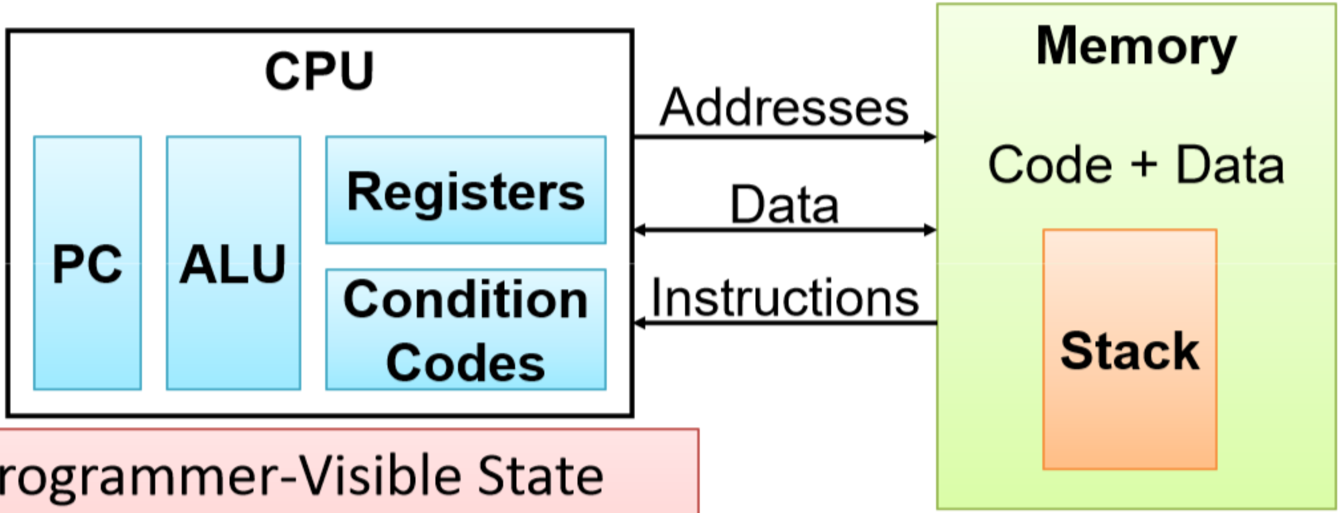
Computer Abstractions and Technology

Dr. Prasenjit Chanak

Department of Computer Science and Engineering
Indian Institute of Technology (BHU), Varanasi
UP, 221005

The Abstract Machine



- Programmer-Visible State
  - PC   Program Counter
  - Register File
    - Heavily used data
  - Condition Codes

- □ Memory
  - Byte array
  - Code + data
  - stack

Abstraction

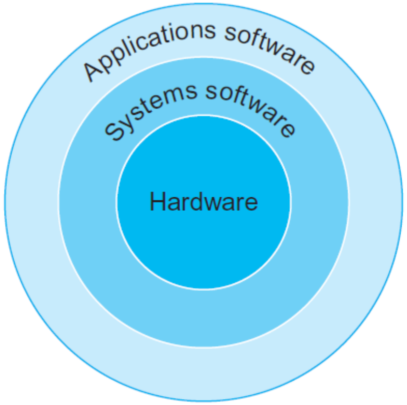
- A typical application, such as a word processor or a large database system, may consist of millions of lines of code and rely on sophisticated soft ware libraries that implement complex functions in support of the application
- The hardware in a computer can only execute extremely simple low-level instructions
- To go from a complex application to the simple instructions involves several layers of soft ware that interpret or translate high-level operations into simple computer instructions
- **Systems soft ware:** Soft ware that provides services that are commonly useful, including operating systems, compilers, loaders, and assemblers
- There are many types of systems soft ware, but two types of systems soft ware are central to every computer system today:
    - Operating system
    - Compiler

Contd.

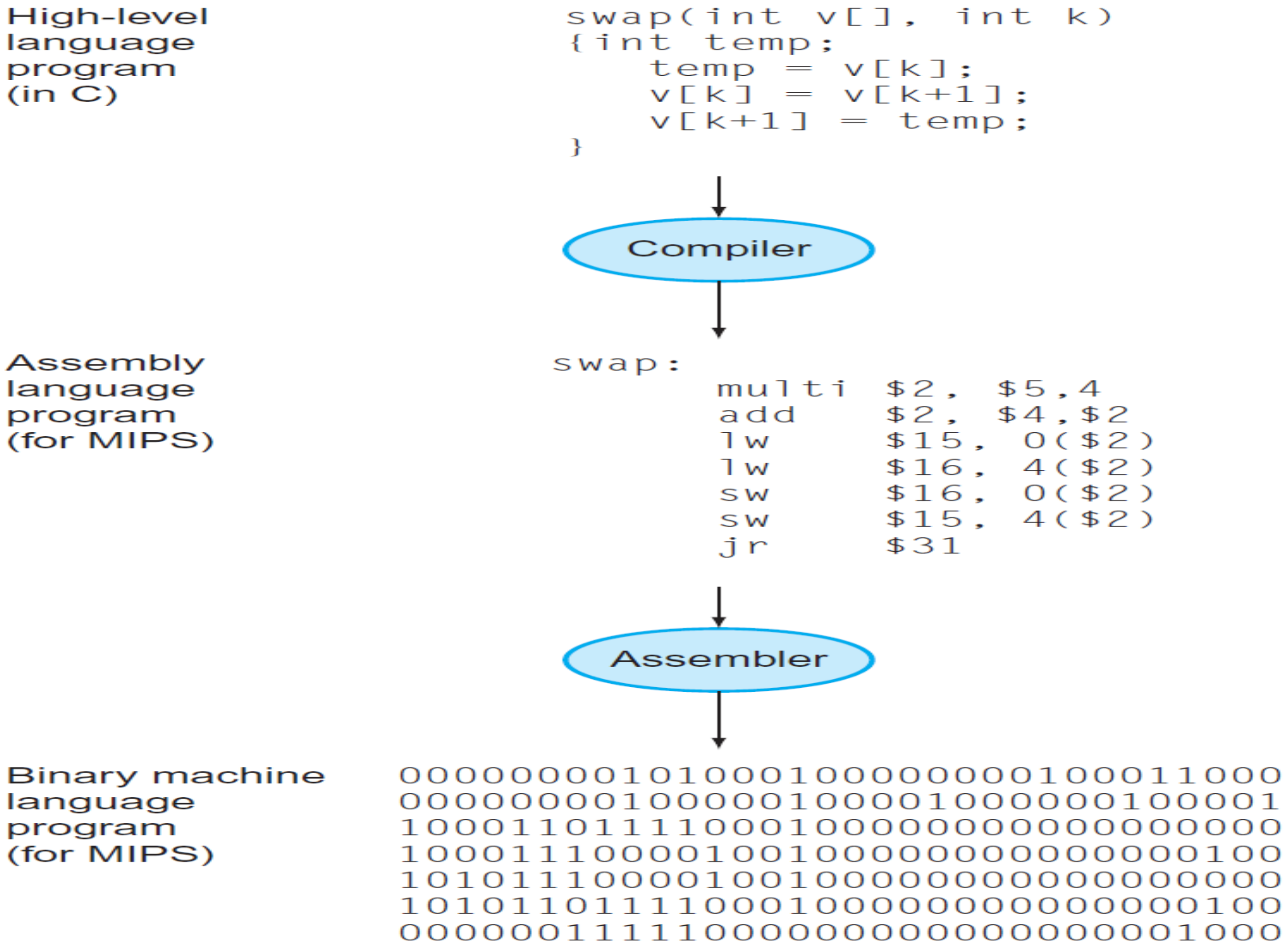
- An **operating system** interfaces between a user’s program and the hardware and provides a variety of services and supervisory functions
- **Operating system:** Supervising program that manages the resources of a computer for the benefit of the programs that run on that computer.
- Among the most important functions are:
  - Handling basic input and output operations
  - Allocating storage and memory
  - Providing for protected sharing of the computer among multiple applications using it simultaneously
- Examples of operating systems in use today are Linux, iOS, and Windows

Contd.

- **Compilers** perform another vital function: the translation of a program written in a high-level language, such as C, C, Java, or Visual Basic into instructions that the hardware can execute
- Given the sophistication of modern programming languages and the simplicity of the instructions executed by the hardware, the translation from a high-level language program to hardware instructions is complex
- **Compiler:** A program that translates high-level language statements into assembly language statements



From a High-Level Language to the Language of Hardware



High-level language program (in C)

```
swap(int v[], int k)
{int temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
}
```

Assembly language program (for MIPS)

```
swap:
        multi $2, $5,4
        add   $2, $4,$2
        lw    $15, 0($2)
        lw    $16, 4($2)
        sw    $16, 0($2)
        sw    $15, 4($2)
        jr    $31
```

Binary machine language program (for MIPS)

```
00000000101000100000000100011000
00000000100000100001000000100001
10001101111000100000000000000000
10001110000100100000000000000100
10101110000100100000000000000000
10101101111000100000000000000100
00000011111000000000000000001000
```

From a High-Level Language to the Language of Hardware

- The easiest signals for computers to understand are *on* and *off* , and so the computer alphabet is just two letters
- The two symbols for these two letters are the numbers 0 and 1, and we commonly think of the computer language as numbers in base 2, or *binary numbers*
- **Binary digit** Also called a **bit**. One of the two numbers in base 2 (0 or 1) that are the components of information
- Computers are slaves to our commands, which are called **instructions**. Instructions, which are just collections of bits that the computer understands and obeys, can be thought of as numbers

From a High-Level Language to the Language of Hardware

- The first programmers communicated to computers in binary numbers, but this as so tedious that they quickly invented new notations that were closer to the way humans think
- At first, these notations were translated to binary by hand, but this process was still tiresome
- Using the computer to help program the computer, the pioneers invented programs to translate from symbolic notation to binary
- The first of these programs was named an **assembler**. This program translates a symbolic version of an instruction into the binary version

From a High-Level Language to the Language of Hardware

- The name coined for this symbolic language, still used today, is **assembly language**
- **Assembly language:** A symbolic representation of machine instructions
- In contrast, the binary language that the machine understands is the **machine language**
- **Machine language:** A binary representation of machine instructions
- Programmers today owe their productivity—and their sanity—to the creation of **high-level programming languages** and compilers that translate programs in such languages into instructions
- **High-level programming language:** A portable language such as C, C, Java, or Visual Basic that is composed of words and algebraic notation that can be translated by a compiler into assembly language

Instruction Set Architecture

- **Instruction set architecture** Also called **architecture**. An abstract interface between the hardware and the lowest-level soft ware that encompasses all the information necessary to write a machine language program that will run correctly, including instructions, registers, memory access, I/O, and so on
- Typically, the operating system will encapsulate the details of doing I/O, allocating memory, and other low-level system functions so that application programmers do not need to worry about such details
- The combination of the basic instruction set and the operating system interface provided for application programmers is called the **application binary interface (ABI)**

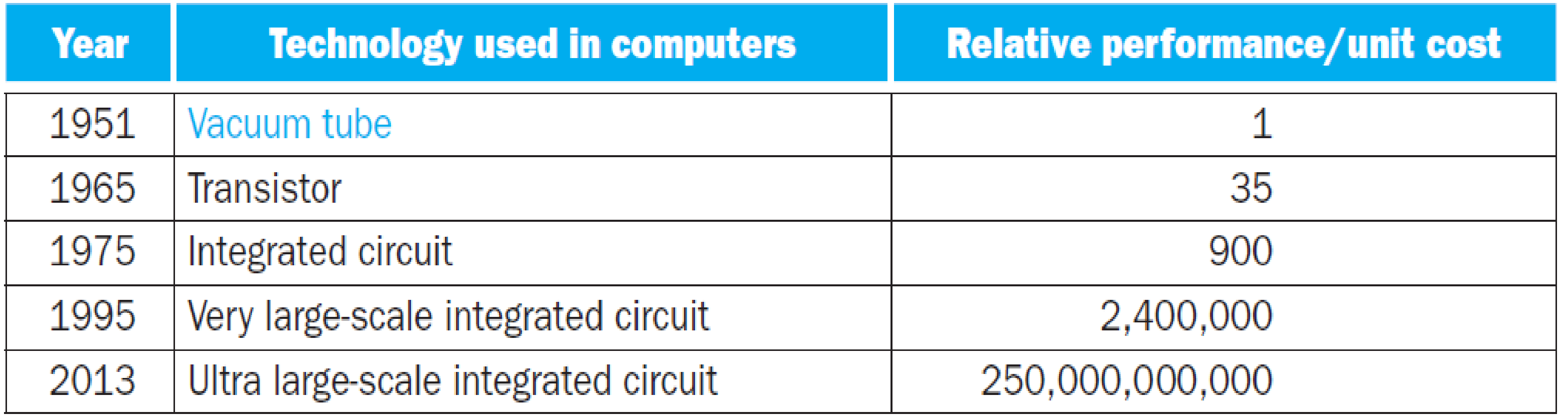
Instruction Set Architecture

- An instruction set architecture allows computer designers to talk about functions independently from the hardware that performs them
- Computer designers distinguish architecture from an **implementation** of an architecture along the same lines: an implementation is hardware that obeys the architecture abstraction

A Safe Place for Data

- **Volatile memory:** Storage, such as DRAM, that retains data only if it is receiving power
- **Nonvolatile memory:** A form of memory that retains data even in the absence of a power source and that is used to store programs between runs. A DVD disk is nonvolatile
- **Main memory** also called **primary memory**. Memory used to hold programs while they are running; typically consists of DRAM in today's computers
- **Secondary memory** Nonvolatile memory used to store programs and data between runs; typically consists of flash memory in PMDs and magnetic disks in servers
- **Magnetic disk** also called **hard disk**. A form of nonvolatile secondary memory composed of rotating platters coated with a magnetic recording material. Because they are rotating mechanical devices, access times are about 5 to 20 milliseconds

Technologies for Building Processors and Memory

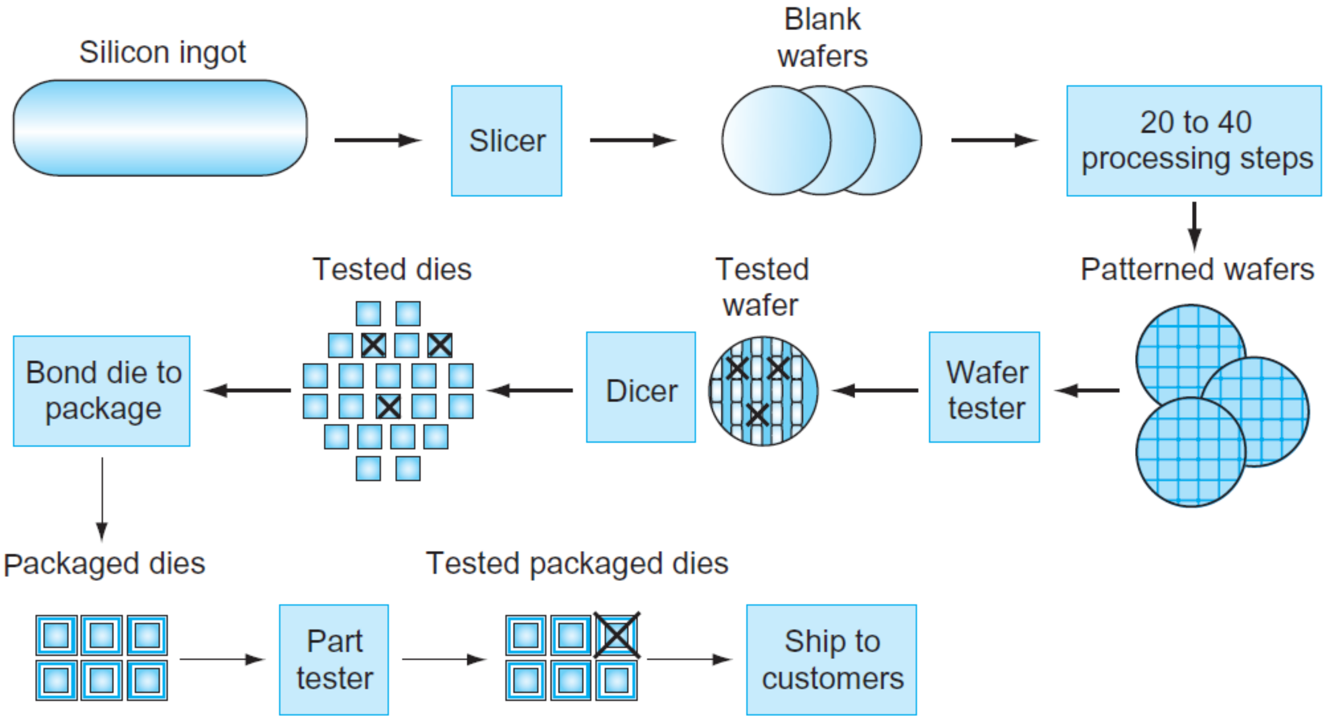


Year	Technology used in computers	Relative performance/unit cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit	900
1995	Very large-scale integrated circuit	2,400,000
2013	Ultra large-scale integrated circuit	250,000,000,000

- A **transistor** is simply an on/off switch controlled by electricity. The *integrated circuit* (IC) combined dozens to hundreds of transistors into a single chip
- **Very large-scale integrated (VLSI) circuit** A device containing hundreds of thousands to millions of transistors
- **Silicon** A natural element that is a semiconductor
- **Semiconductor** A substance that does not conduct electricity well

Technologies for Building Processors and Memory

- **Silicon crystal ingot:** A rod composed of a silicon crystal that is between 8 and 12 inches in diameter and about 12 to 24 inches long
- **Wafer** A slice from a silicon ingot no more than 0.1 inches thick, used to create chips



Silicon ingot
Slicer
Blank wafers
20 to 40 processing steps
Patterned wafers
Wafer tester
Tested wafer
Dicer
Tested dies
Bond die to package
Packaged dies
Part tester
Tested packaged dies
Ship to customers