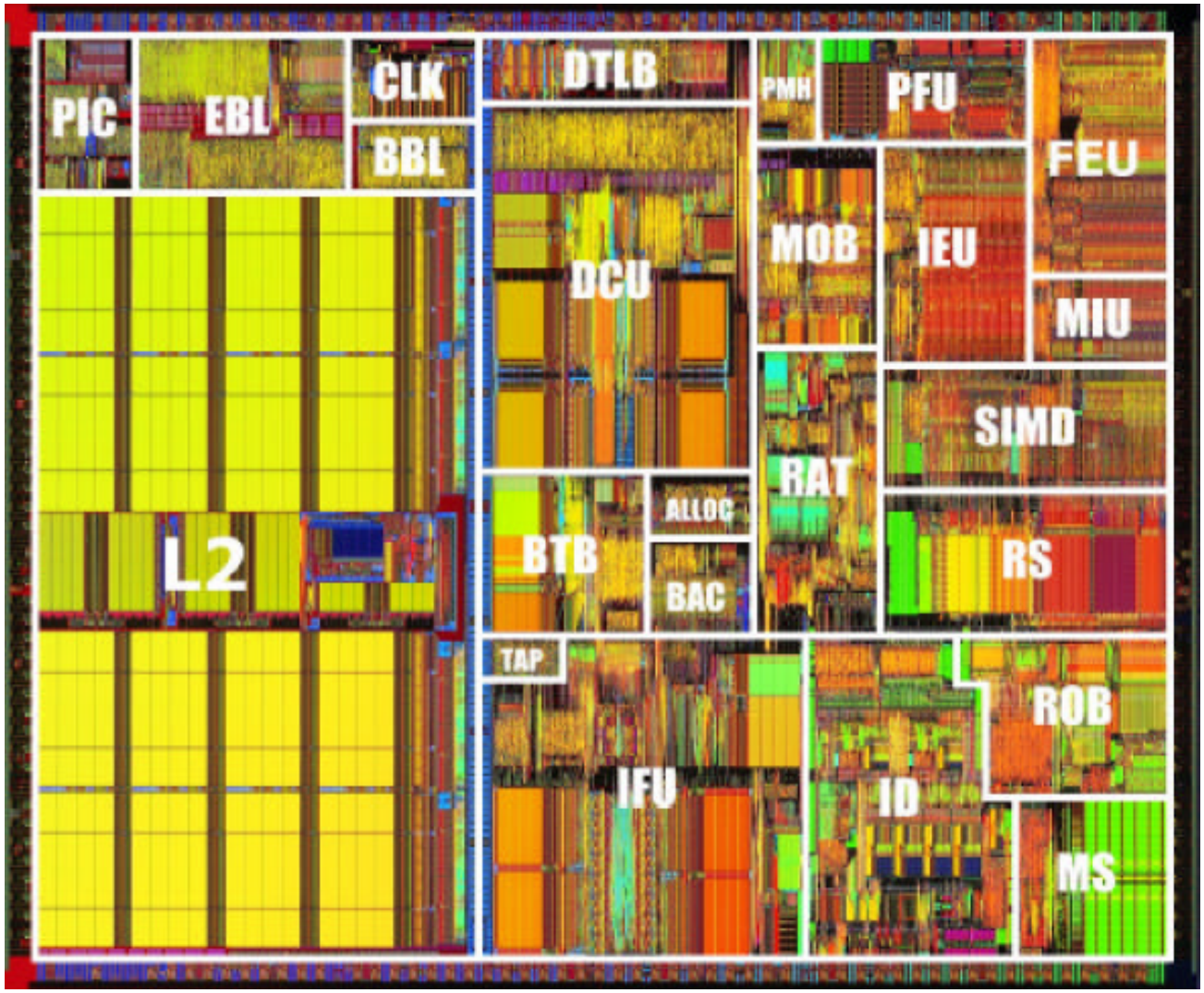
Pentium : 3.1 M Transistors (1993)



Pentium II : 7.5 M Transistors (1997)



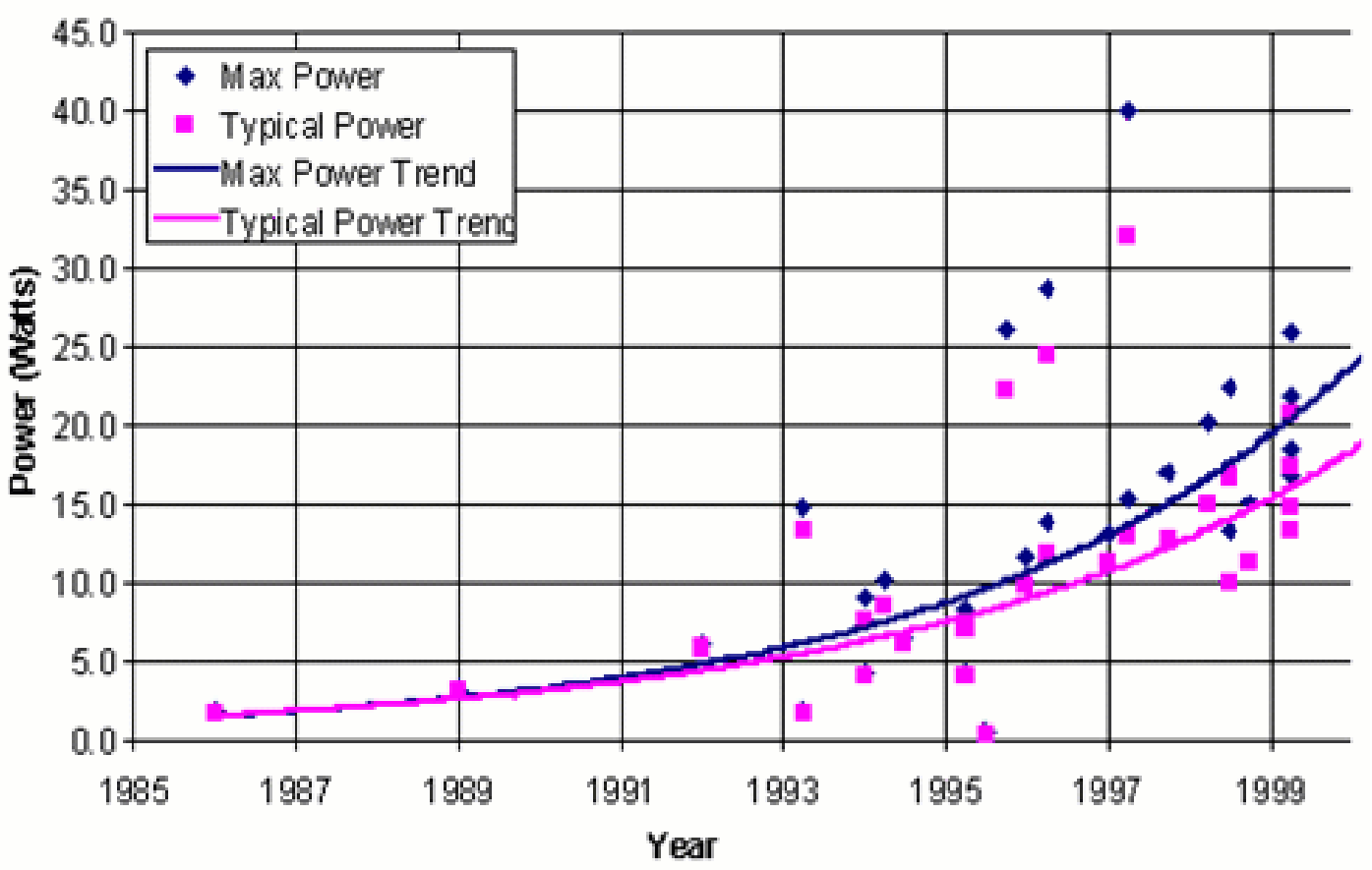
Pentium III : 28.1 M Transistors (1999)



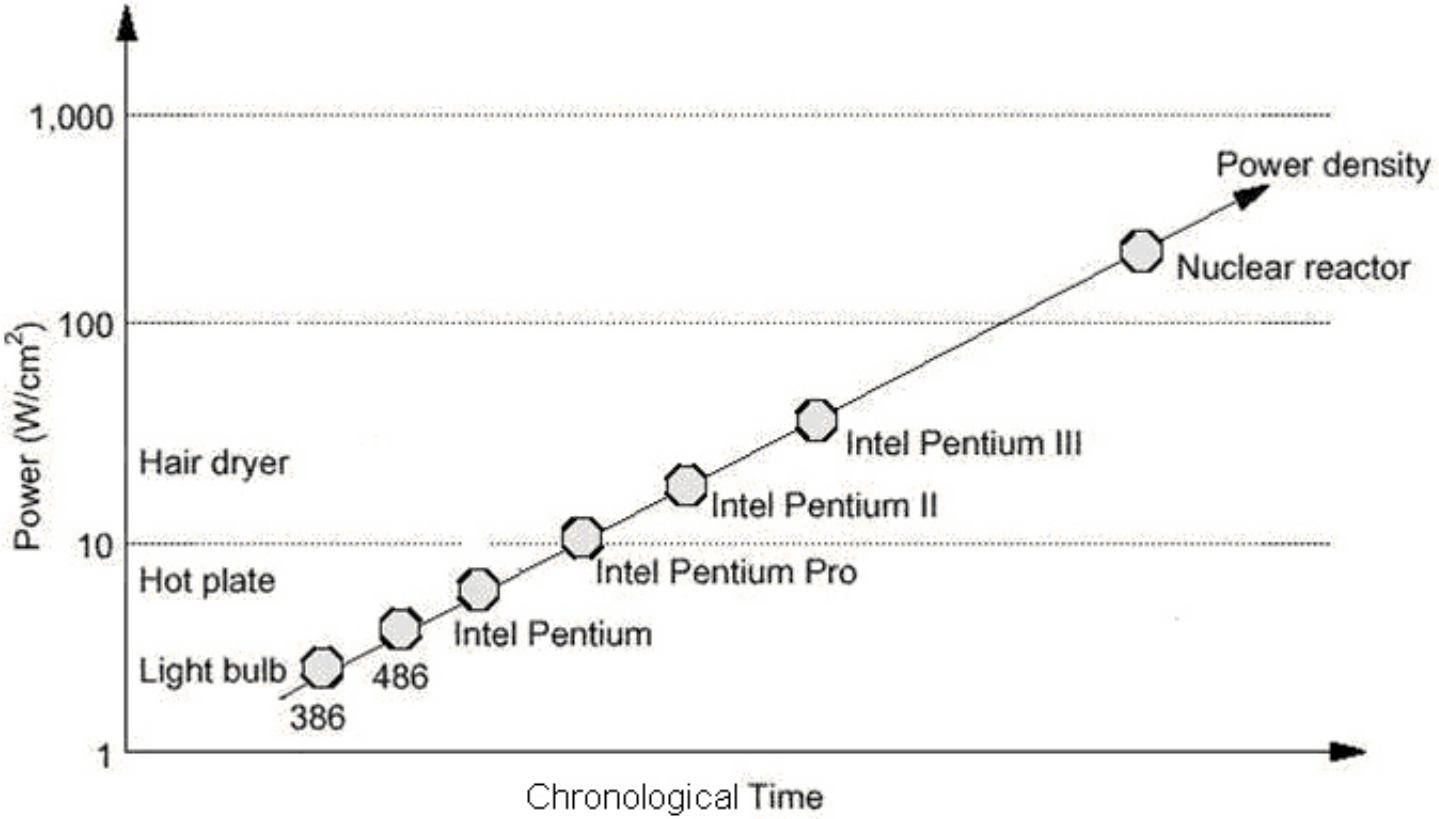
Microprocessor : Developmental Trends

- Power consumption of a chip
- Power density in a chip
- Gate count of a chip
- Transistor count of a chip
- Operating frequency of a chip
- Size of a device used in chip

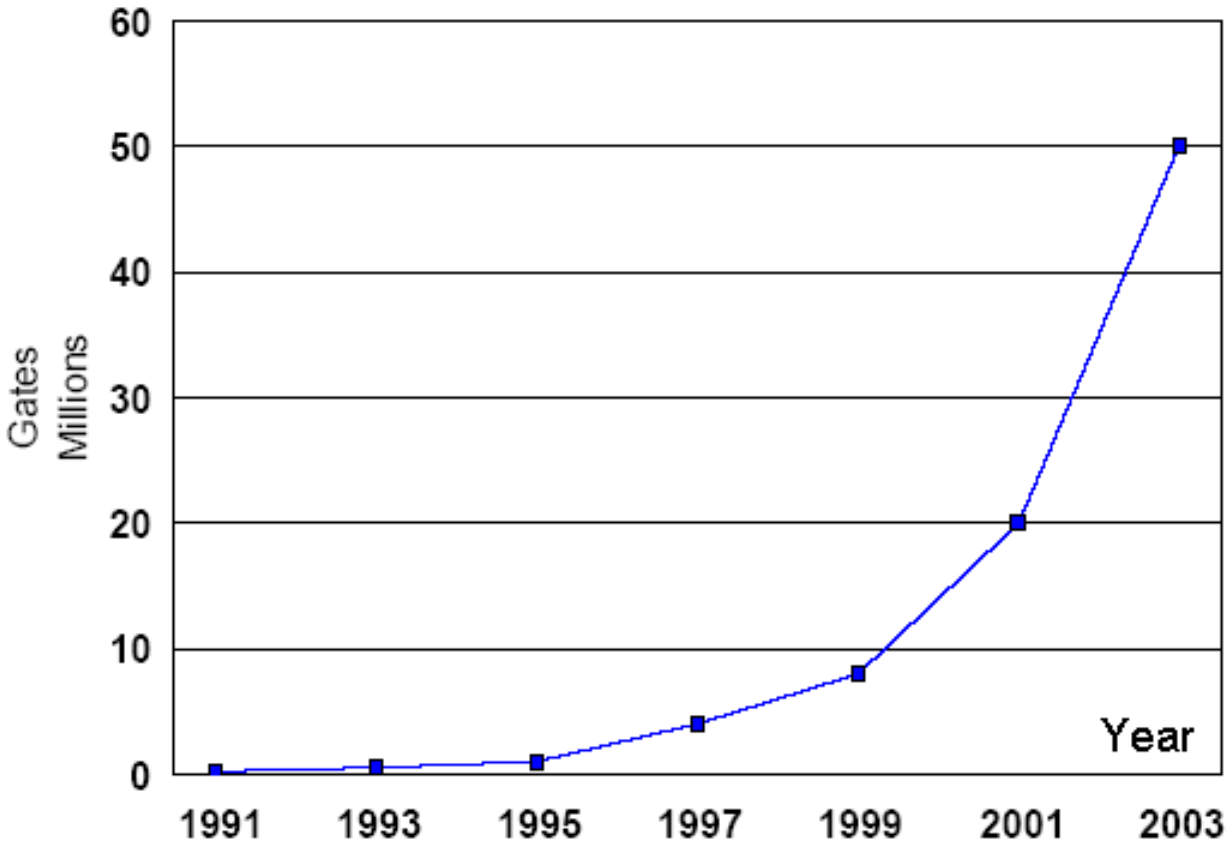
Increase in Power Consumption



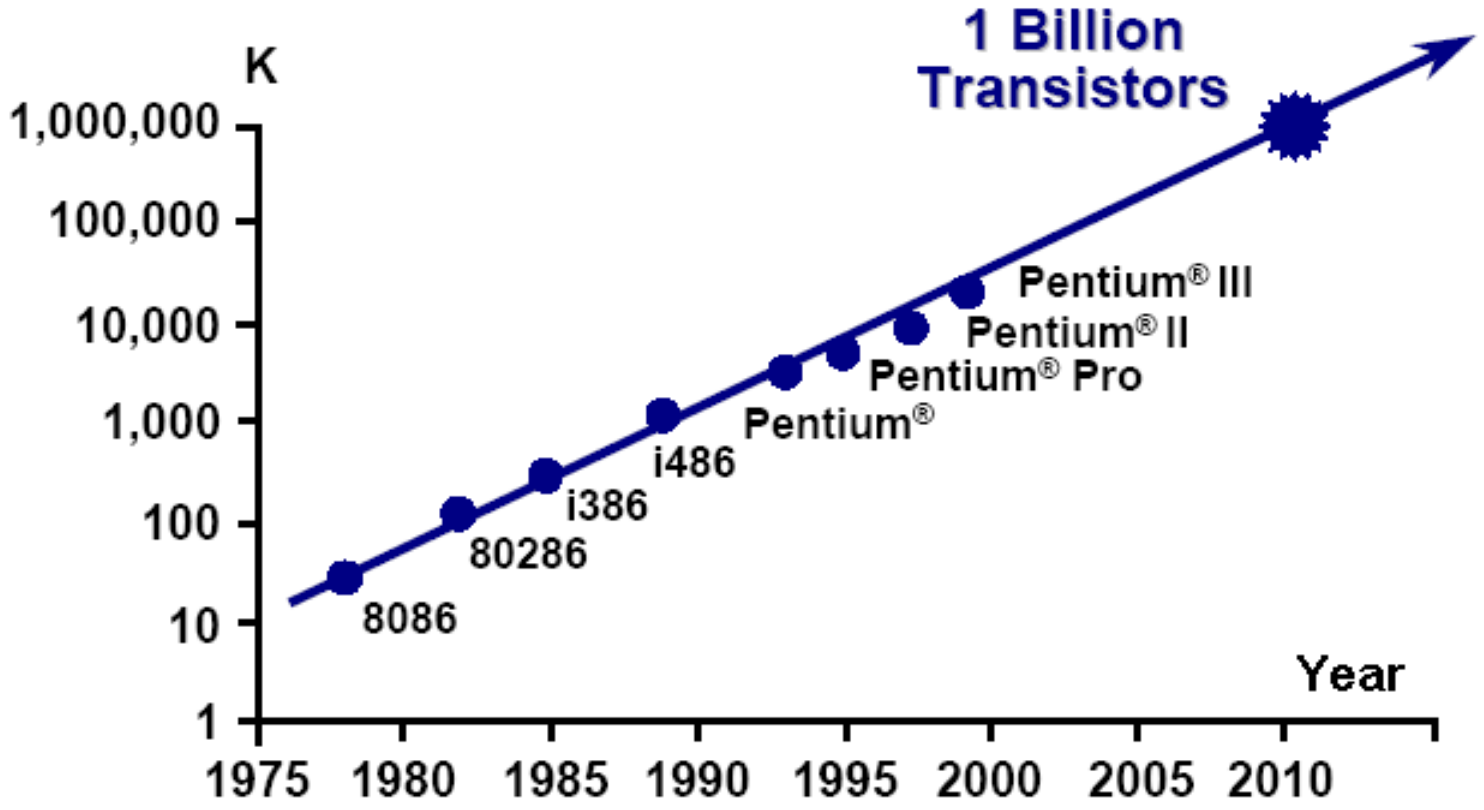
Increase in Power Density



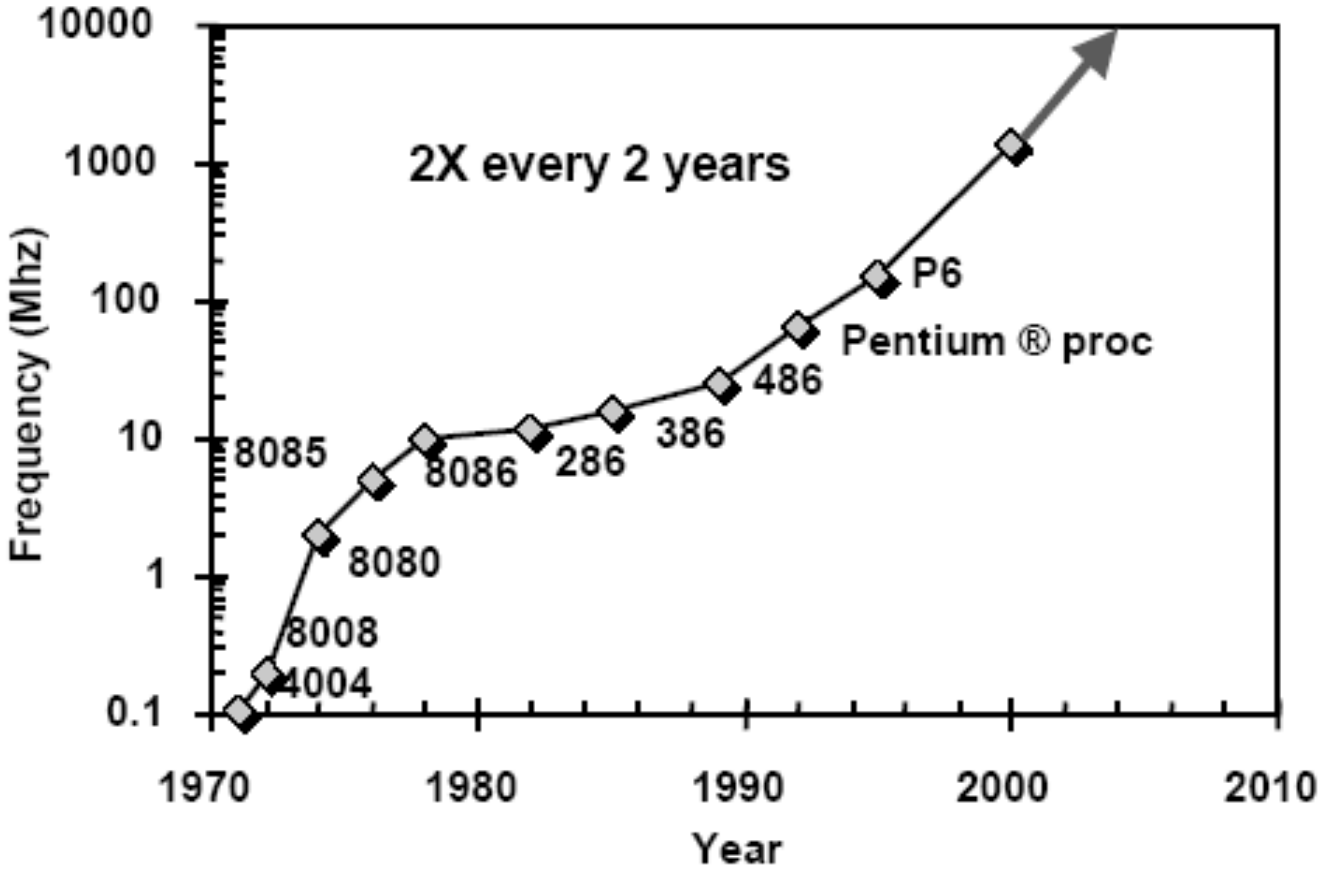
Increase in Gate Count



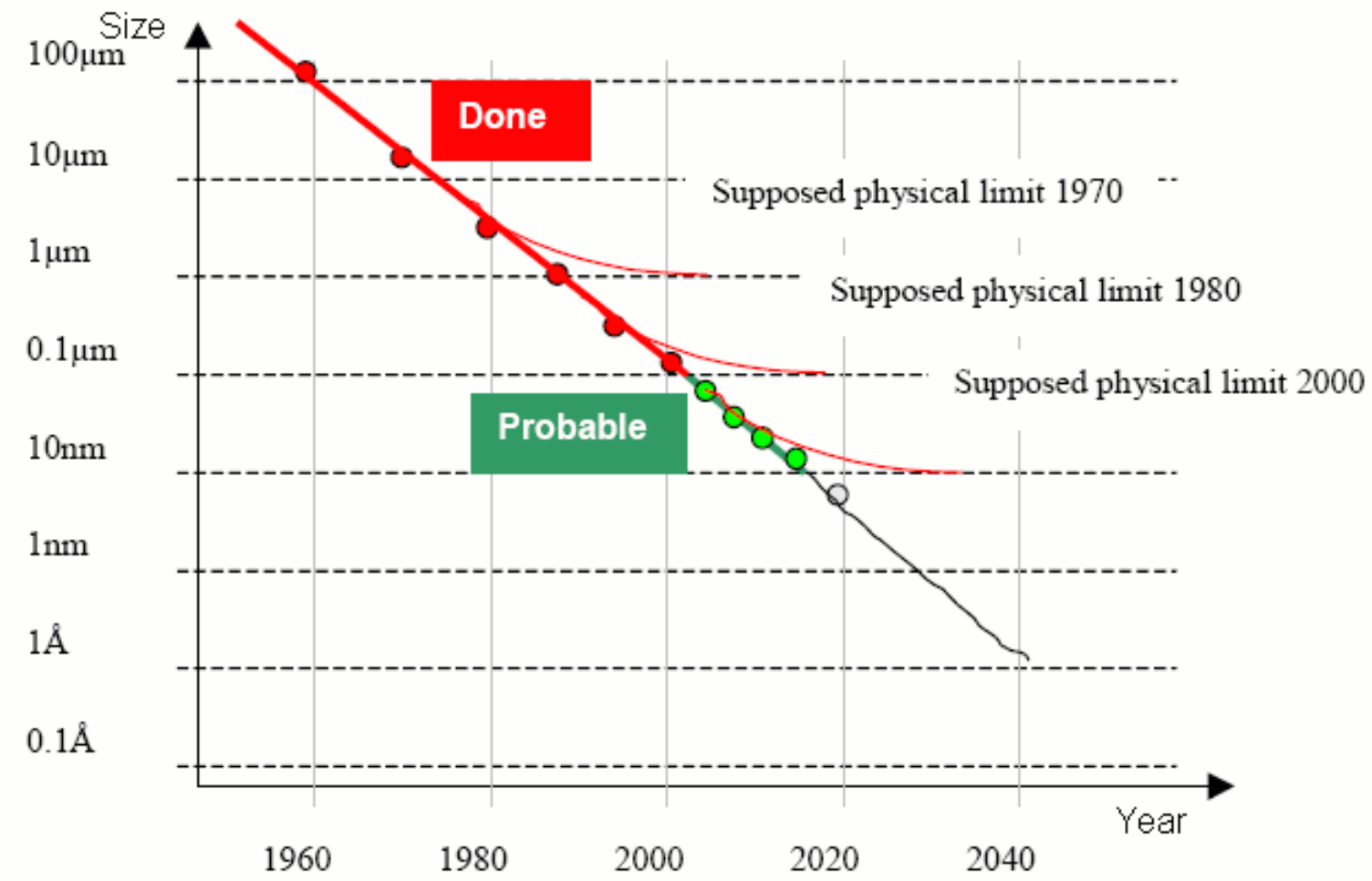
Increase in Transistor Count



Increase in Operating Frequency (Performance)



Decrease in Feature Size



Digital Systems : Information Representation

Digital system → manipulates *discrete elements of information* represented by physical quantities called signals (voltages, currents), mostly using two discrete values – binary signals. (HIGH – LOW, TRUE-FALSE, 1-0, positive / negative logic).

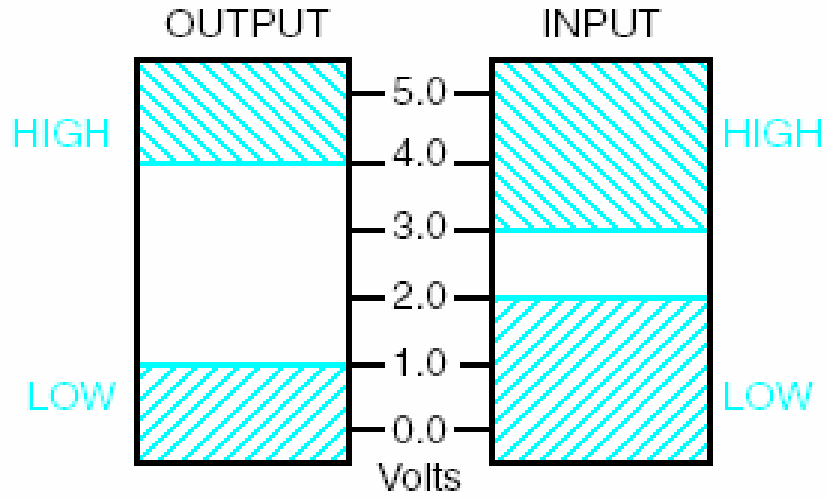


Fig. 1-1 An Example of Voltage Ranges for Binary Signals

Why is Binary Used ??

- It is easy to distinguish between two states: high or low voltage, presence or absence of electric charge or a switch in the on or off position of a transistor.
- To reduce cost of electronic circuits.
- High noise margin compared to the multi-valued logic circuits.

In this course …. ???

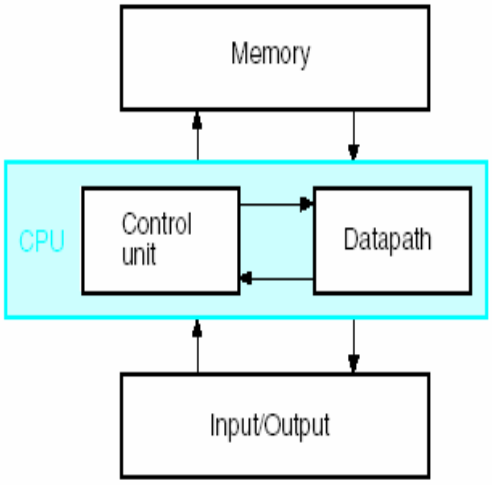


Fig. 1-2 Block Diagram of a Digital Computer

CPU = Control unit (supervises information flow between the units) + datapath (operations as specified by the program).

FPU = like the CPU except its datapath and control unit perform floating-point operations.

Memory = MMU + internal cache + external cache +RAM. (Internal / external cache allow the CPU/FPU to get at the data to be processed much faster than with the RAM alone.

I/O bus: keyboard, graphics adapter card, disk controller…all attached to the I/O bus.

Design of each of computer components at gate level.