Computer Architecture

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Topics

- Introduction to changes in SW & HW
- Moore's law
- Language evolution
- Components of a computer
- Instruction set architecture (ISA)

Technology Changes Rapidly

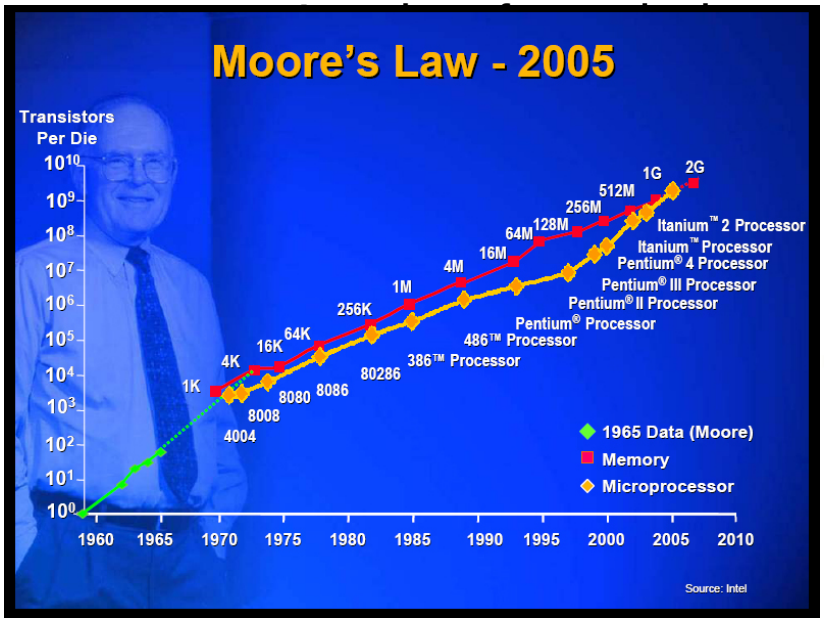
- HW
  - Vacuum tubes: Electron emitting devices
  - Transistors: On-off switches controlled by electricity
  - Integrated Circuits(IC/ Chips): Combines thousands of transistors
  - Very Large-Scale Integration(VLSI): Combines millions of transistors
  - What next?
- SW
  - Machine language: Zeros and ones
  - Assembly language: Mnemonics
  - High-Level Languages: English-like
  - Artificial Intelligence languages: Functions & logic predicates
  - Object-Oriented Programming: Objects & operations on objects

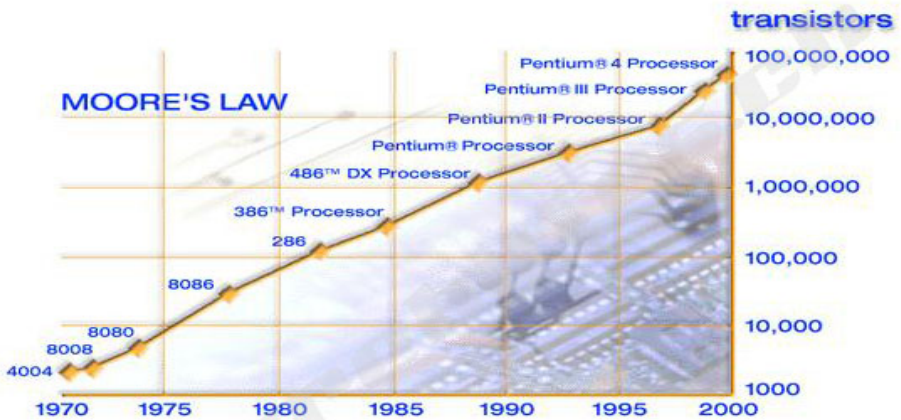
Technology Advances Rapidly

- Processor
  - Logic capacity: ⇑ ~ 30% / yr
  - Clock rate: ⇑ ~ 20% / yr
- Memory
  - DRAM capacity: ⇑ ~ 60% / yr
  - Memory speed: ⇑ ~ 10% / yr
  - Cost per bit: ⇓ ~ 25% / yr
- Disk
  - Capacity: ⇑ ~ 60% / yr

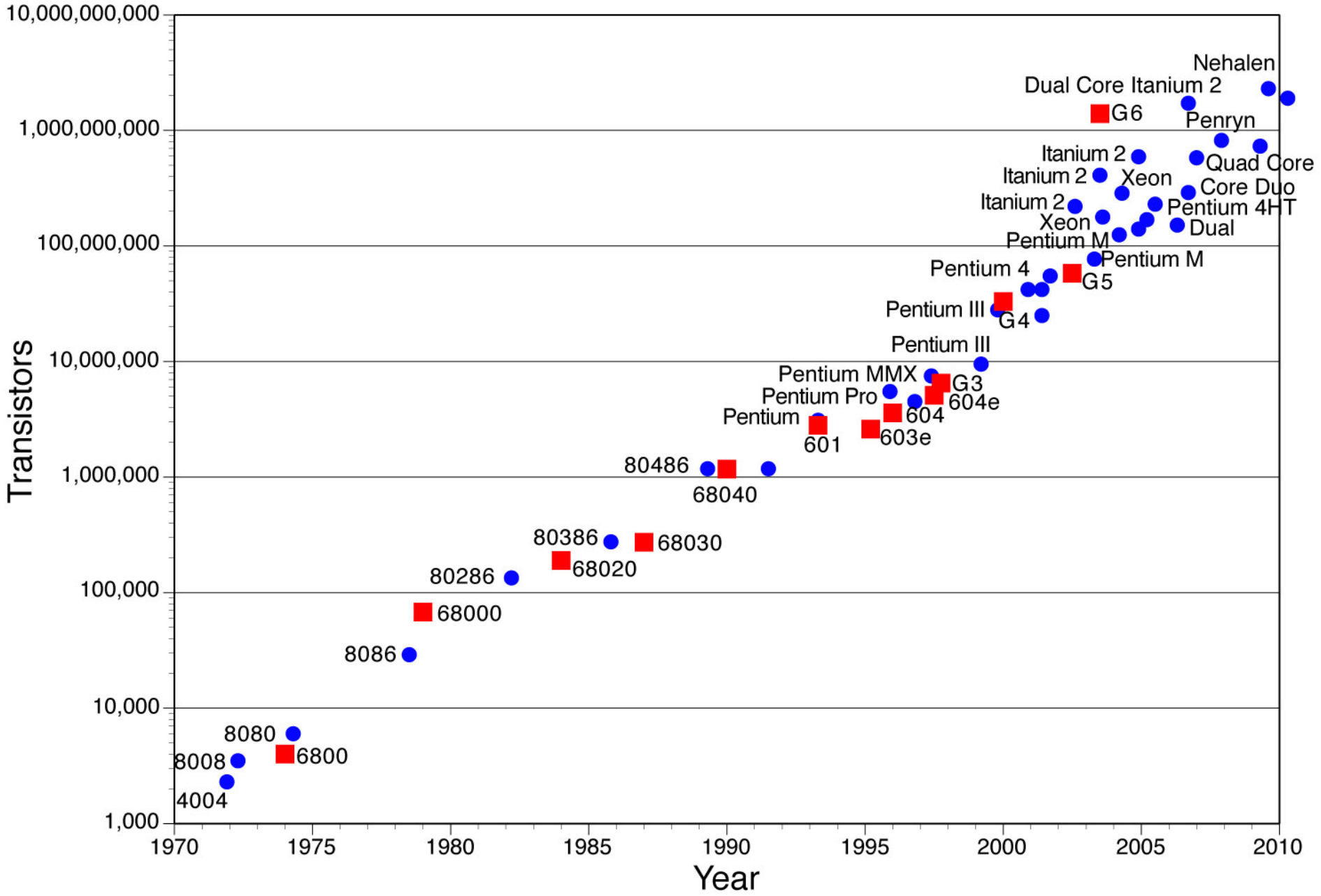
Moore's Law

- Definition:
  - TechDictionary
    - The logic density of silicon has approximately doubled every year since the invention of the silicon chip. This means the amount of information that can be stored on a chip of the same siz





Moore's Law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Dual Core Itanium 2
G6
Penryn
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Quad Core
Itanium 2
Xeon
Core Duo
Itanium 2
Pentium 4HT
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Dual
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Pentium M
Pentium 4
G5
Pentium III
G4
Pentium III
Pentium MMX
G3
Pentium Pro
604e
Pentium
604
601
603e
80486
68040
80386
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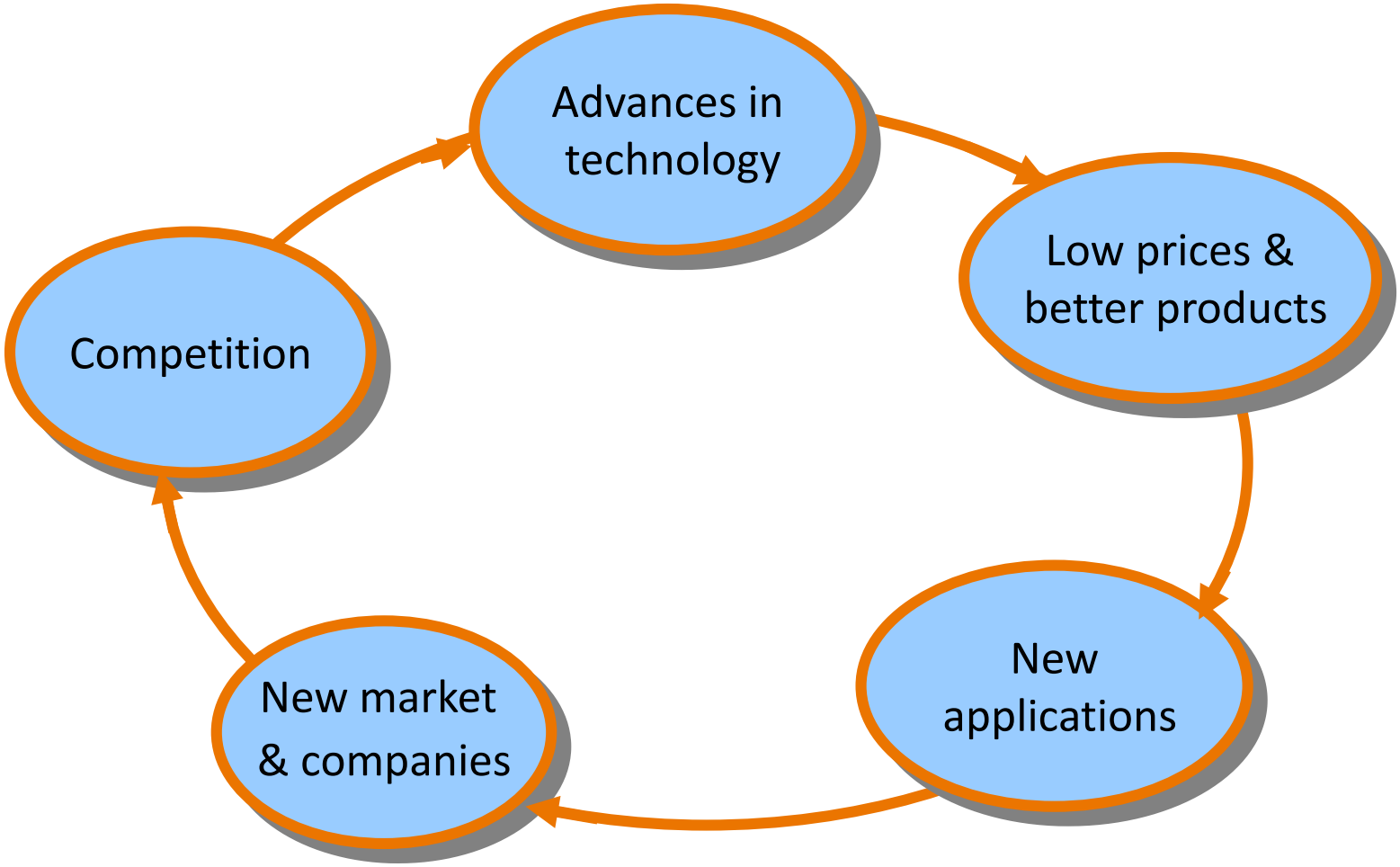
68020
80286
68000
8086
8080
6800
8008
4004

Virtuous Circle

- A result of Moore's law



Laws of Software

- Tannenbaum:

  "Software is a gas. It expands to fill the container holding it"

  - Meaning:
    - SW continues to acquire features that demand faster processors, bigger memories, & more i/o capacities

- Niklaus Wirth:
  - "Software gets slower faster than hardware gets faster"

Program Performance

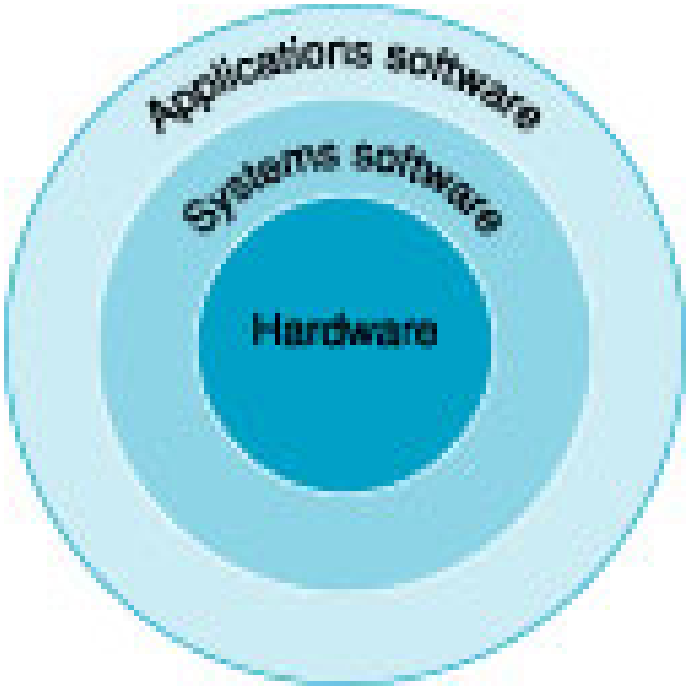
- Performance in the 1970's:
  - Minimize memory space to make programs fast
- Performance now:
  - Performance depend on efficient algorithms, compilers, & computer hardware
    - Memory in hierarchical structure (Cache,…)
    - Parallel processors
    - Programmers need to more knowledge of computer organization

Program Performance

Component	Effect on performance
Algorithm	Determines number of source code statements & I/O operations
Programming language, Compilers, & Architecture	Determine number of machine instructions
Processor & memory	Determine how fast instructions can execute
I/O system (HW & OS)	Determines how fast I/O operations may be executed

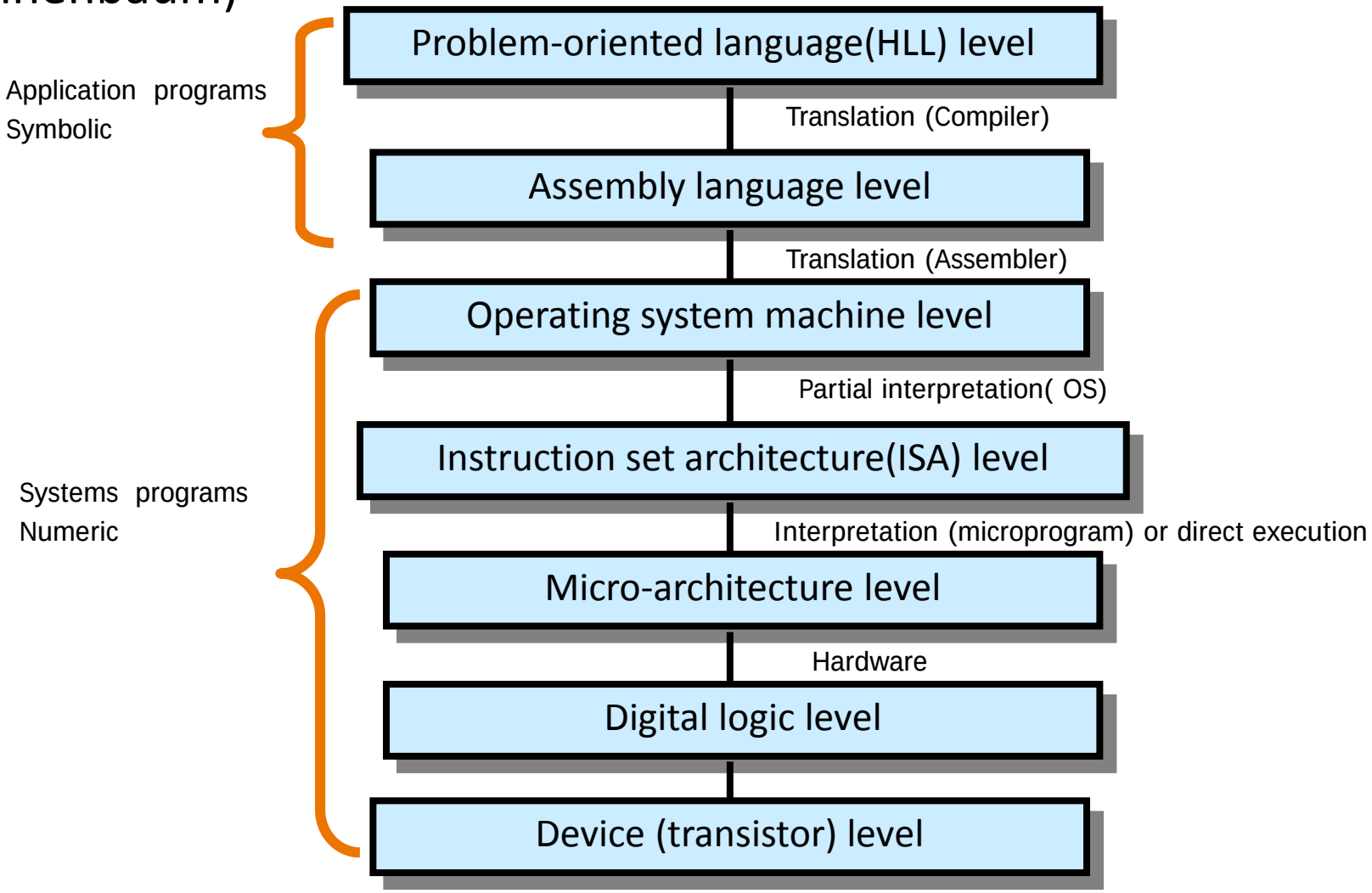
Below Your Program

- Several software layers are organized in hierarchical fashion
  - In complex applications there could be multiple layers of application software



Another HW/SW Hierarchy

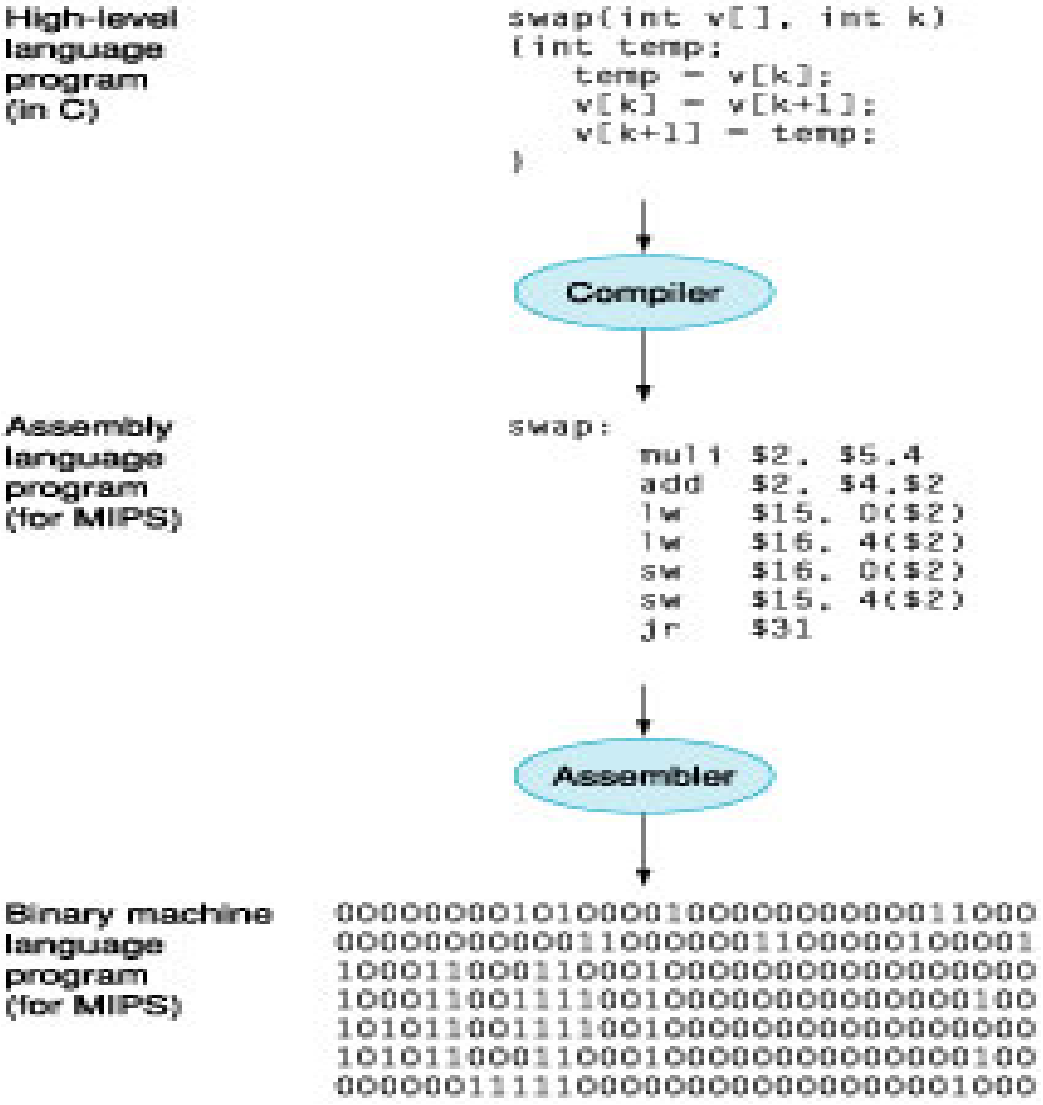
- (Tannenbaum)



Language Evolution

- Machine language
- Assembly language
- High-level languages
- Subroutine libraries
- There is a large gap between what is convenient for computers & what is convenient for humans
- Translation/Interpretation is needed between both

Language Evolution



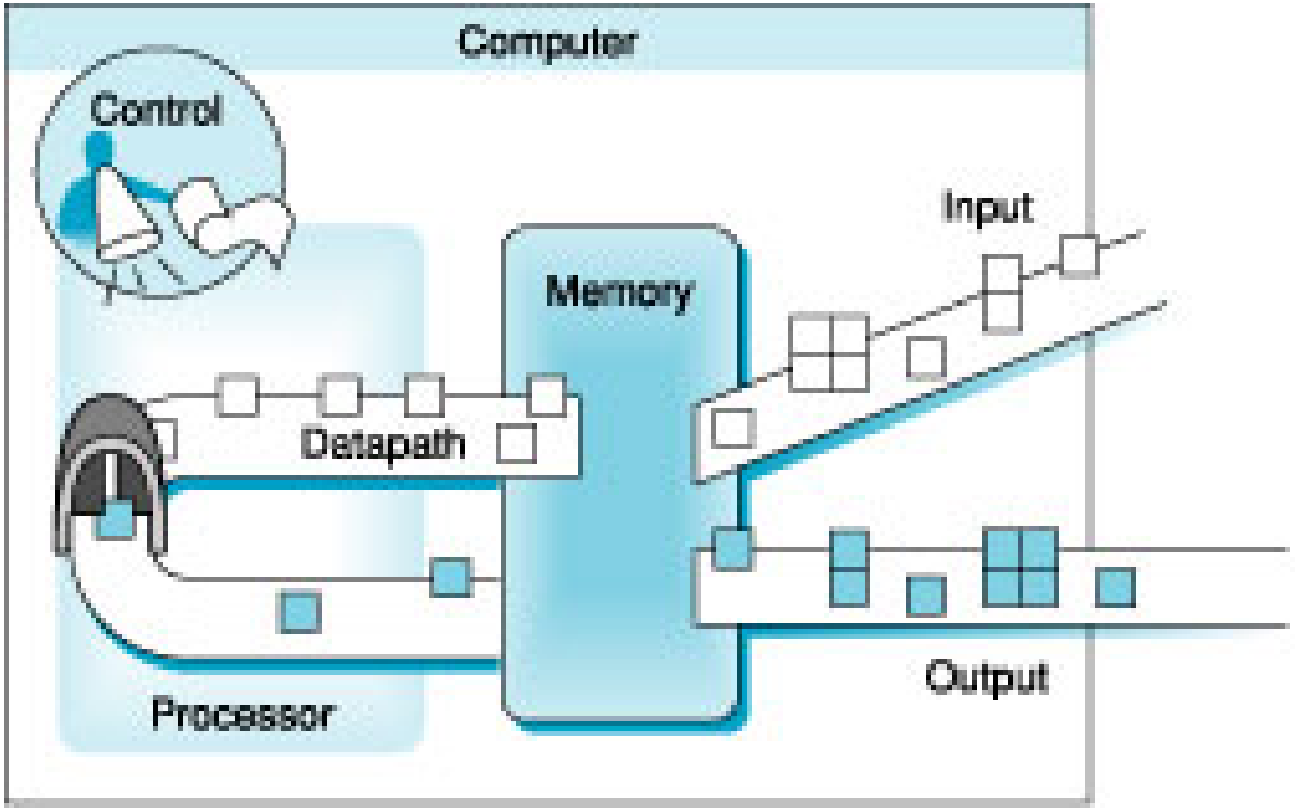
Organization vs. Architecture

- Architecture ≅ Specification
  - Attributes visible to the programmer
  - Attributes:
    - Instruction set
    - Number of bits representing data
    - I/O mechanism
    - Addressing modes used
  - Has direct impact on logical program execution

Organization vs. Architecture

- Organization ≅ Implementation
  - Operational units and their interconnection that realizes the architecture
  - Attributes:
    - HW details
    - Control signals
    - I/O interfaces
    - Memory technology used

Computer Components

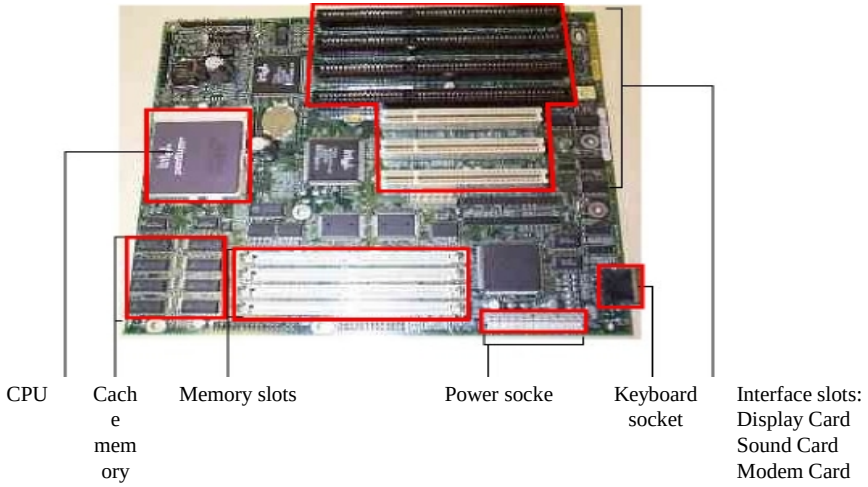


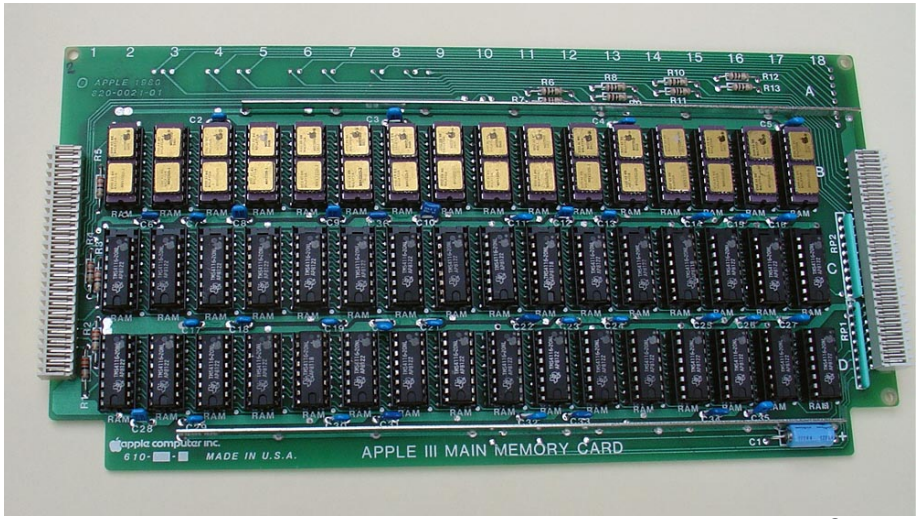
Memory Categories

- Volatile memory
  - Loses information when power is switched-off
  - RAM
- Non-volatile memory
  - Keeps information when power is switched-off
  - Optical & magnetic disks
  - Magnetic tape

Volatile Memory Types

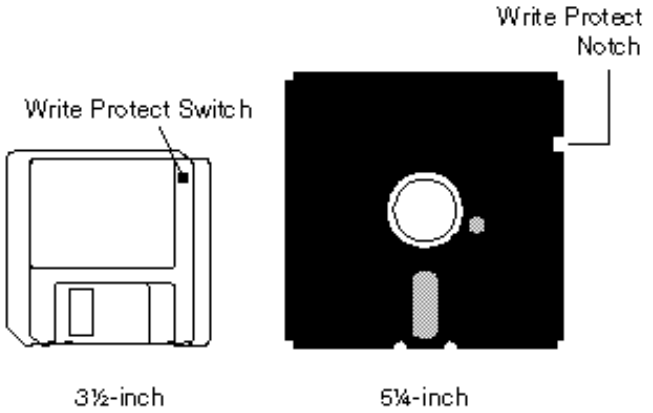
- Cache:
  - Fast but expensive
  - Smaller capacity
  - Placed closer to the processor
- Main memory
  - Less expensive
  - More capacity
  - Slower

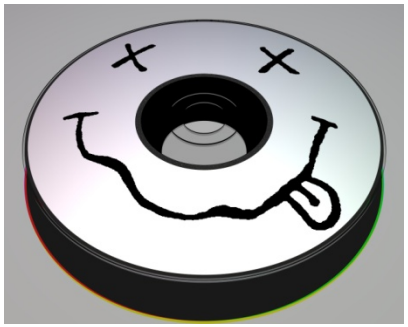


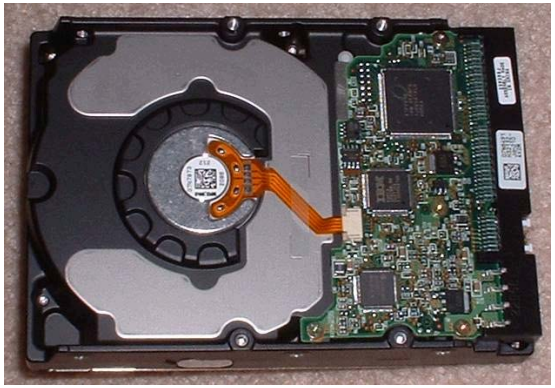


Non-volatile Memory Types

- Secondary memory
  - Low cost
  - Very slow
  - Unlimited capacity
- Types
  - Diskettes
  - CD-ROMS
  - Hard disk
  - Flash Drives
  - Who knows what comes next??







Input-Output (I/O)

- I/O devices have the hardest organization
  - Wide range of speeds
    - Graphics vs. keyboard
  - Wide range of requirements
    - Speed
    - Standard
    - Cost . . .
  - Least amount of research done in this area

Instructions

- Instruction:
  - Webopedia
    - A basic command. The term *instruction* is often used to describe the most rudimentary programming commands. For example, a computer's *instruction set* is the list of all the basic commands in the computer's machine language
- Instruction set:
  - Complete set of instructions used by a machine

Instruction Set Architecture (ISA)

- Specification
- Abstract interface between the HW and lowest-level SW.
- Encompasses information needed to write machine-language programs including
  - Instructions
  - Memory size
  - Registers used

Instruction Set Architecture (ISA)

- ISA is considered part of the SW
- Several implementations for the same ISA can exist
- Modern ISA's:
  - 80x86/Pentium/K6
  - PowerPC
  - DEC Alpha
  - MIPS
  - SPARC
  - HP
  - Athlon
- We are going to study MIPS