What is the study of Computer Architecture?

It's the study of the _____ of computers

- **Structure:** static arrangement of the parts
- **Organization:** dynamic interaction of the parts and their control
- **Implementation:** design of specific building blocks
- **Performance:** behavioral study of the system or of some of its components

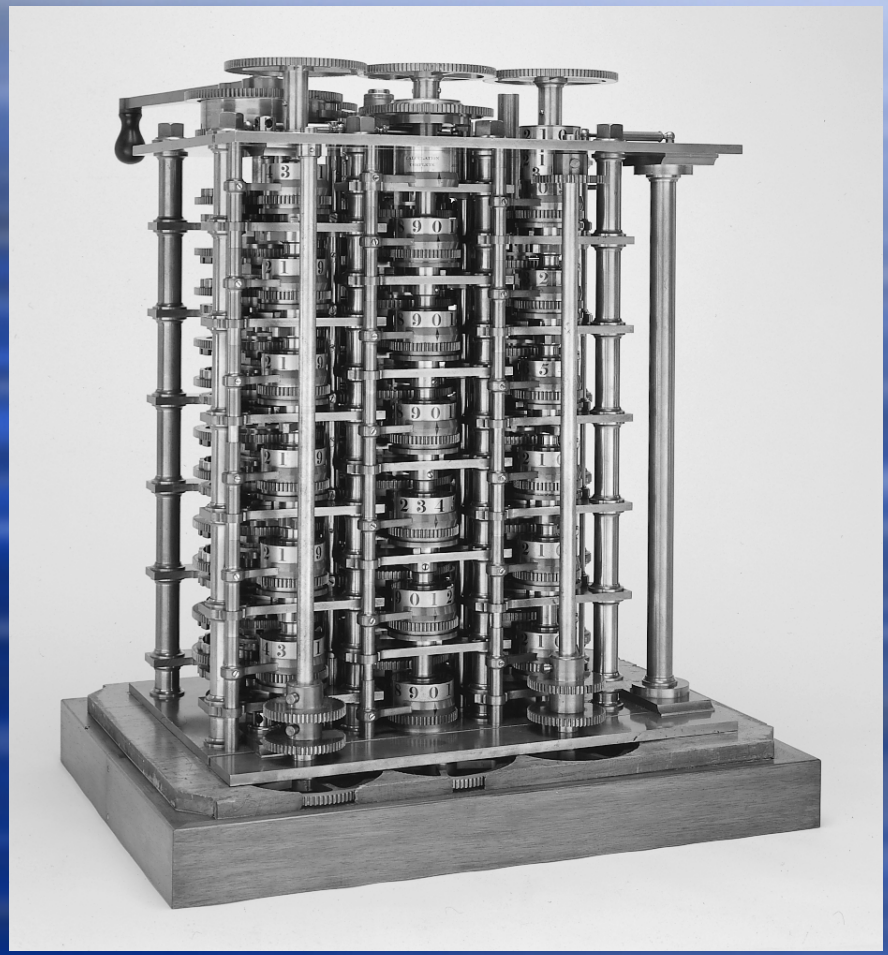
What is *a* Computer Architecture

- Two defintions:
  - (1) Architecture is an **interface** between layers
  - ISA is the interface between hardware and software
  - ISA is what is visible to the programmer (and ISA might be different for O.S. and applications)
  - ISA consists of:
    - instructions (operations and how they are encoded)
    - information units (size, how they are addressed etc.)
    - registers (or more generally processor state)
    - input-output control
    - Execution model

a Computer Architecture

- (2) The microarchitecture (organization)
  - the basic blocks of a computer system, more specifically
    - basic blocks of the CPU
    - basic blocks of the memory hierarchy
  - how are the basic blocks designed, controlled, connected?
  - Organization used to be transparent to the ISA.
  - Today more and more of the ISA is *"exposed"* to the user/compiler.

The Babbage Machine

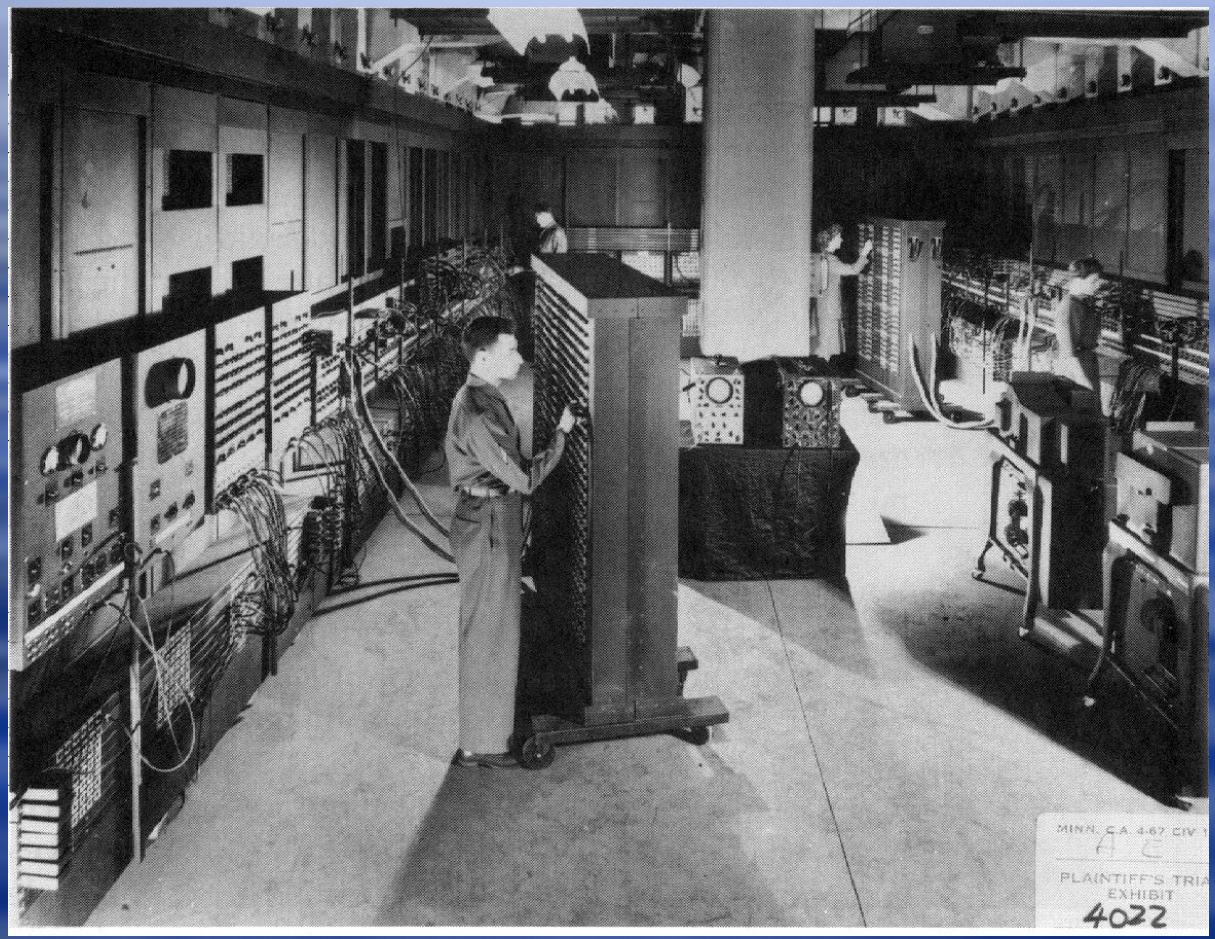


The Babbage Difference Engine (1832)

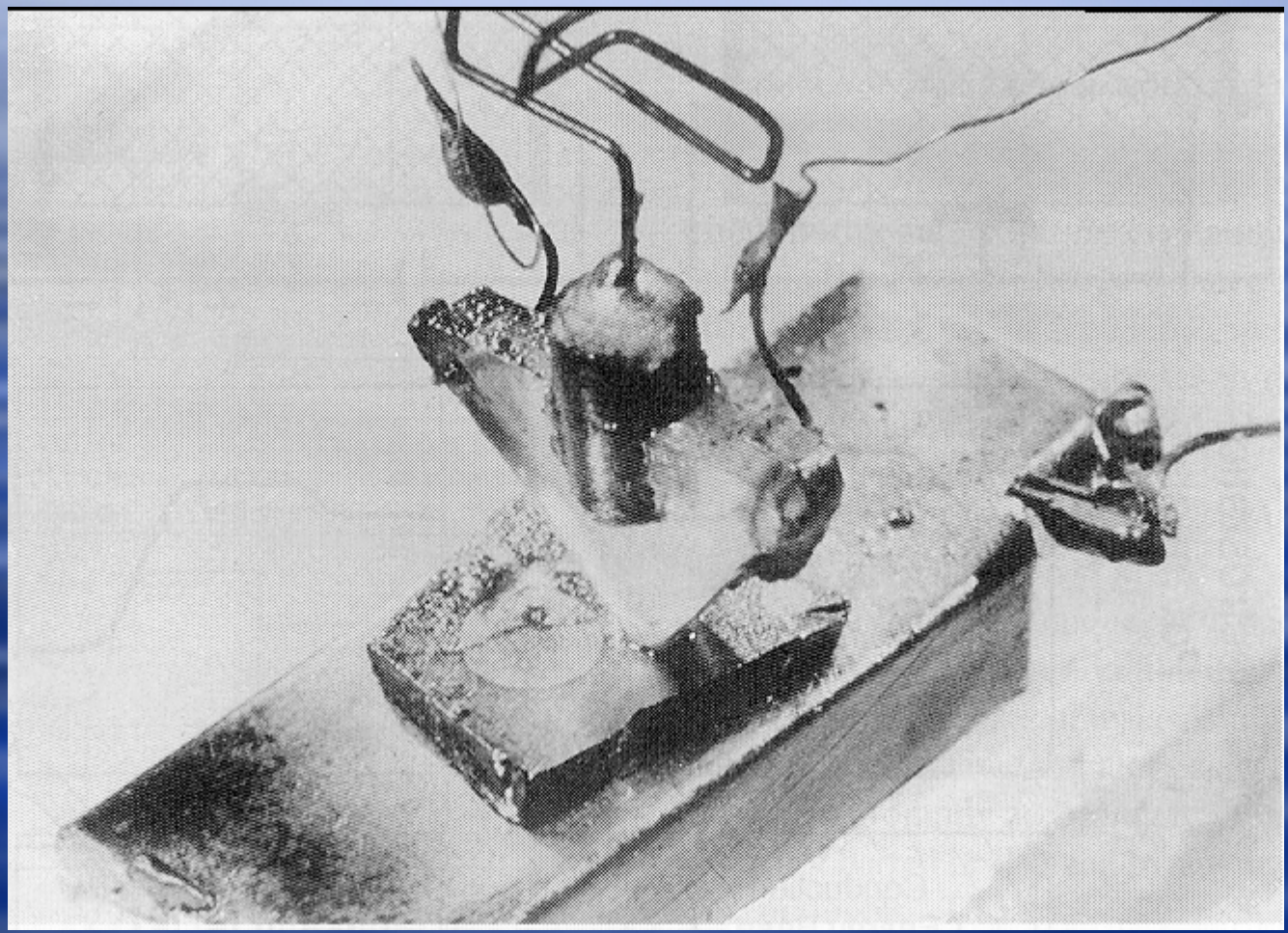
25,000 parts

cost: £17,470

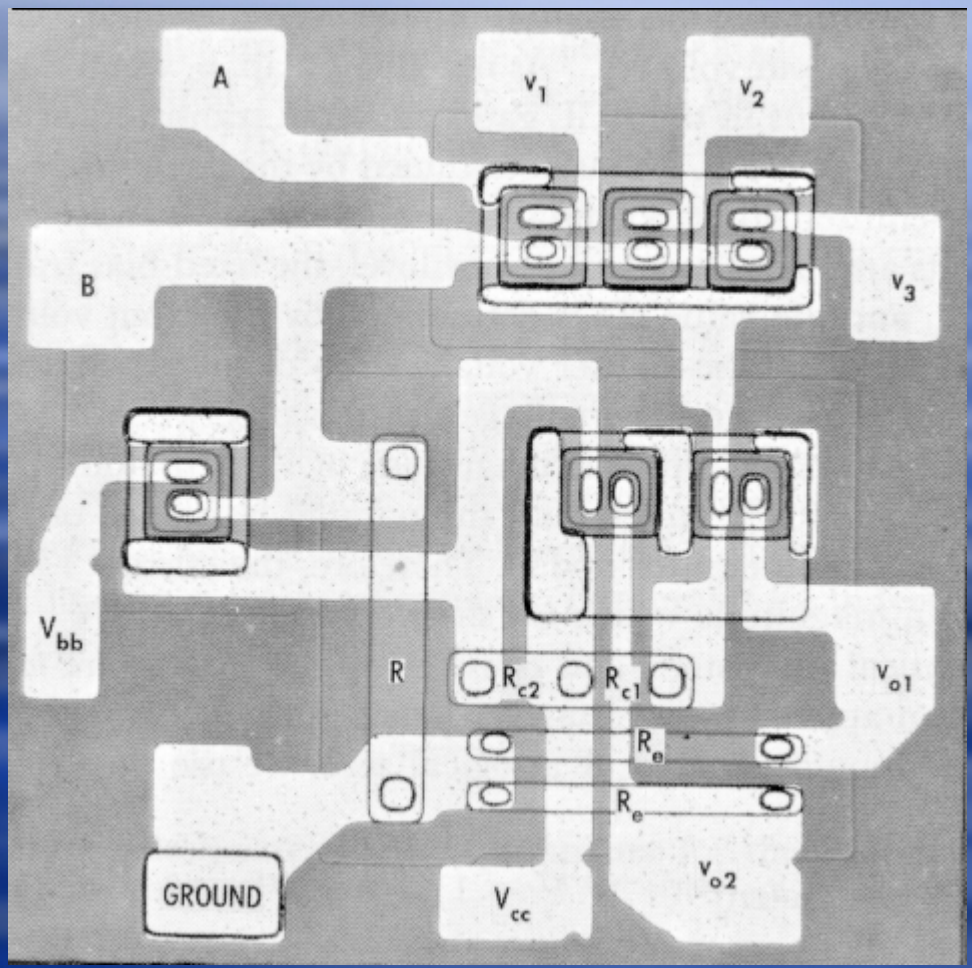
ENIAC



The First Transistor

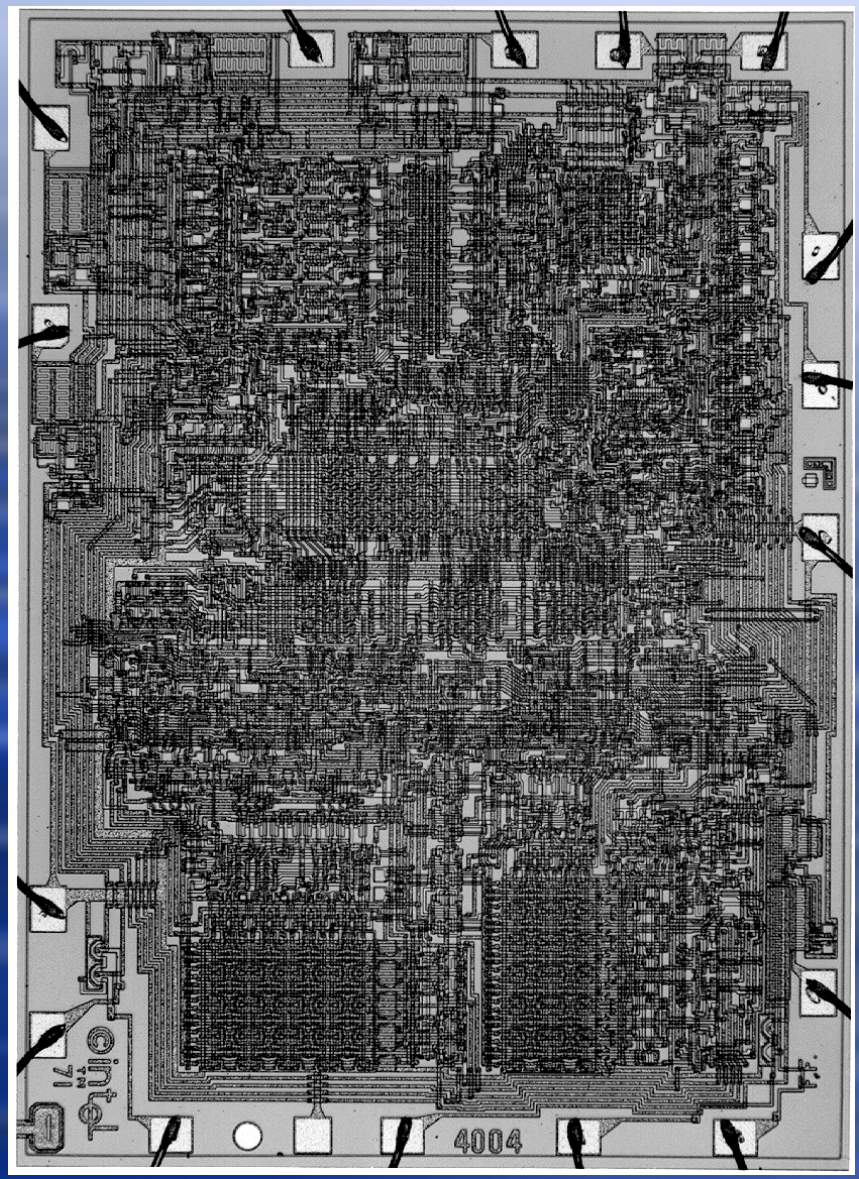


The integrated circuit



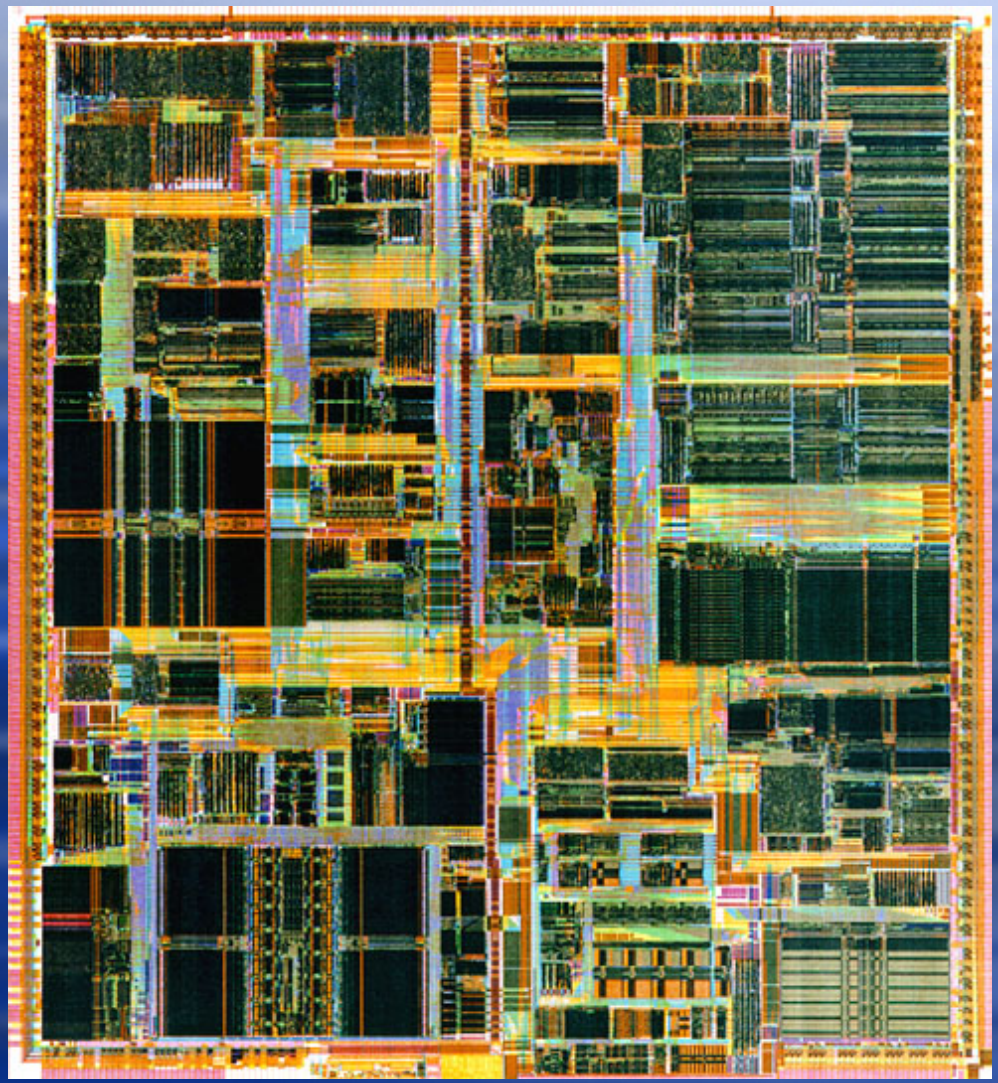
1966, ECL Logic

Intel 4004



~ 1000 xtrs
1971

Pentium IV



~ 44M xtrs
2000

Memory

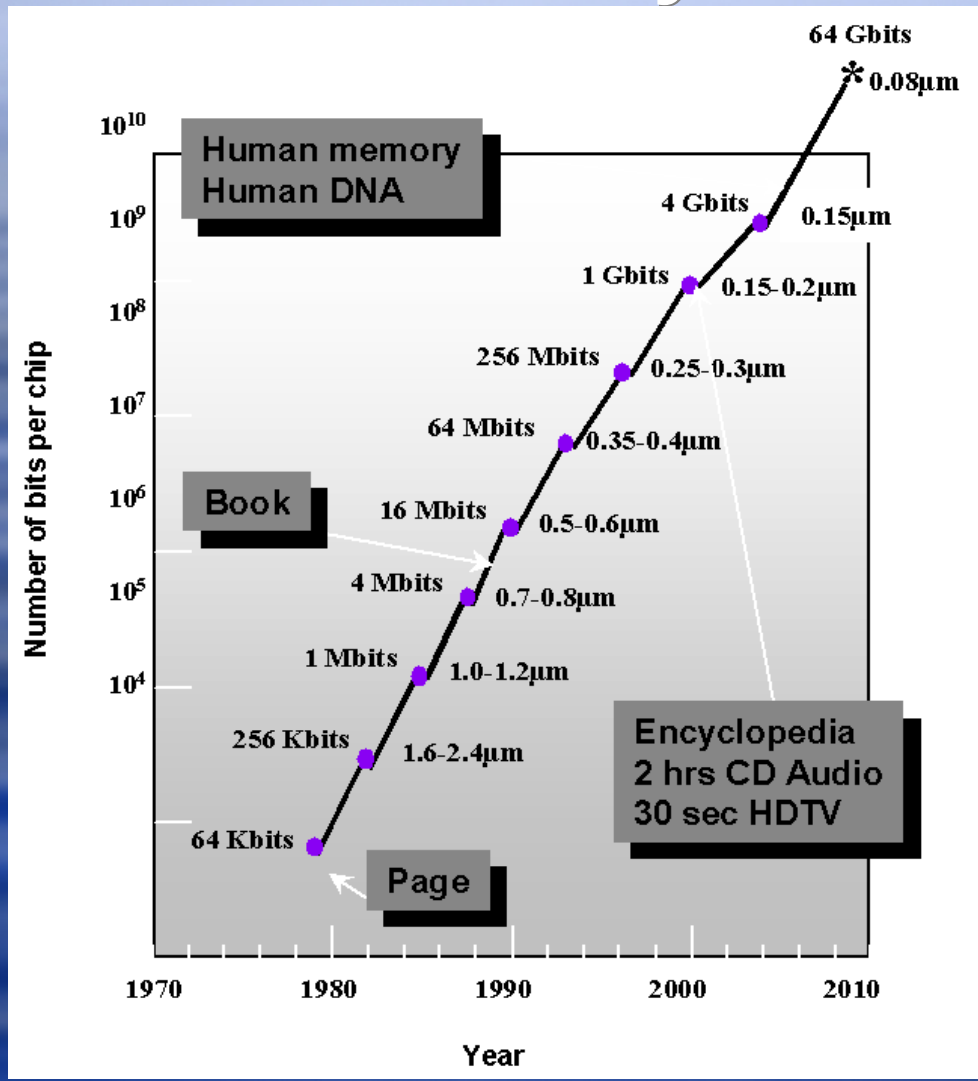
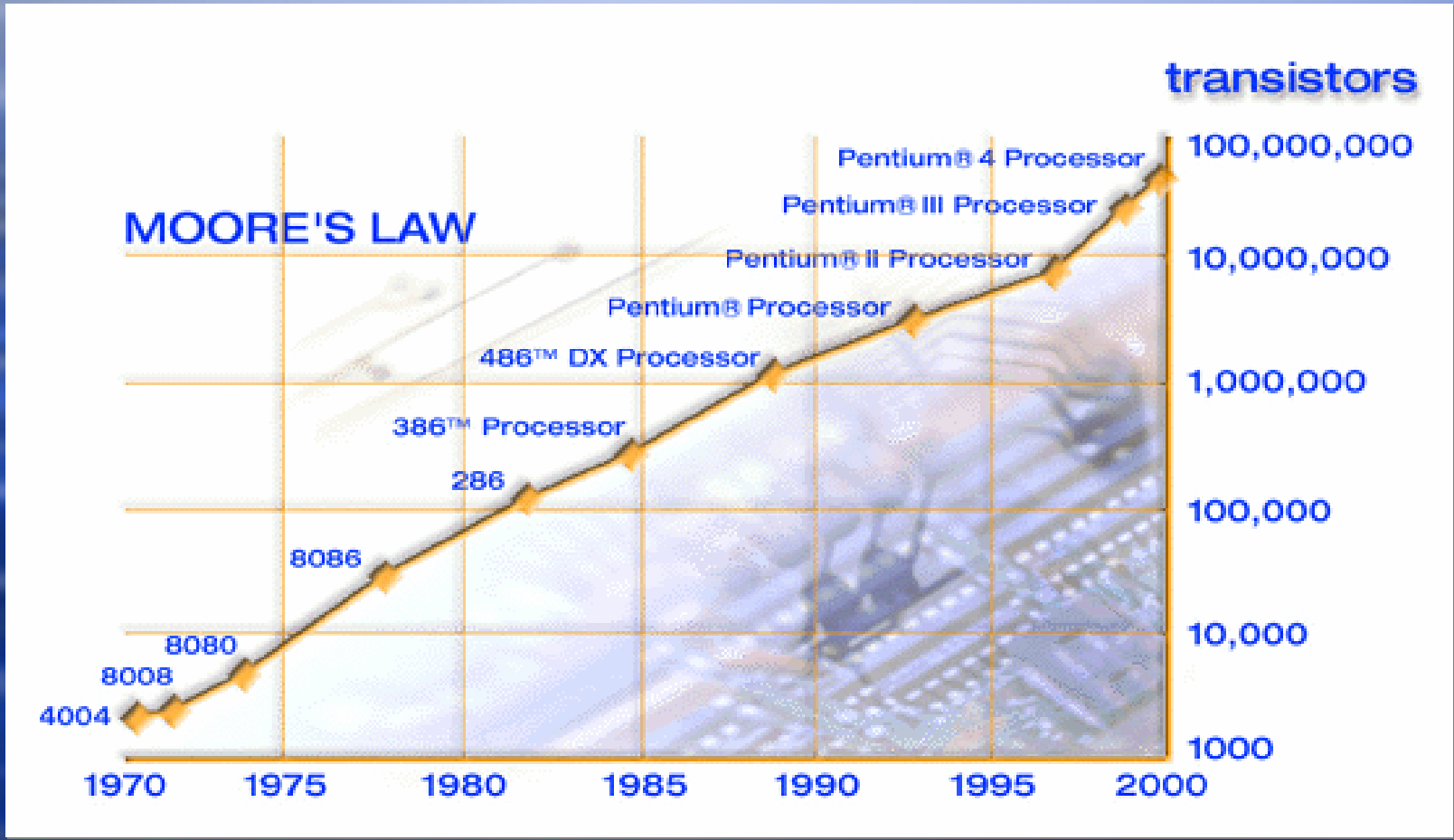
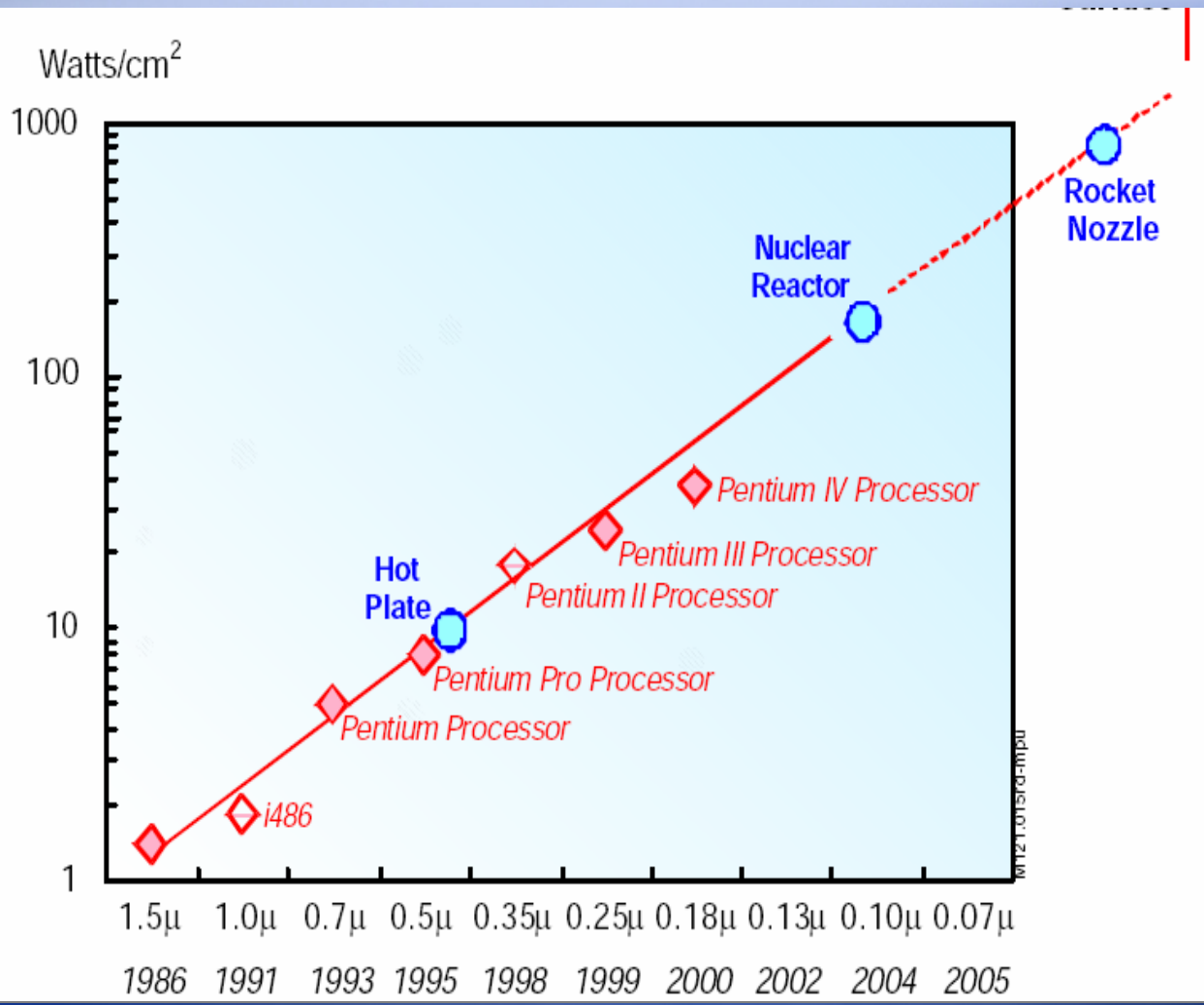

64 Gbits
0.08µm
Human memory
Human DNA
4 Gbits
0.15µm
1 Gbits
0.15-0.2µm
256 Mbits
0.25-0.3µm
64 Mbits
0.35-0.4µm
Book
16 Mbits
0.5-0.6µm
4 Mbits
0.7-0.8µm
1 Mbits
1.0-1.2µm
256 Kbits
1.6-2.4µm
64 Kbits
Page
Encyclopedia
2 hrs CD Audio
30 sec HDTV
Number of bits per chip
Year
1970
1980
1990
2000
2010

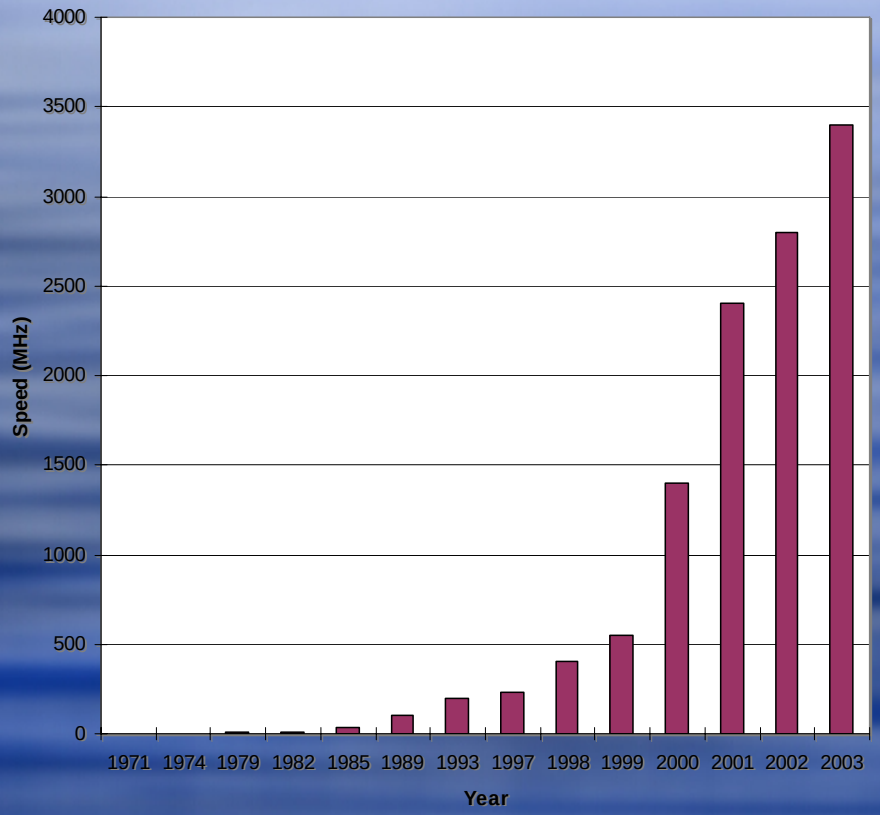
Illustration of Moore's Law



Power Dissipation



Evolution of Intel Microprocessor Speeds



Why have an ISA?

- Computers that have the same (or very similar) ISA
  - Compatibility of software between various implementations
- IBM
  - 704, 709, 70xx etc.. From 1955 till 1965
  - 360, 370, 43xx, 33xx From 1965 to the present
  - Power PC
- DEC
  - PDP-11, VAX From 1970 till 1985
  - Alpha (now Compaq, now HP) in 1990's

More computer families

- Intel
  - Early micros 40xx in early 70's
  - x86 (086,...,486, Pentium, Pentium Pro, Pentium 3, Pentium 4) from 1980 on
  - IA-64 (Itanium) in 2001
- SUN (Berkeley RISC)
  - Sparc, Ultra Sparc 1985 0n
- MIPS-SGI (Stanford RISC)
  - Mips 2000, 3000, 4400, 10000 from 1985 on

MIPS is a RISC

- RISC = *R*educed *I*nstruction *S*et *C*omputer
- R could also stand for “regular”
- All arithmetic-logical instructions are of the form
- MIPS (as all RISC’s) is a *Load-Store* architecture
  - ALU operates only on operands that are in registers
  - The only instructions accessing memory are load and store

$$R_a \leftarrow R_b \ \text{op} \ R_c$$

Registers

- Registers are the "*bricks*" of the CPU
- Registers are an essential part of the ISA
  - Visible to the hardware and to the programmer
- Registers are
  - Used for high speed storage for operands. For example, if variables *a,b,c* are in registers 8,9,10 respectively

    add $8,$9,$10 # a = b + c
  - Easy to name (most computers have 32 registers visible to the programmer and their names are 0, 1, 2, ...,31)
  - Used for addressing memory