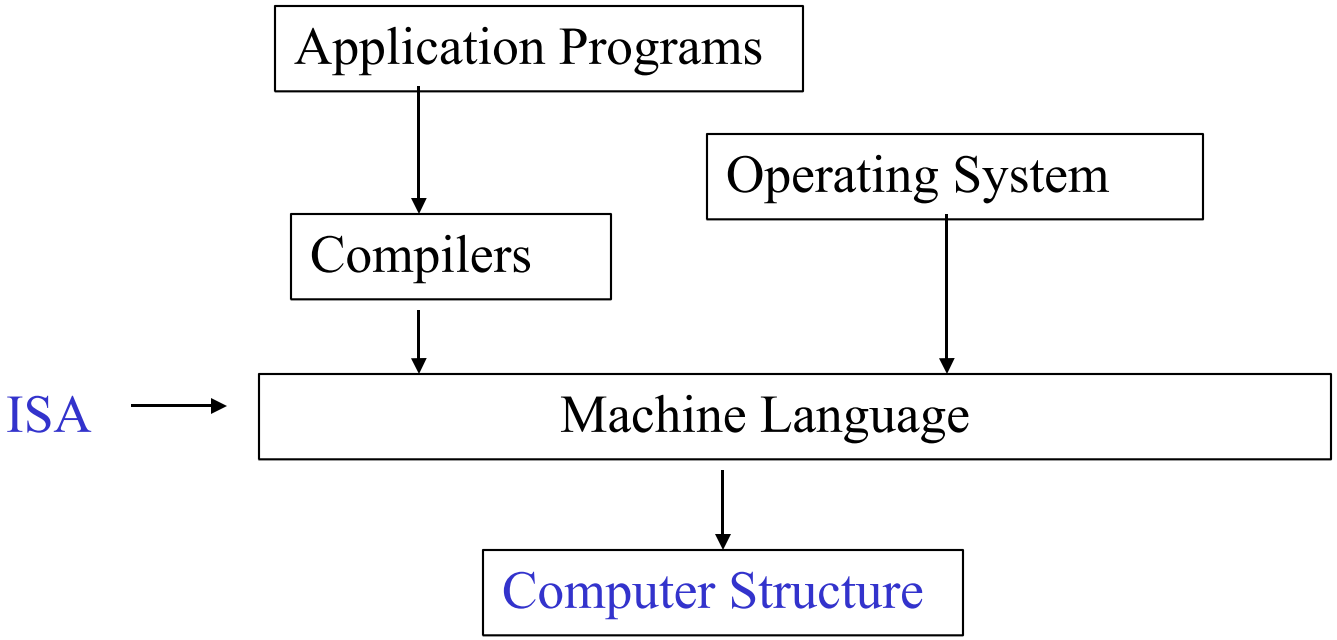
Machine Organization and Assembly Language Programming

- Machine Organization
  - Hardware-centric view (in this class)
  - Not at the transistor (bit) level but at the building block level (registers, adders, memory words etc.)
- Assembly Language
  - A way to learn about the Instruction Set Architecture, the interface between the hardware and the software.

Hierarchical Layers

- Top Layer: Application programs
  - Written in high-level languages: C, C++, Java, html etc
- Basic Software Layer
  - Translates programs written in high-level languages into machine language made up of a sequence of instructions (assembly language is a symbolic rendering of machine language). The translators are programs called compilers.
  - A program, the Operating System, controls the execution of the translated application programs. The O.S. is responsible for functions such as I/O, allocating storage, scheduling etc.
- Hardware
  - Executes the instructions

Layered View



Programmatic view

a = b + c; HLL

```
lw    $2, 0($15)      # load b
lw    $3, 4($15)      # load c
add   $4, $2, $3      #compute b + c
sw    $4, 8($15)      #store in a
```

Assembly language

```
10001101111000100000000000000000
10001101111001100000000000000010
00000000010000110010000000100001
10101101111001000000000000001000
```

Machine language

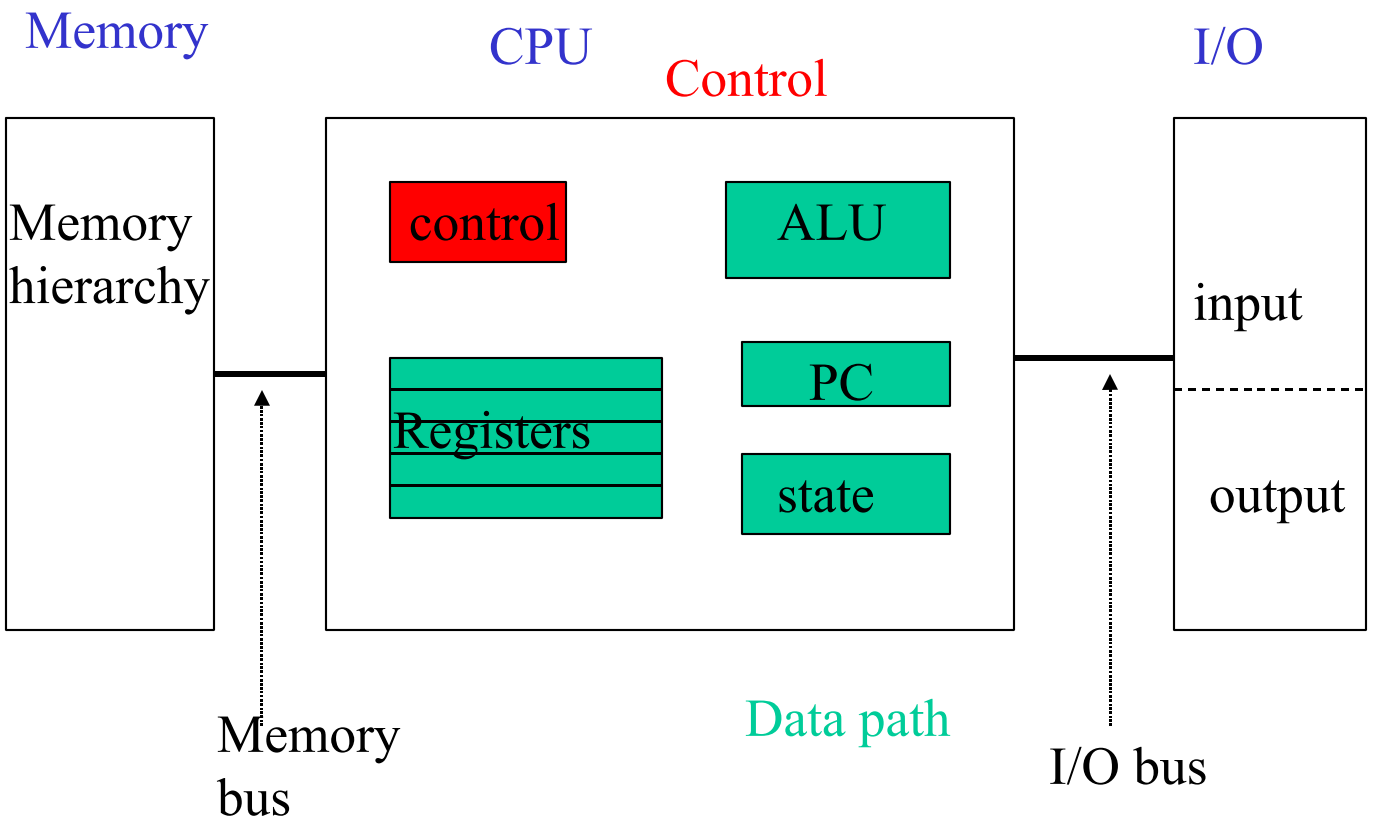
What is Machine Organization (aka Computer Organization, aka Computer Architecture)?

- **Structure:** static arrangement of the parts of a computer system
- **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

Alternate definition: Instruction Set Architecture (ISA) (subset of previous def.)

- 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

Computer structure: Von Neumann model



Computer Organization/Architecture

- Organization and architecture often used as synonyms
- **Organization** (in this course) refers to:
  - what are 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 in order to improve performance.

Advances in technology

Processor technology	Vacuum tubes	Transistors	Integrated circuits	VLSI
Memory technology	Vacuum tubes	Ferrite core	Semi-conductor	Semi-conductor
Processor structure	Single processor	Main frames	Micros and minis	PC's 64-bit arch Superscalar Multithreaded

Evolution of Intel Microprocessor Speeds

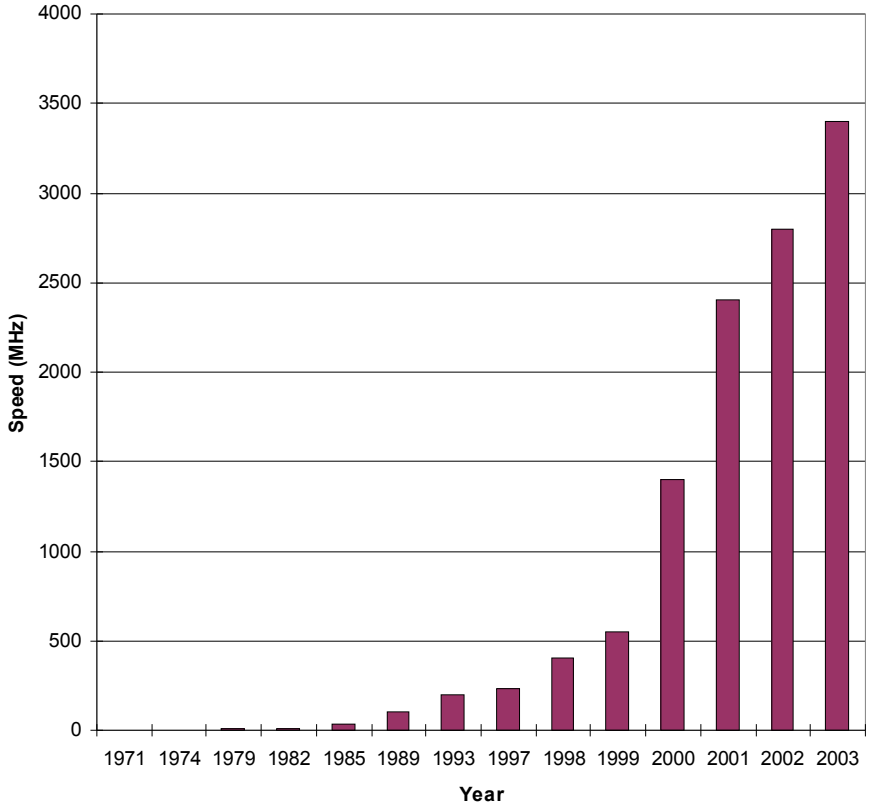
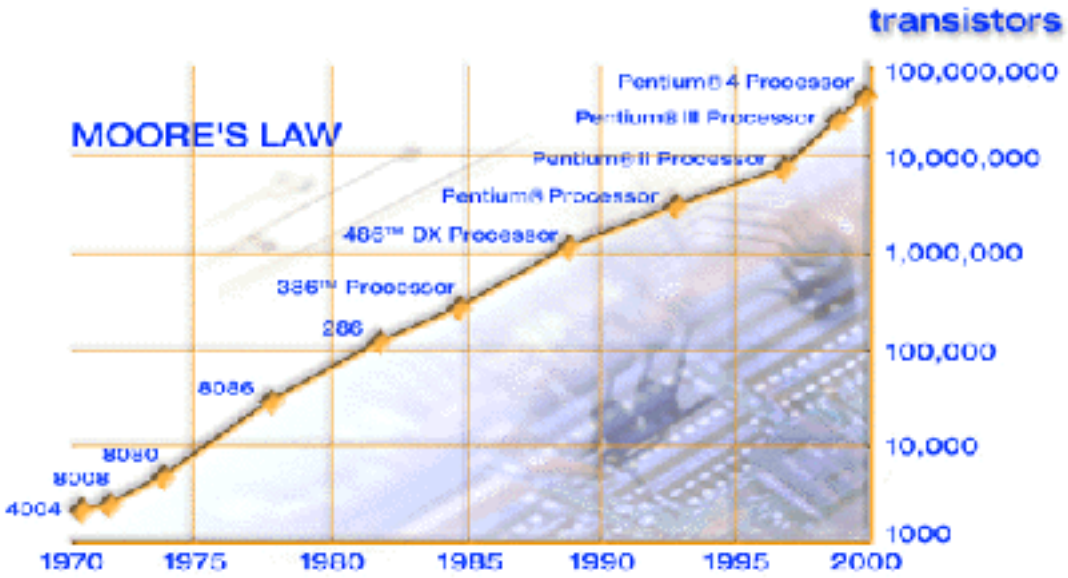
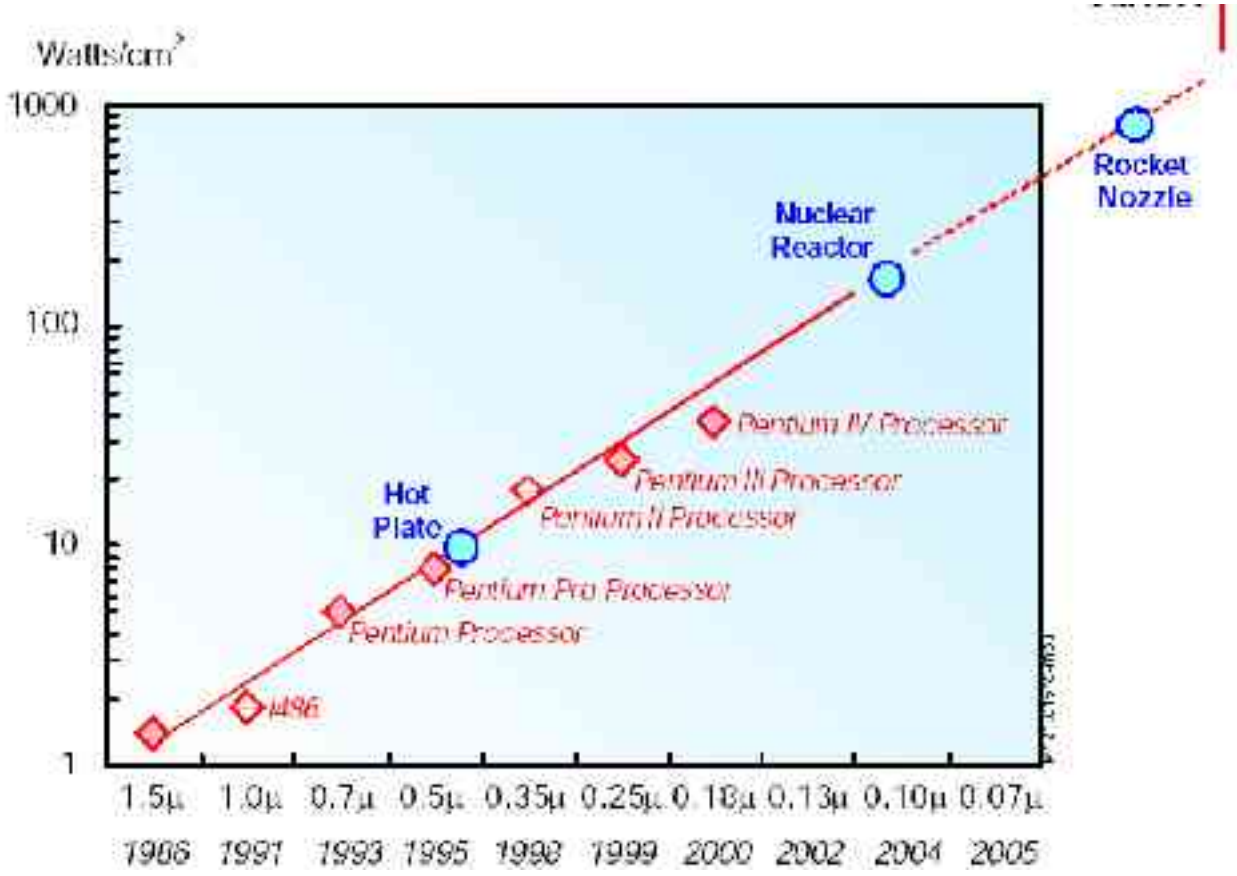


Illustration of Moore's Law



Power Dissipation



Some Computer families

- 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
  - Sparc, Ultra Sparc 1985 0n
- MIPS-SGI
  - Mips 2000, 3000, 4400, 10000 from 1985 on