Digital Design Concepts: A Broad Overview (Instructor: Saraju P. Mohanty)

- 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
- Moore's Law

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.

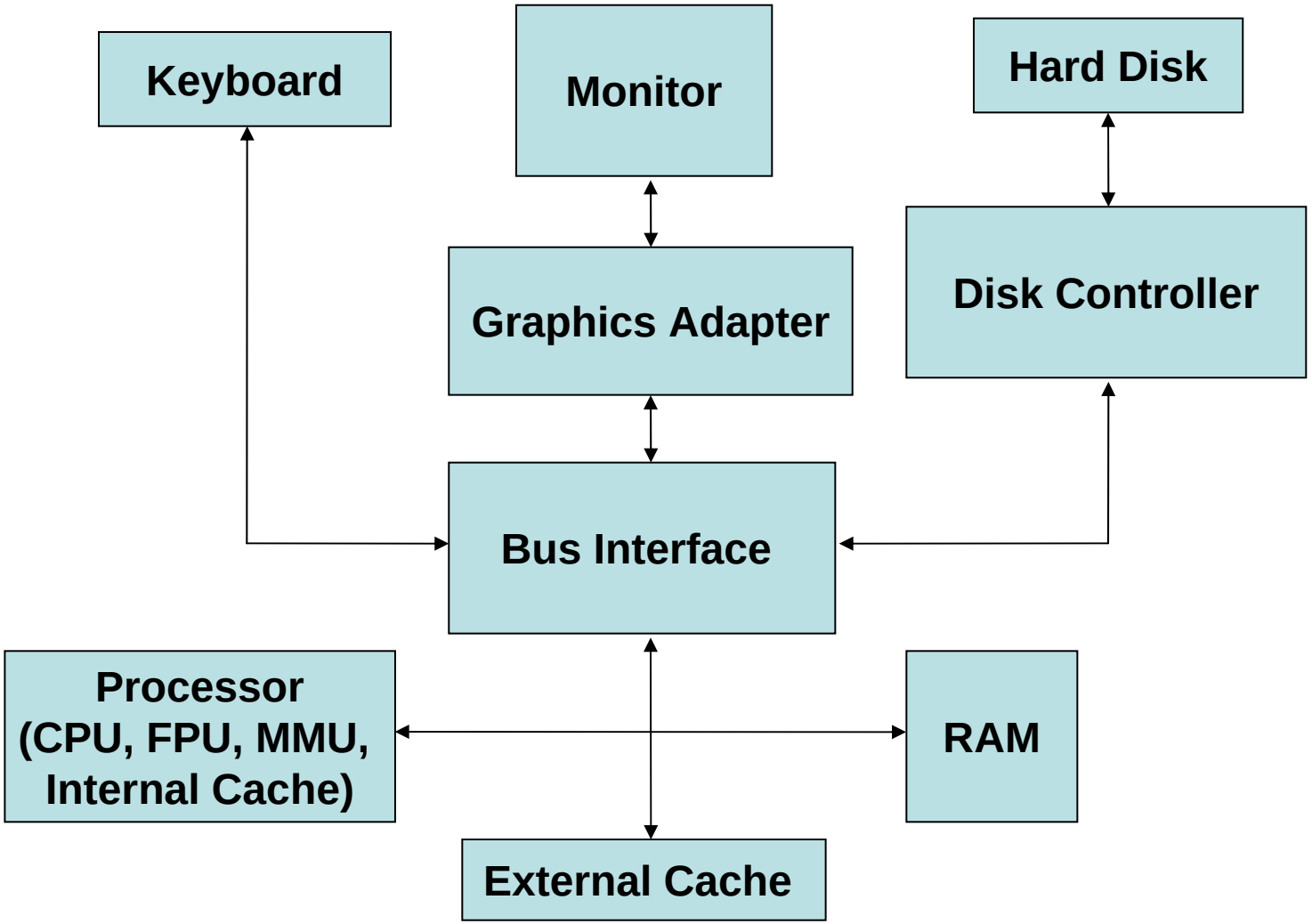
List of instructions → Computer program

Internal storage → Memory

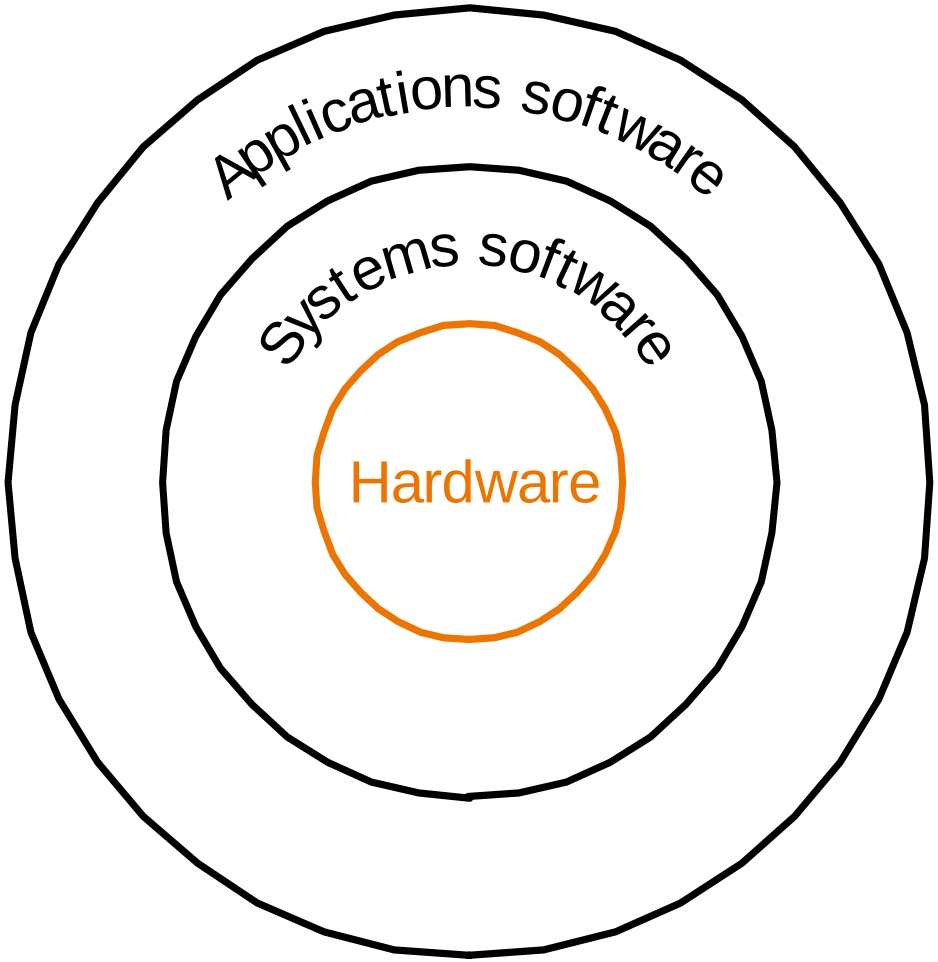
Different Types and Forms of Computer

- Personal Computers (Desktop PCs)
- Notebook computers (Laptop computers)
- Handheld PCs
- Pocket PCs
- Workstations (SGI, HP, IBM, SUN)
- ATM (Embedded systems)
- Supercomputers

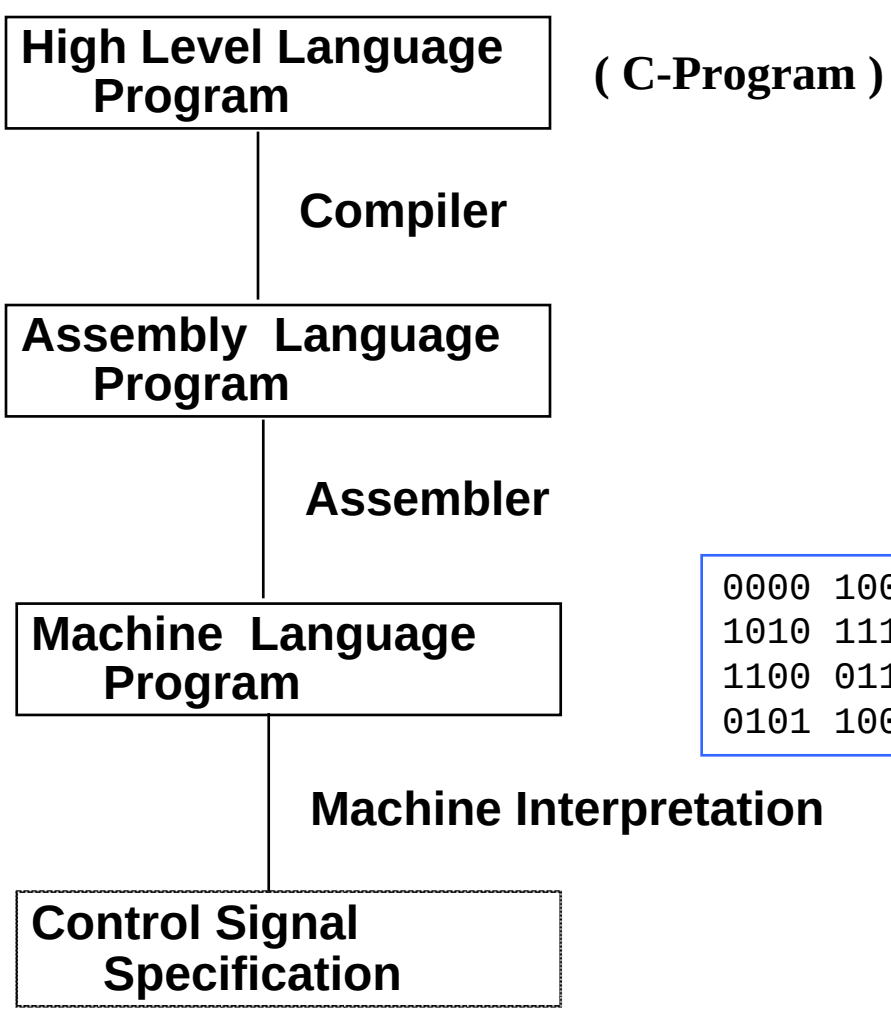
A Personal Computer System: Hardware



Software-Hardware Hierarchy in a Digital Computer



Digital Computer : Program Execution Flow

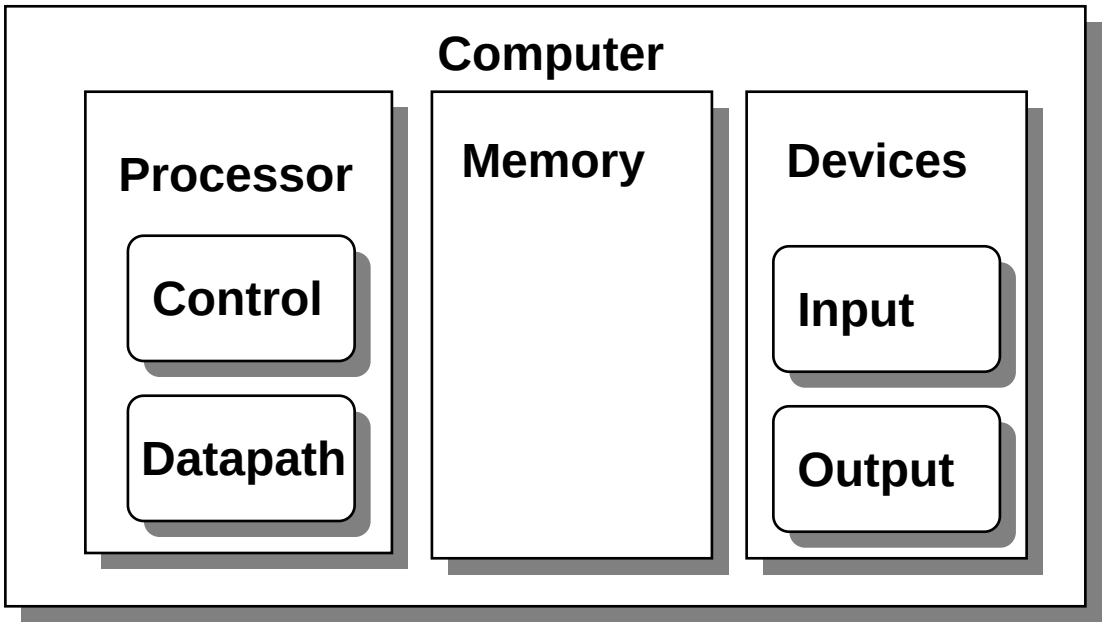



```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

```
0000 1001 1100 0110 1010 1111 0101 1000
1010 1111 0101 1000 0000 1001 1100 0110
1100 0110 1010 1111 0101 1000 0000 1001
0101 1000 0000 1001 1100 0110 1010 1111
```

Five classic components of a Computer



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

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.

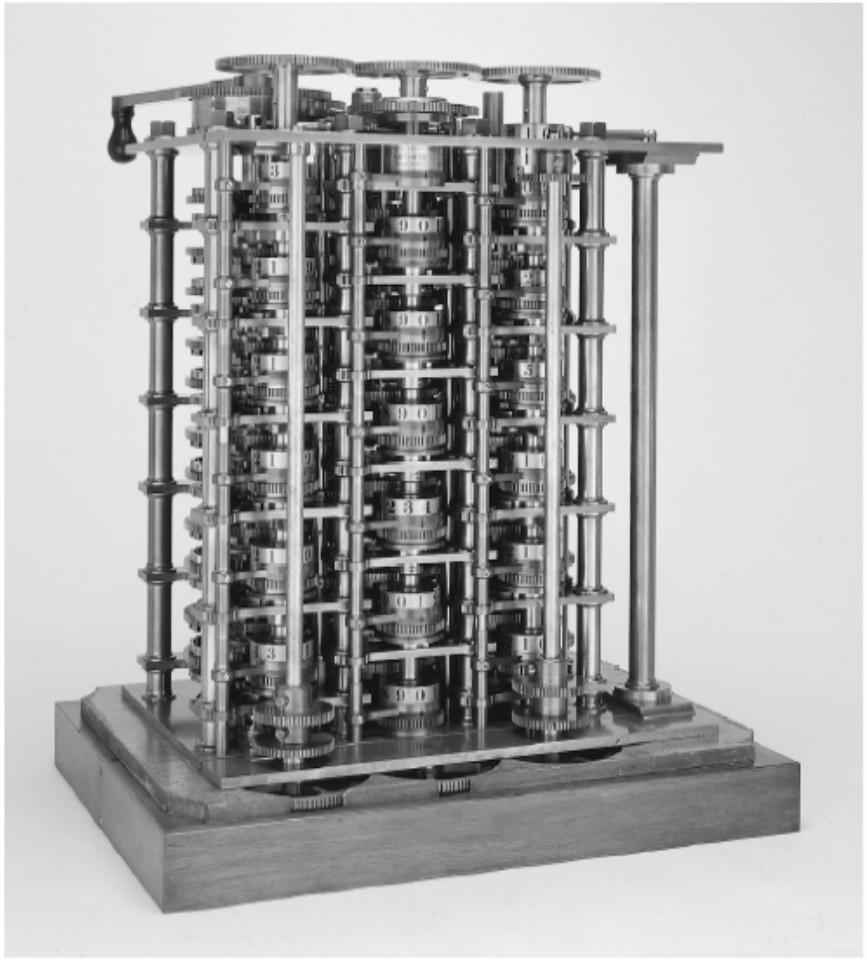
- Processor can be “general purpose” or “special purpose”. A special purpose processor is also known as “application specific integrated circuit” (ASIC).

The terms have become more or less fuzzy at present.

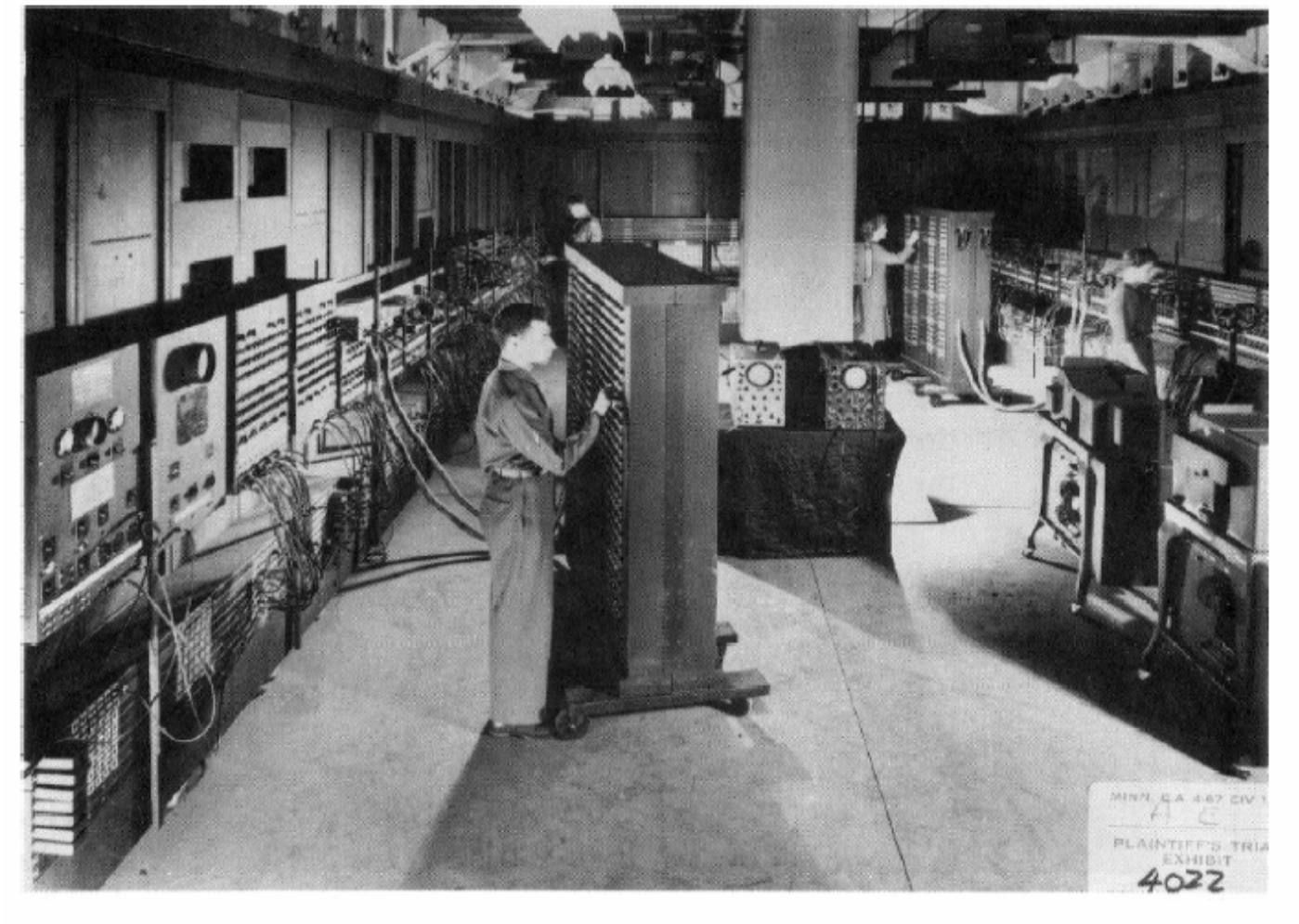
History of Computers

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

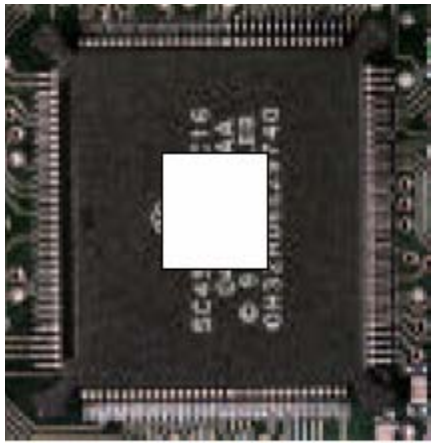
The Babbage Difference Machine in 1832



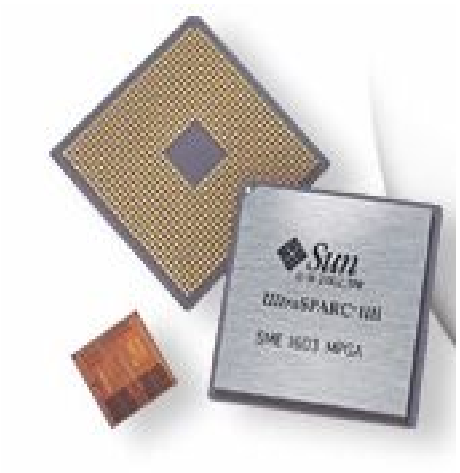
The First Electronic Computer in 1946 (ENIAC)



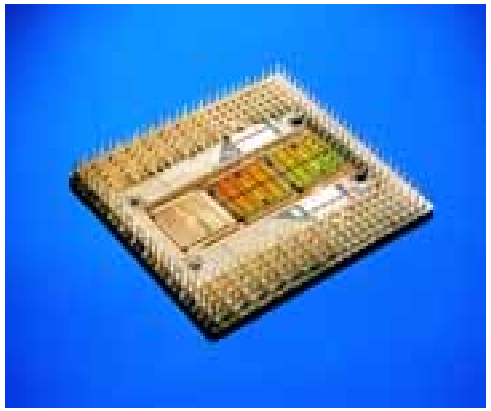
How does a microprocessor look like now ??



(1) ASIC

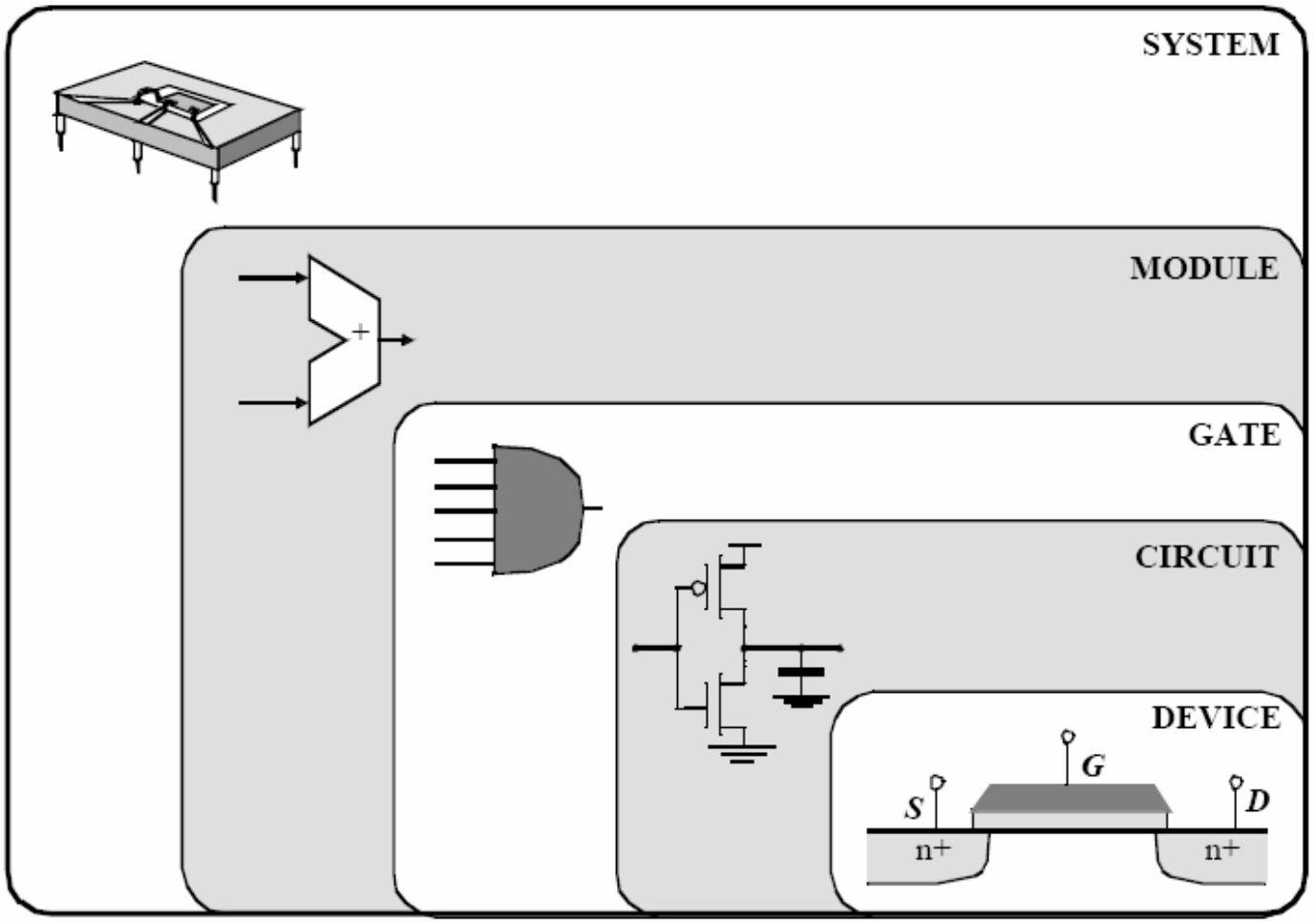


(2) Sun UltraSparc



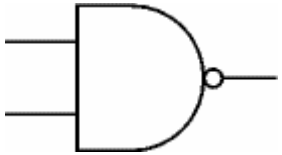
(3) PentiumPro

Digital Circuits : Design Abstraction Levels

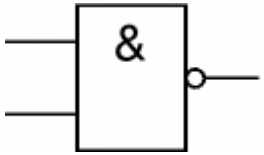


In this Course

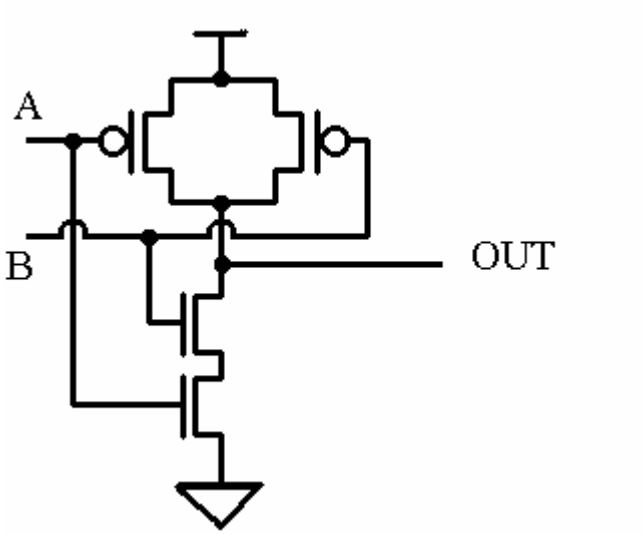
Digital Circuits : Transistor Vs Device



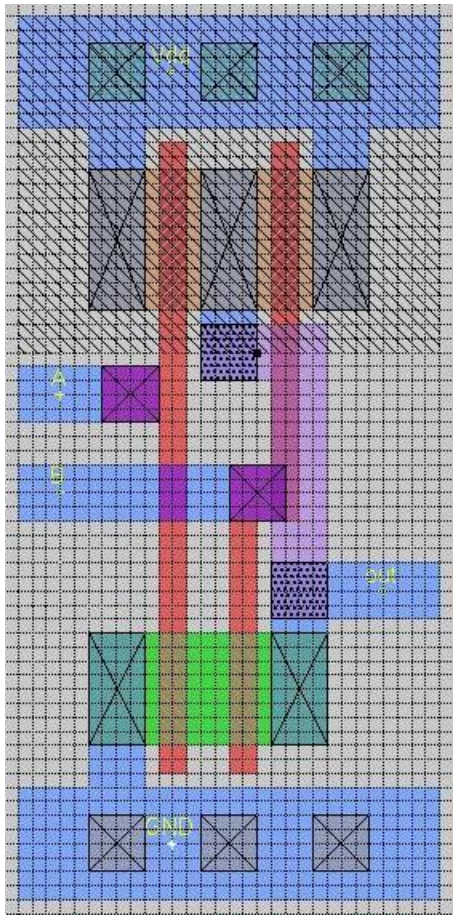
(NAND Gate)



(IEC Symbol)



(Transistor Diagram)



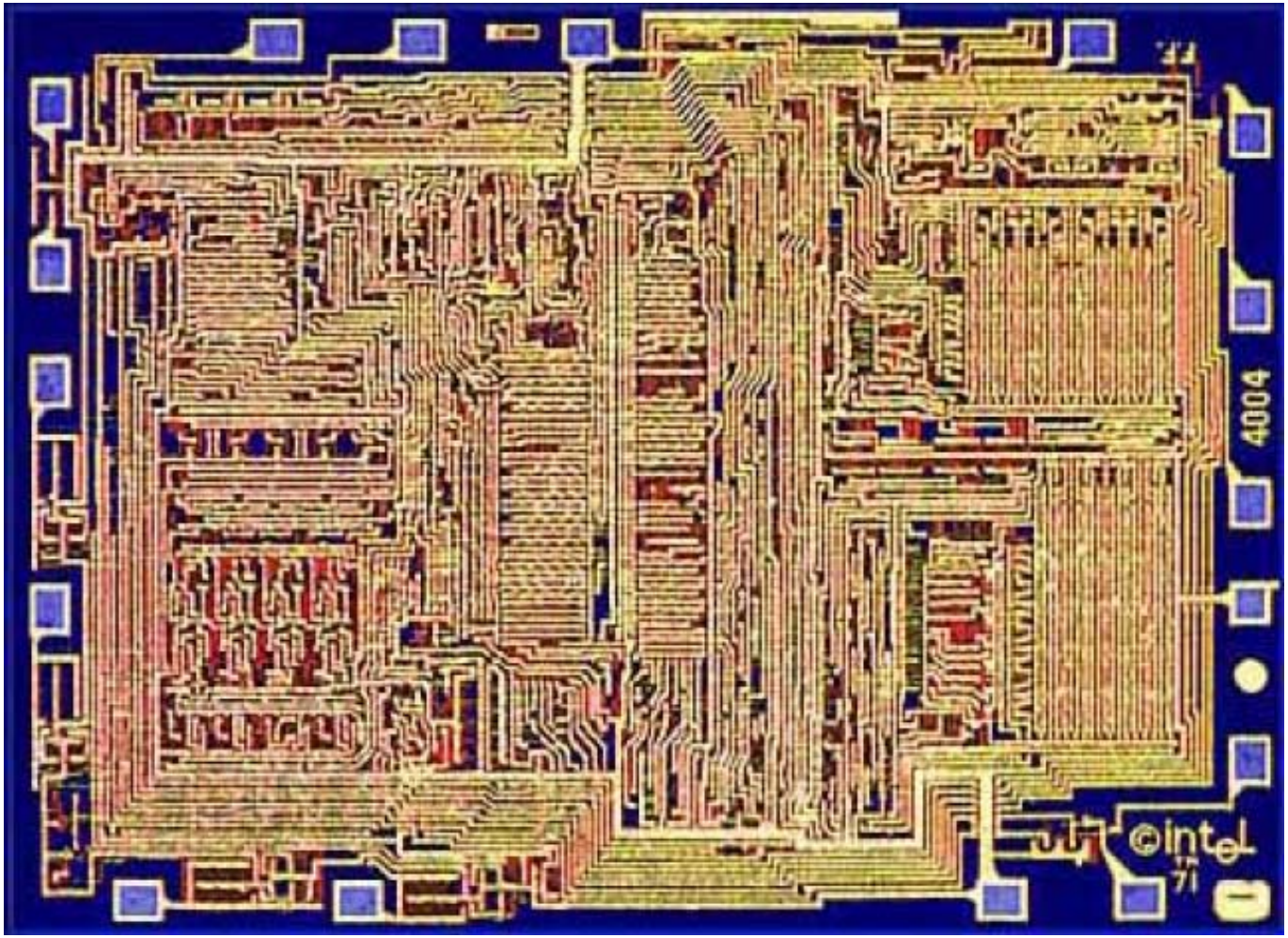
(Layout Diagram)

Different Attributes of a Microprocessor or a Chip

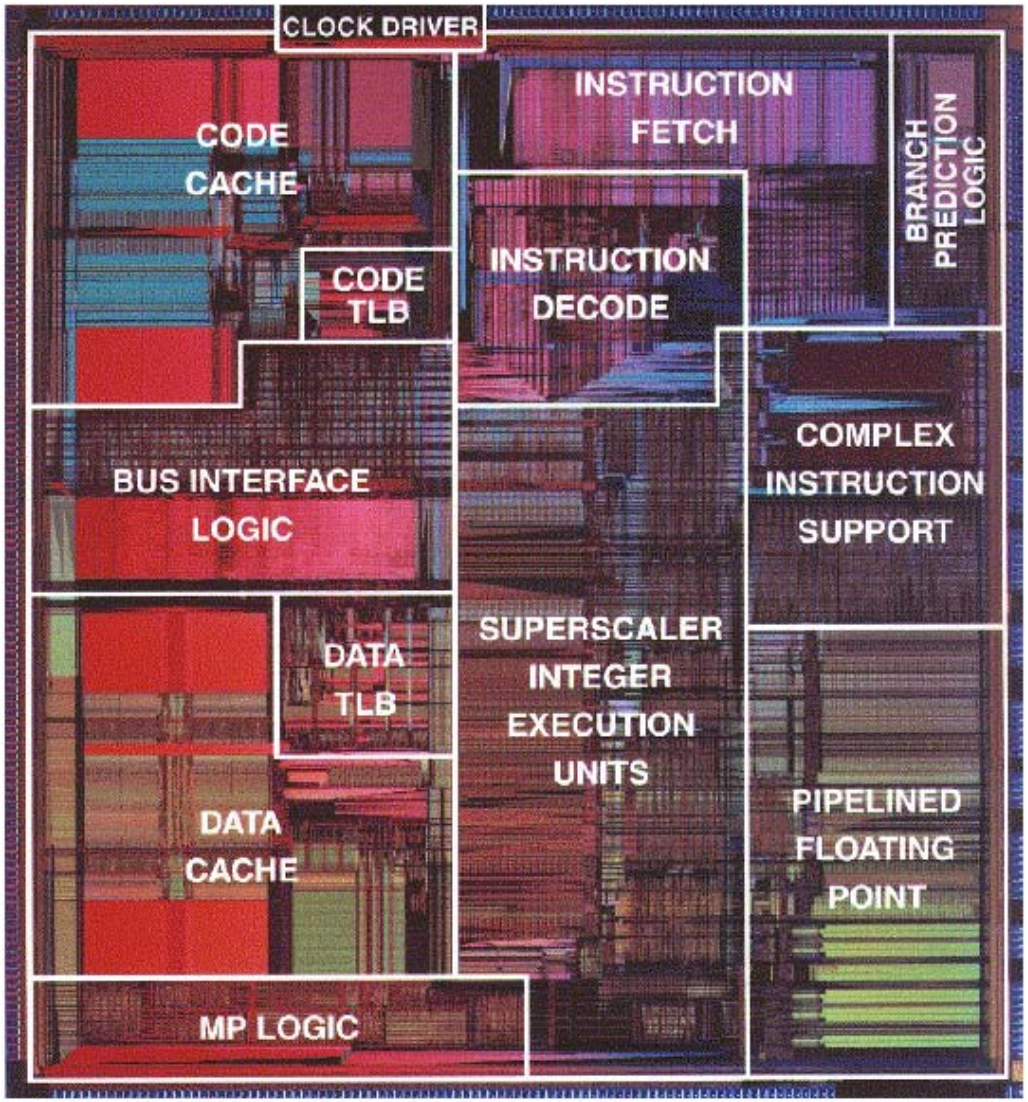
- Gate count of a chip
- Transistor count of a chip
- Operating frequency of a chip
- Power consumption of a chip
- Power density in a chip
- Size of a device used in chip

NOTE: Chip is informal name for IC.

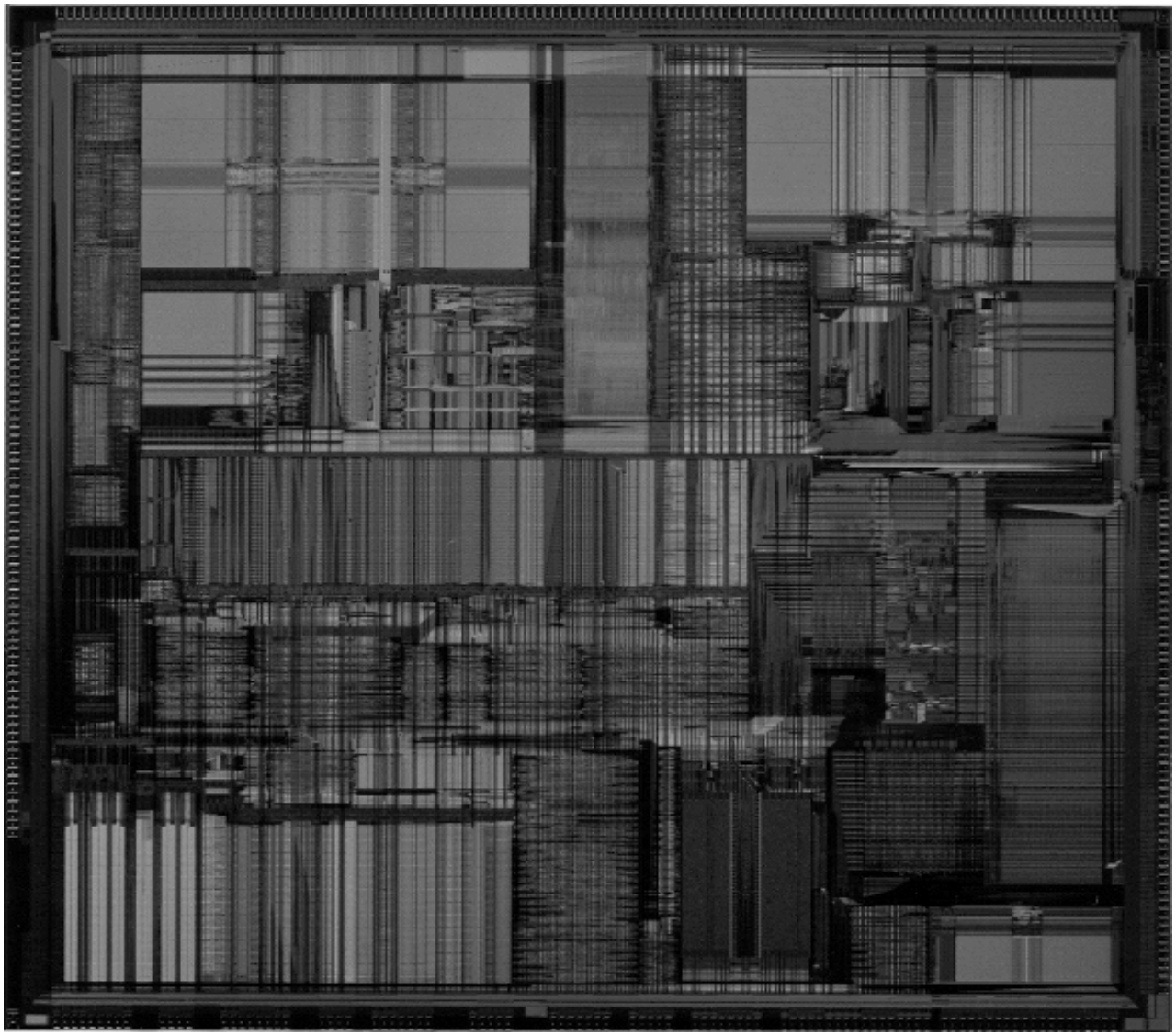
Intel 4004 : 2.3K Transistors (1971)



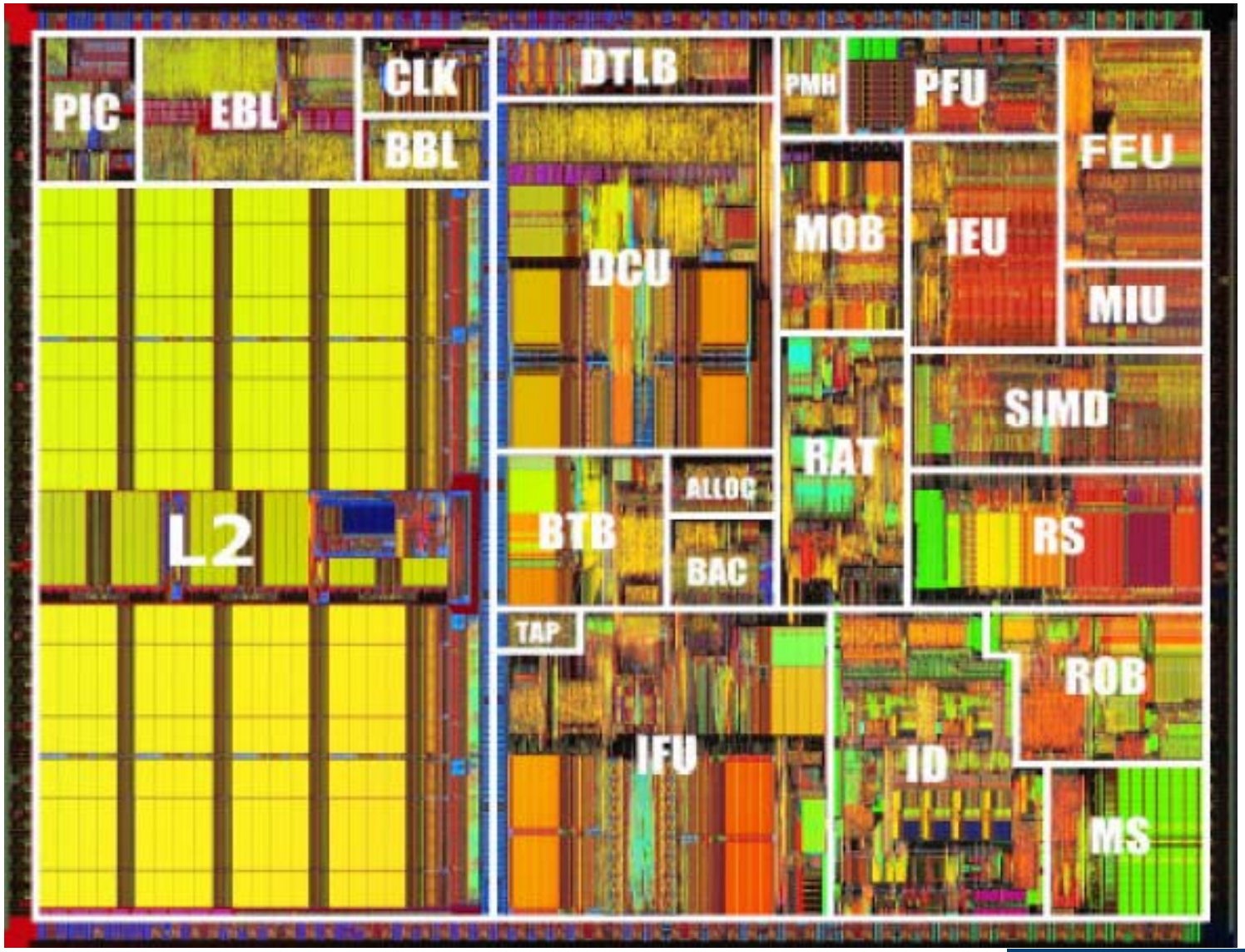
Pentium : 3.1 M Transistors (1993)



Pentium II : 7.5 M Transistors (1997)



Pentium III : 28.1 M Transistors (1999)



Summary of different Intel processors

SL	µ P Name	Bus Bits	MHz	Special Features
1	4004	4	-	2300 transistors, 1st µ P
2	802x, 804x	8	-	µ Computers, 8-10 registers
3	8080A/8085A	8	-	-
4	8086/8088	16	4-16	Cloning started
5	80186 and 80188	-	6-40	Fault tolerance, DMA controller
6	80286	24	6-25	Protected mode
7	80386	32	16-40	Cache introduced
8	80486	32	50-75	1 million transistors, math processor
9	Pentium	32	90-133	3 million transistors, superscalar
10	Pentium Pro	32	100-200	L2 cache
11	Pentium II	32	400	MMX
12	Celeron	32	-	No L2 cache, cheaper
13	Xeon	32	-	½ speed L2 cache
14	Pentium III	32	1000	SIMD, chip ID, 0.18 µ tech
15	Merced	-	1000	VLIW, RISC

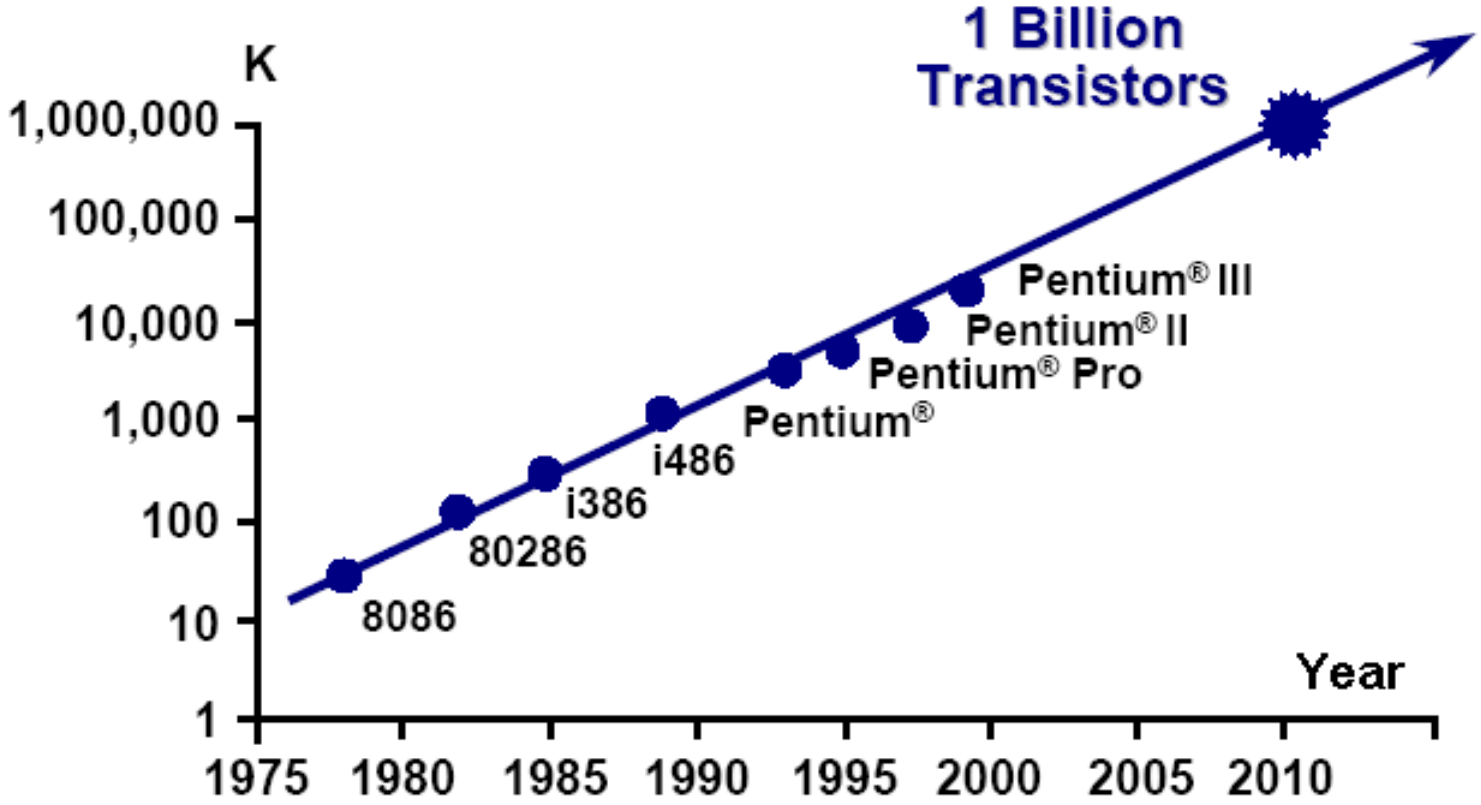
Refer: http://www.pcmech.com/show/processors/35/ or http://www.x86.org/

NOTE: More updated data is available at present.

Summary of different Intel processors ….

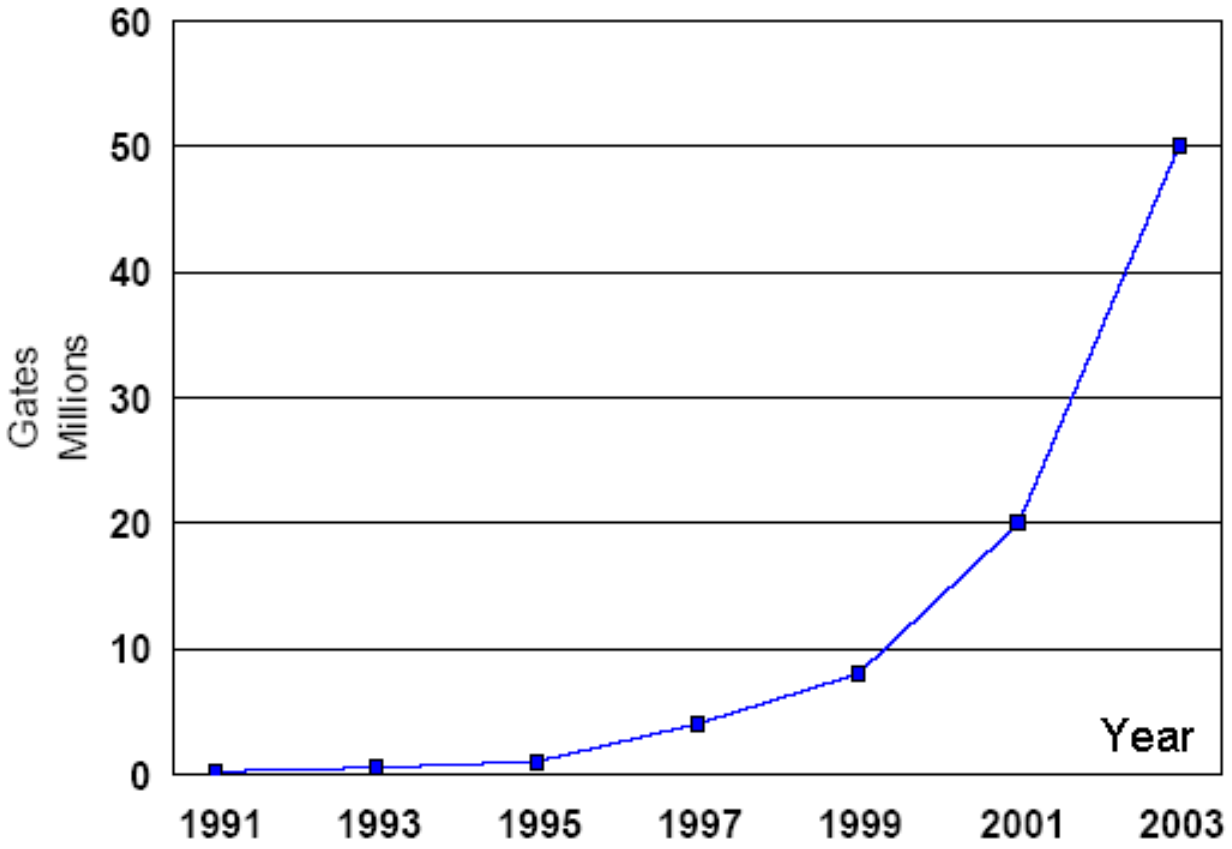
Chip	Date	MHz	Transistors	Notes
4004	4/1971	0.108	2,300	First microprocessor on a chip
8008	4/1972	0.108	3,500	First 8-bit microprocessor
8080	4/1974	2	6,000	First general-purpose CPU on a chip
8086	6/1978	5-10	29,000	First 16-bit CPU on a chip
8088	6/1979	5-8	29,000	Used in IBM PC
80286	2/1982	8-12	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
NA	2004	NA	0.5 Billion	65 nanometer

Increase in Transistor Count

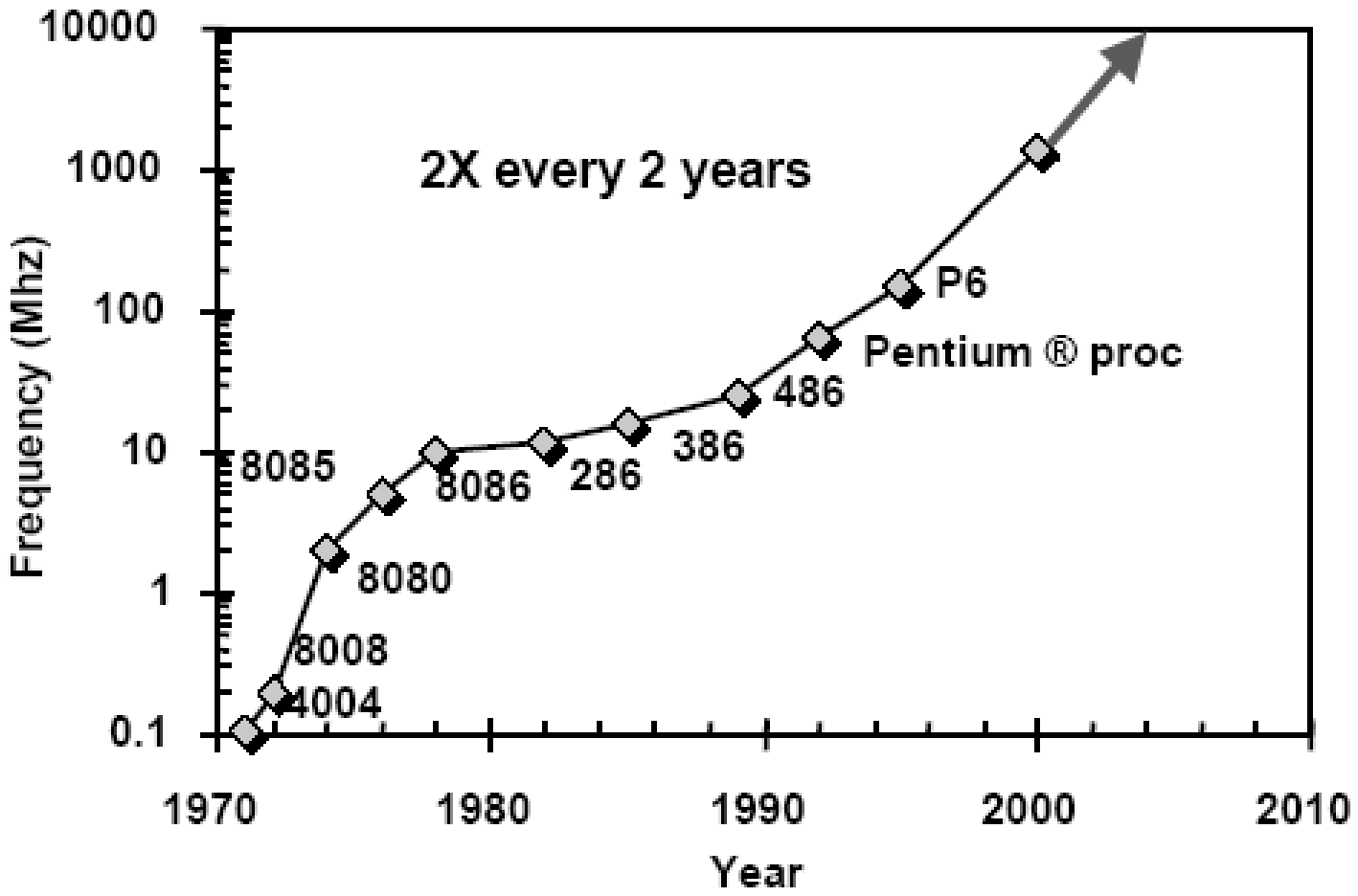


Moore's Law: Number of transistors of a chip doubles every 1.5 to 2 years.

Increase in Gate Count

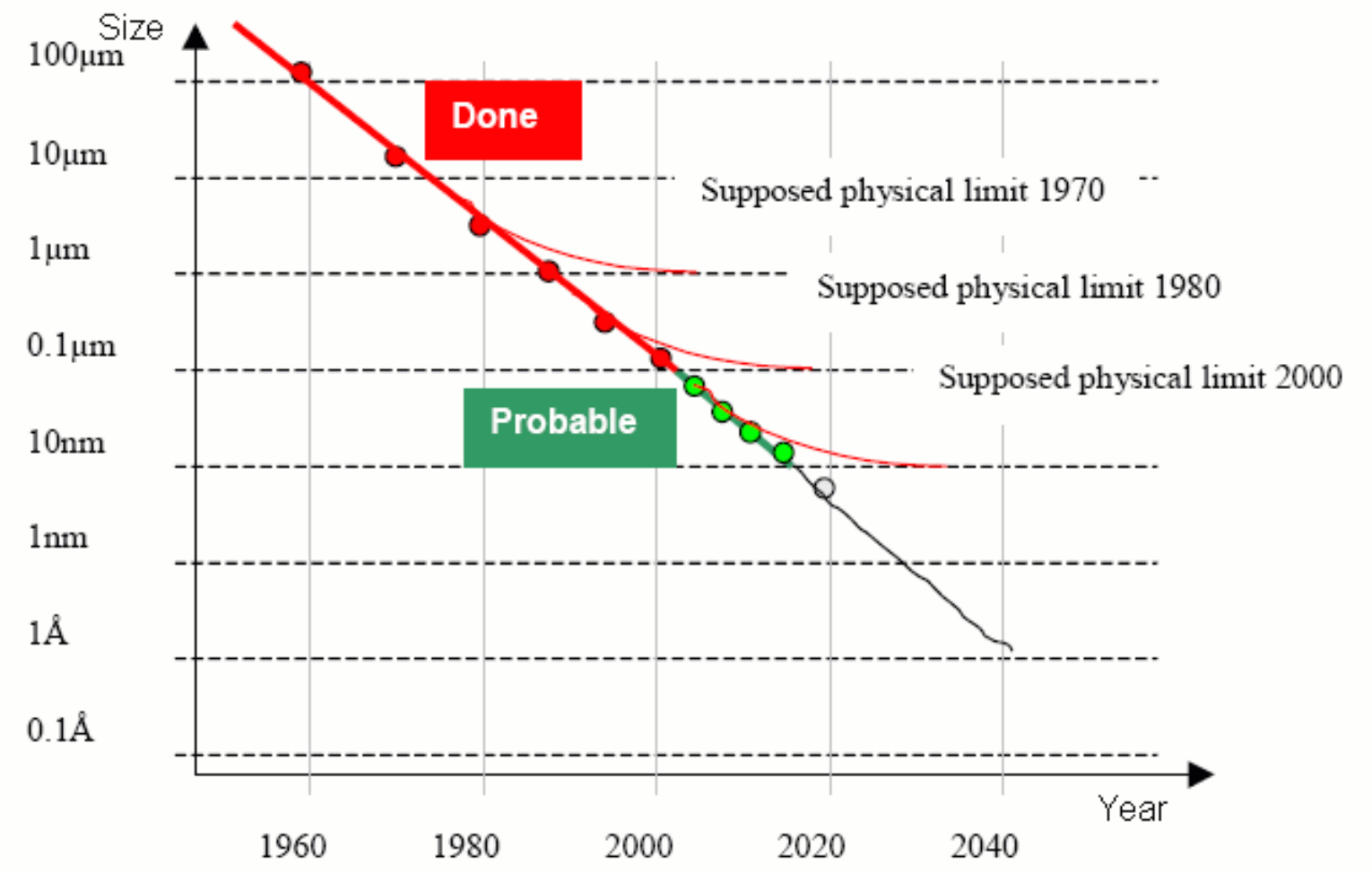


Increase in Operating Frequency (Performance)



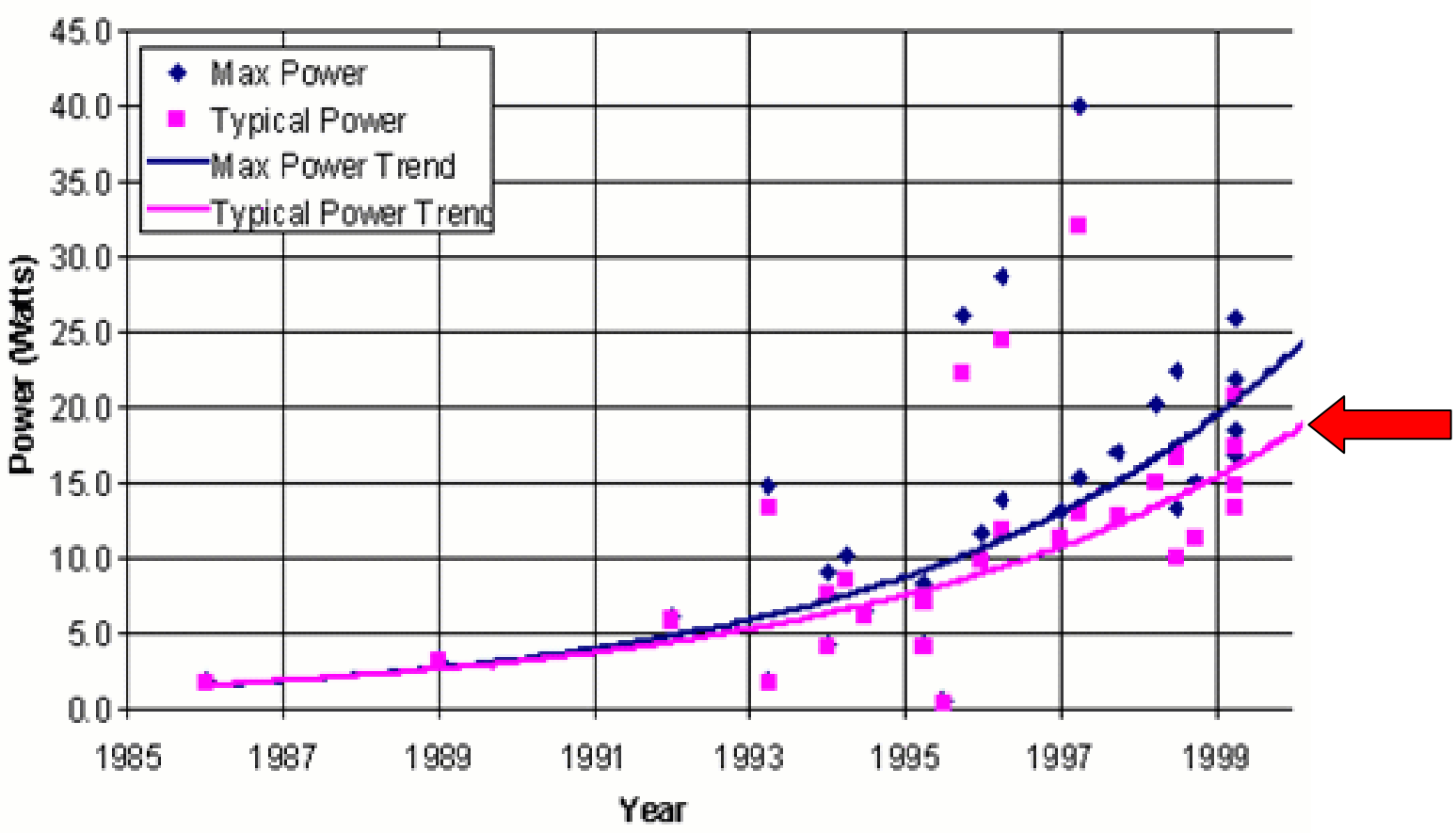
Operating frequency doubles every two years.

Decrease in Feature Size

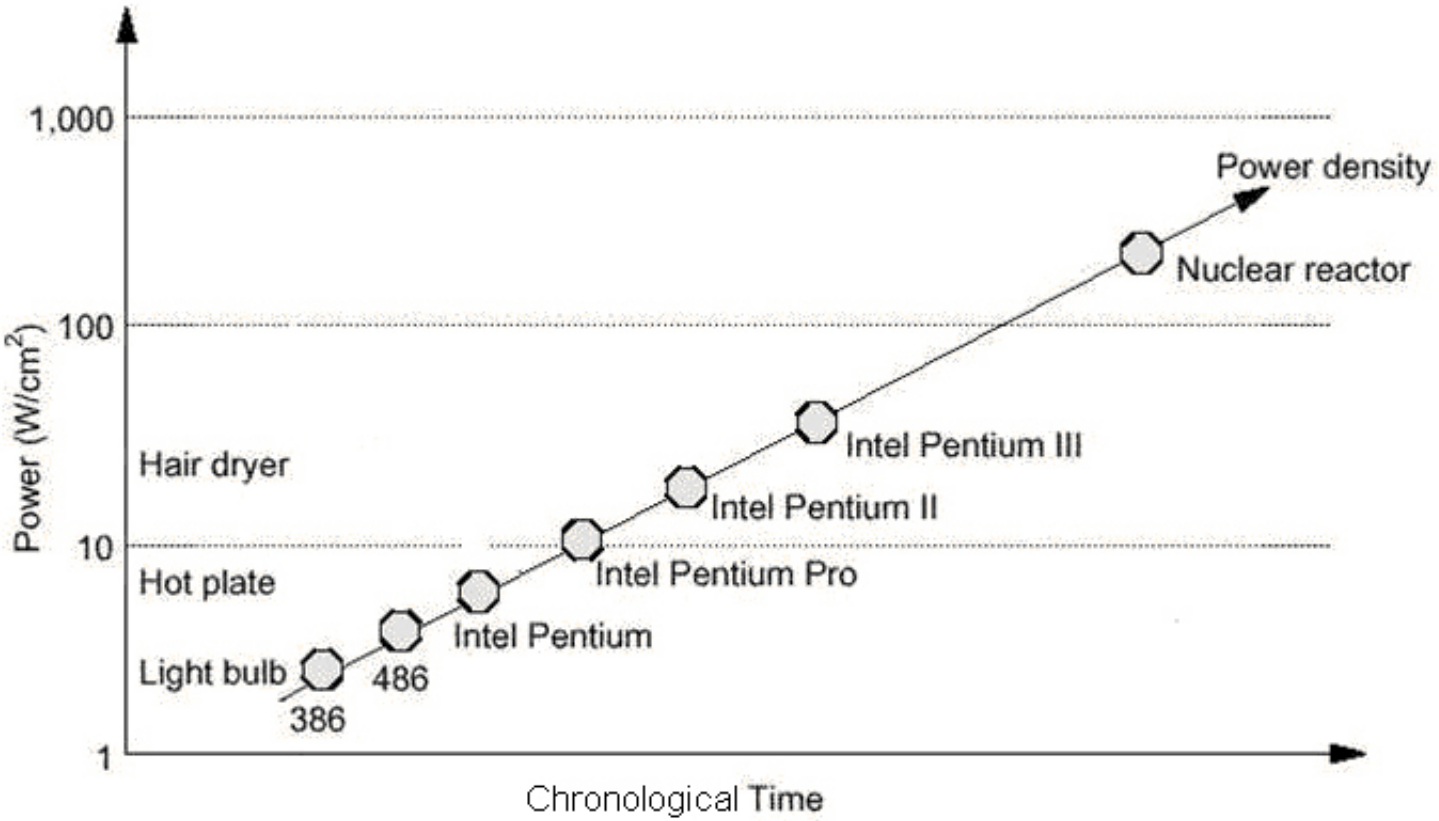


Transistor size is measured in terms of gate length. Minimum gate length is 65nanometer, available from Intel. Refer: SIA roadmap.

Increase in Power Consumption



Increase in Power Density



Power density is power consumption per unit area.

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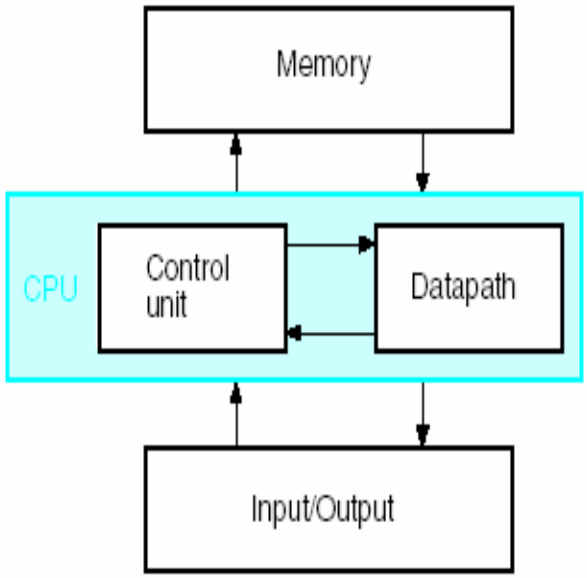

Fig. 1-2 Block Diagram of a Digital Computer

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 = internal cache, external cache, RAM, etc. (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.