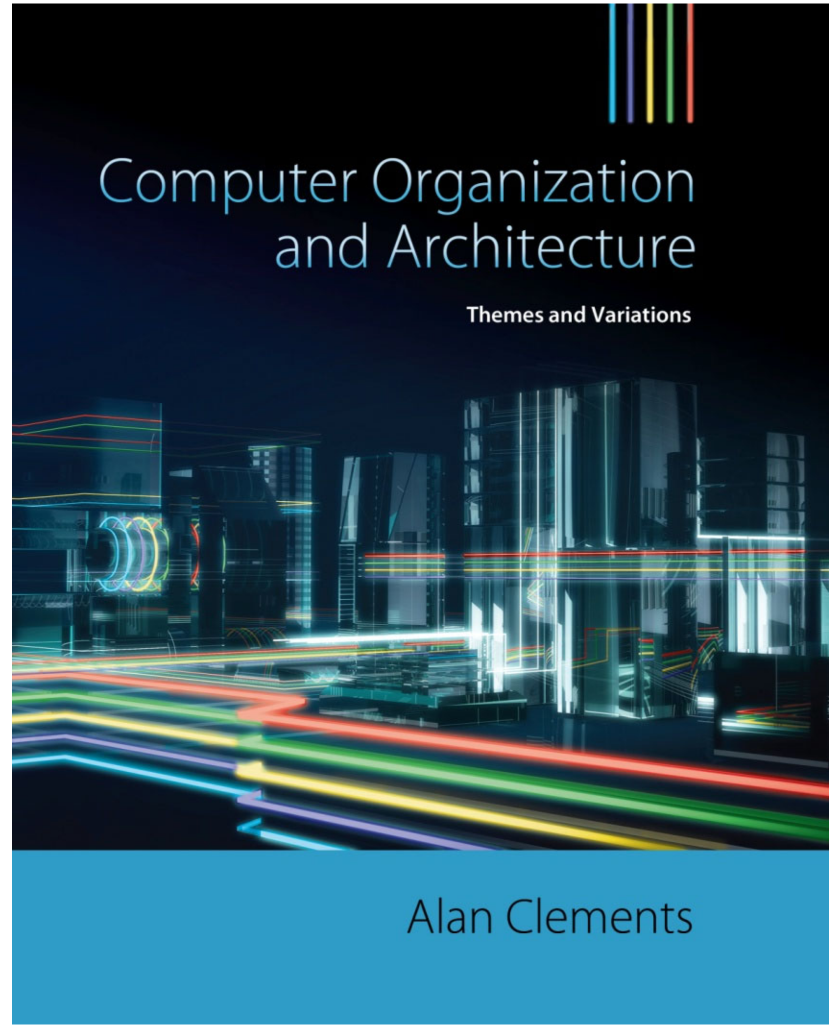
Part 1

CHAPTER 1

Computer Systems Architecture



CENGAGE Learning

Structure of the Book (5 Parts)

Part I ***The Beginning***

introduces the concepts, history and underlying technology of digital computers.

1. ***Computer Systems Architecture***
2. ***Computer Arithmetic and Digital Logic***

Part II ***Instruction Set Architectures (ISAs)***

looks at the ***programming model*** of a computer and
introduces the *register model* of a computer, its *instruction types*, and the *addressing modes* of a typical microprocessor.

3. ***Architecture and Organization***
4. ***Instruction Set Architectures - Breadth and Depth***
5. Computer Architecture and Multimedia

Part III ***Organization and Efficiency***

describes how we measure the performance of computers.

6. Performance - Meaning and Metrics
7. Processor Control
8. Beyond RISC: Superscalar, VLIW, and Itanium

Structure of the Book

Part IV ***The System***

covers the other parts of a computer required to ***convert the microprocessor chip into a complete system***; for example, *peripheral subsystems* and the wide range of *memory systems*, *storage devices*, and *buses* available to the computer systems' designer.

9. Cache Memory and Virtual Memory
10. Main Memory
11. Secondary Storage
12. Input/output

Part V ***Processor-Level Parallelism***

goes beyond the single-processor computer and introduces the notion of ***computers with multiple processors***.

13. Processor-Level Parallelism

Computer Architecture

- A computer is characterized by its *instruction set architecture* (***ISA***)
- An ***ISA*** is an *abstract entity* because it does not consider the specific design or implementation of a computer
- An ***ISA*** is concerned with the computer's *register set*, *instruction set*, and *addressing modes*
- An ***ISA*** defines the model of a computer *from the programmer viewpoint*
- The computer's assembly language embodies its ***ISA***

Computer Organization

- Computer *organization* is concerned with the implementation of an ISA
- Any given ISA can have many different organizations
  - Examples

Should be "***organization***", not "***architecture***", as in the original slide.

- Computer manufacturers regularly *modify the organization* of a processor while *keeping its ISA essentially constant*
- Today, a computer's organization is often referred to as its *microarchitecture*
- In **theory**, ***architecture*** and ***organization*** are orthogonal; that is, they are entirely independent
- You could say that
  - ***architecture*** tells you ***what*** a computer does and
  - ***organization*** tells you ***how*** it does it

Computer Structure

- Figure 1.1 describes the structure of a computer.
- The term computer describes the entire system.
- The CPU is the *Central Processing Unit* that reads instructions and executes them.
- The CPU is often synonymous with microprocessor.
- Modern microprocessors usually include cache (high-speed) memory on-chip.
- A key component of computers is the bus (or family of busses) that moves information around the computer between different functional units (data highway).

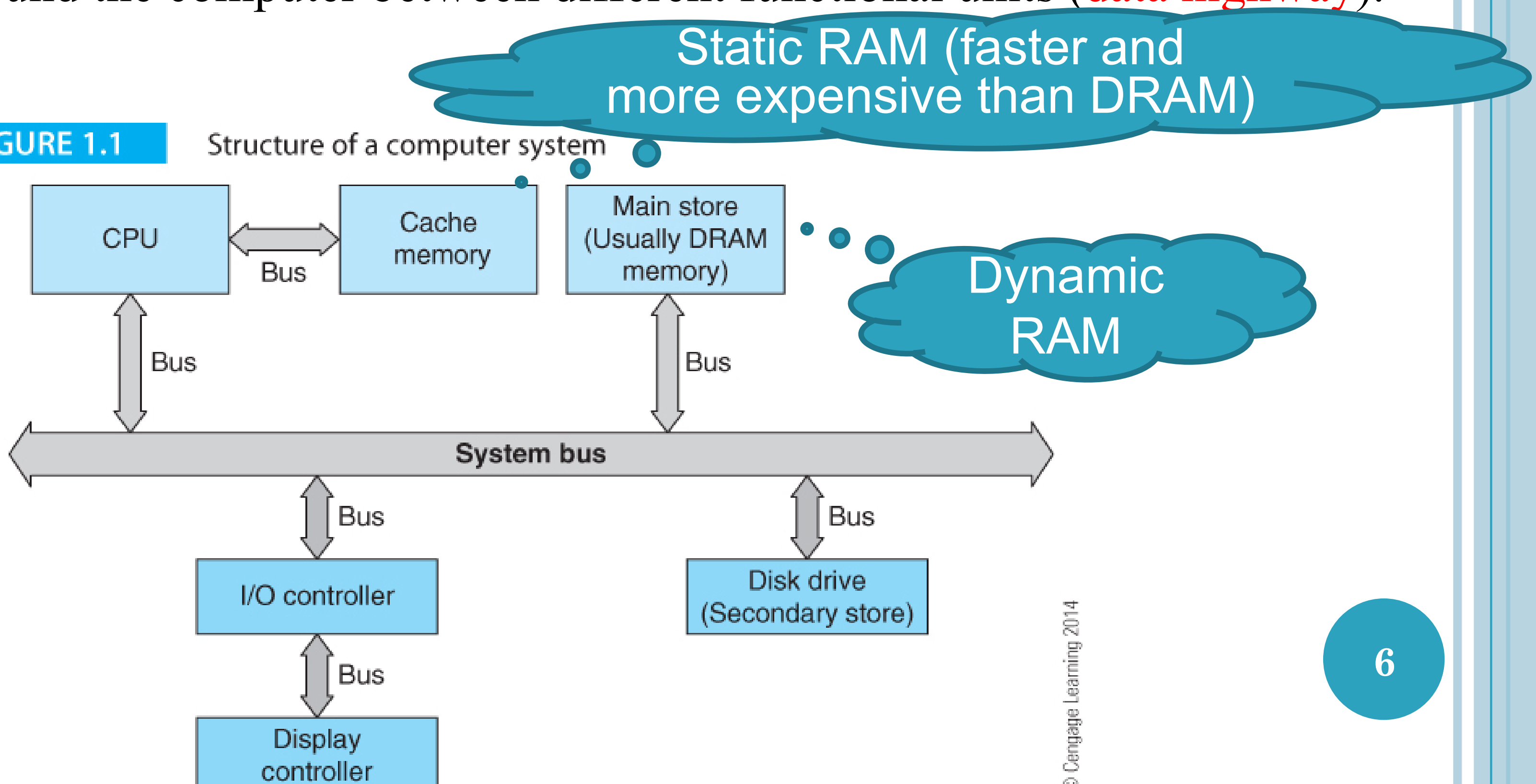


FIGURE 1.1 Structure of a computer system

Processor Register

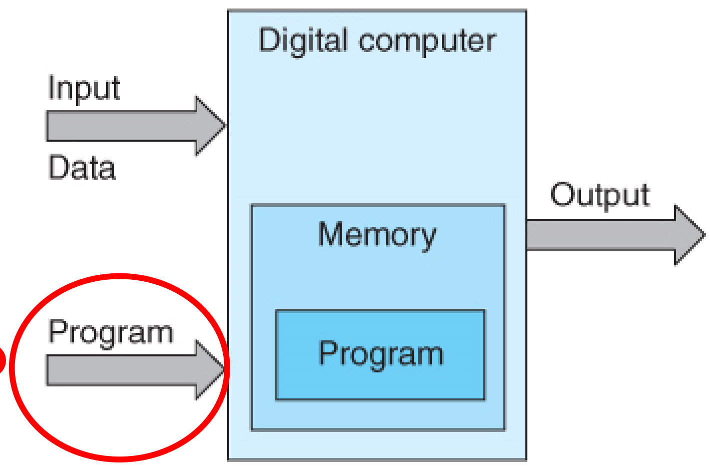
- A processor register is a memory element that holds a single unit data (a word of data).
- A processor register is specified in terms of the number of bits it holds, which is typically, 8, 16, 32, or 64.
  - Currently, most of computers either have 32-bit or 64-bit-wide registers.
- Each processor has a specified number or registers.
- There is no fundamental difference between
  - a register and
  - a word in memory.
- The practical difference is that registers are located within the CPU
  - can be accessed more rapidly than other memories.

Computer Types

- Computers are either dedicated or general-purpose.
  - A dedicated computer solves only one class of problems (e.g., a computer in a calculator, a cruise speed control, or washing machine).
  - A general-purpose computer can be programmed to solve any problem.
- Figure 1.2 describes the structure of a general-purpose computer.
- A key feature of the general-purpose computer is that *the program* and *its data* are held in the same memory.
- Such a computer is called a **von Neumann machine**.

The ability to freely change the program is the main difference between a dedicated and a general-purpose computers.

FIGURE 1.2 The general-purpose computer

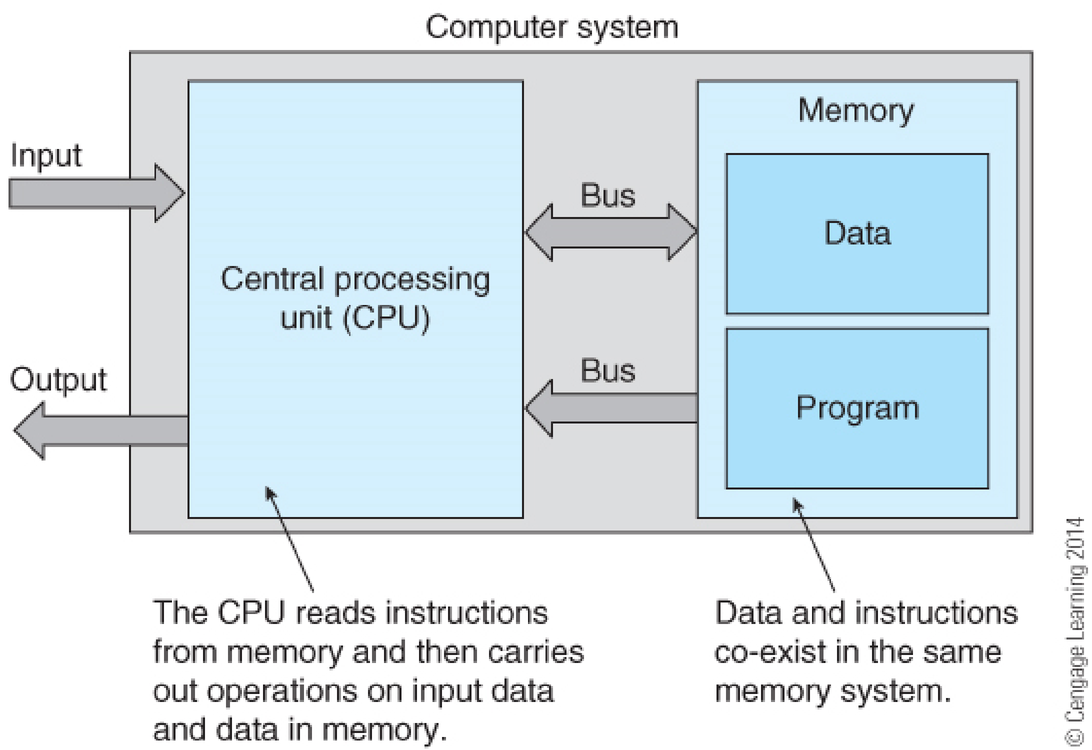


General-purpose digital machine. By changing the program, this machine can carry out any task capable of being performed by a computer.

Stored Program Computer

- Figure 1.3 emphasizes the nature of the stored program computer.
  - The CPU reads instructions from memory and then
  - carries out operations on input data and data in memory
  - Data and instructions co-exist in the same memory system

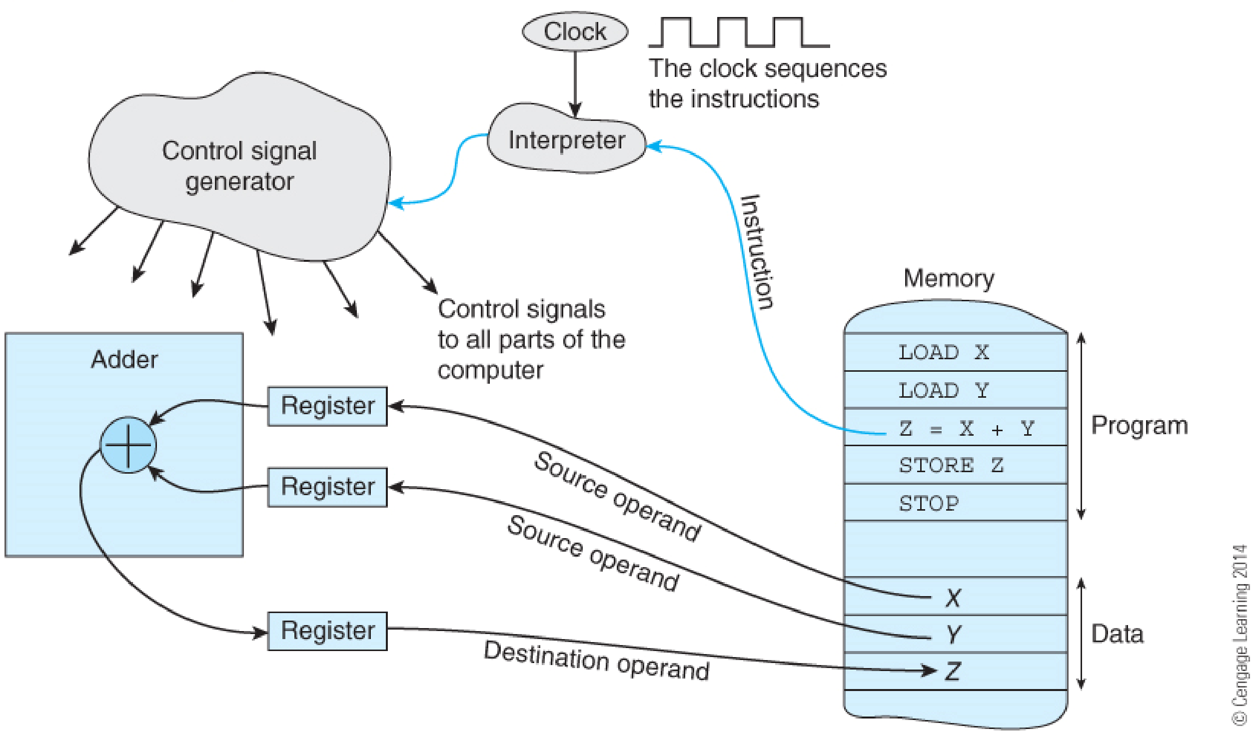
FIGURE 1.3 Structure of the stored program computer



Stored Program Computer

- Figure 1.4 illustrates the operation of a stored program, where the operation Z = X + Y is read from memory, interpreted and used to add X and Y to create Z.
- A clock (a stream of pulses) sequences all operations in a computer.
- All events in a computer are triggered by clock pulses.

FIGURE 1.4 Executing a program



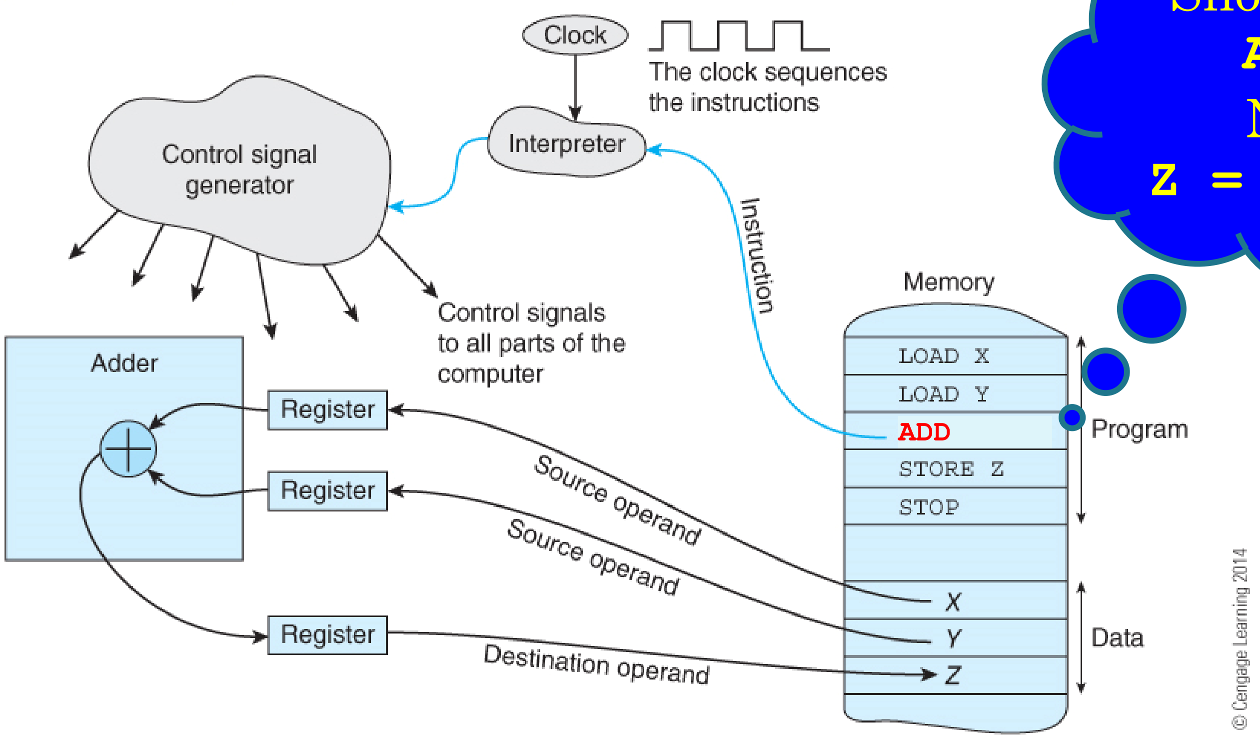
Stored Program Computer

- LOAD moves data from memory to a register and
- STORE moves data from a register to memory.
- Z = X + Y performs a simple operation on data (addition).
- Memory is a bottleneck because
  - instructions have to flow from it.
  - Data has to flow from it to take part in operations and
  - Data has to flow back to store the result.

How many memory access do we need to execute this program?

Should be **ADD** Not **Z = X + Y**

FIGURE 1.4 Executing a program



The Clock

- Most digital electronic circuits have a clock that generates a continuous stream of regularly spaced electrical pulses.
- It's called a clock because the pulses are used to time or sequence all events within the computer; for example, a processor might start executing a new instruction each time a clock pulse arrives.
- A clock is defined in terms of its *repetition rate* i.e., *frequency*.
- Typical clock frequencies in computers range from 1 MHz to about 4.5 GHz.
- Clocks are also defined in terms of the width of a clock pulse, which is the reciprocal of its frequency; that is $f = 1/T$;
  for example a ***1 MHz*** clock has a duration of ***1 μs (i.e., 10^{-6}s)***,
  and a ***1 GHz*** clock has a duration of ***1 ns (i.e., 10^{-9}s)***.
- A ***5 GHz*** clock has a period of ***0.2 ns*** or simply ***200 ps*** (picoseconds)—***1 ps = 10^{-12} s***
- To feel how a ***ps*** is small, light travels approximately ***6 cm*** in ***200 ps***.