CMSC104

- Lecture 2
- Remember to report to the lab on Wednesday

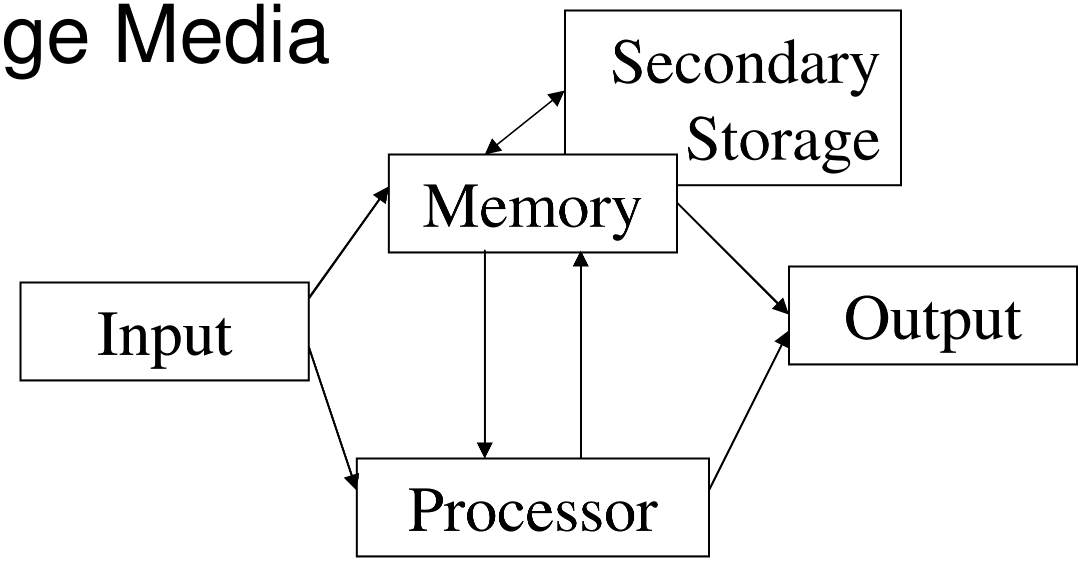
Machine Architecture and Number Systems

Topics

- Major Computer Components
- Bits, Bytes, and Words
- The Decimal Number System
- The Binary Number System
- Converting from Binary to Decimal
- Converting from Decimal to Binary
- The Hexadecimal Number System

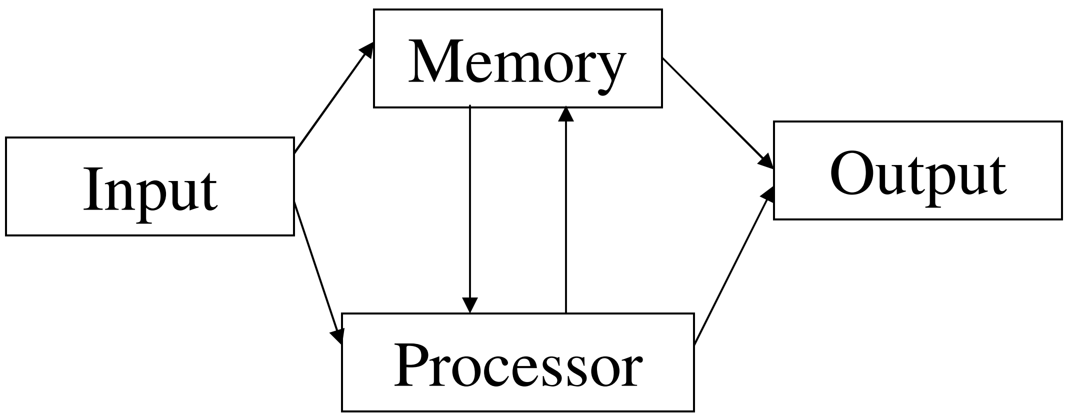
Major Computer Components

- Central Processing Unit (CPU)
- Bus
- Main Memory (RAM)
- Secondary Storage Media
- I / O Devices



Von Neumann Machine

- Most modern computers are considered to be stored-program computers or "von Neumann" machines, named after the famed computer scientist, John von Neumann.
- Both data and programs are stored in the computer



First Computer?

- Charles Babbage – The Father of Computers
  - Difference Engine (1822)
  - Analytical Engine – external program computer
- Ada Augusta Byron – The First Programmer
  - Countess of Lovelace; daughter of Lord Byron
  - Wrote programs for the Analytical Engine
  - The computer language "Ada", designed for the U.S. Department of Defense, was named so, in her honor.

Schematic Diagram of a Computer

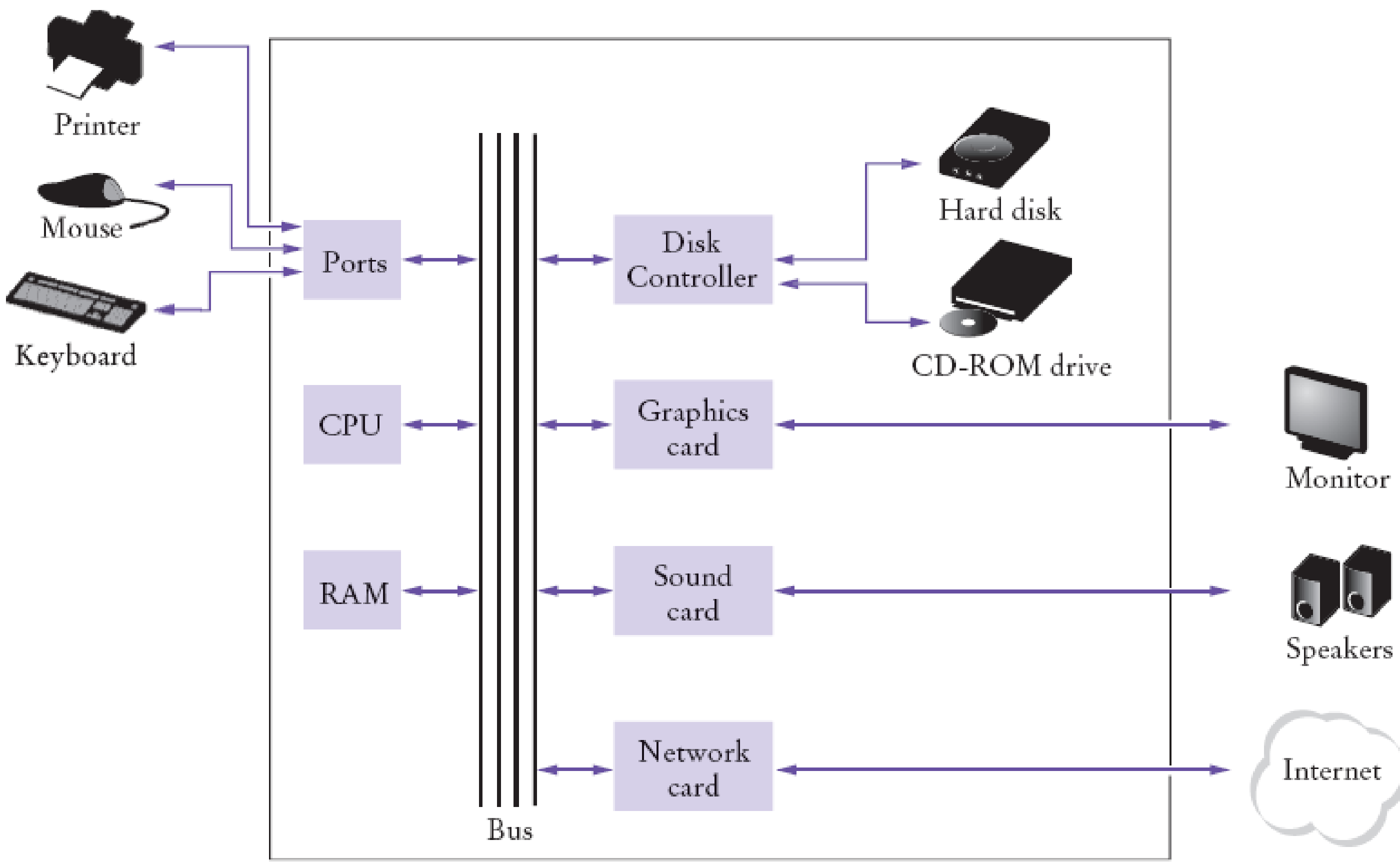


Figure 5 Schematic Diagram of a Computer

Diagram taken from Java Concepts, Fourth Edition

The CPU

- Central Processing Unit
- The “brain” of the computer
- Controls all other computer functions
- In PCs (personal computers) also called the microprocessor or simply processor.

The Bus

- Computer components are connected by a bus.
- A bus is a group of parallel wires that carry control signals and data between components.

Main Memory

- Main memory holds information such as computer programs, numeric data, or documents created by a **word processor**.
- Main memory is made up of **capacitors.**
- If a capacitor is charged, then its state is said to be **1,** or **ON**.
- We could also say the **bit is set**.
- If a capacitor does not have a charge, then its state is said to be **0,** or **OFF**.
- We could also say that **the bit is reset** or **cleared**.

Main Memory (cont.)

- Memory is divided into **cells**, where each cell contains 8 **bits** (a 1 or a 0). Eight bits is called a **byte**.
- Each of these cells is uniquely numbered.
- The number associated with a cell is known as its **address**.
- Main memory is **volatile** storage. That is, if power is lost, the information in main memory is lost.

Main Memory (cont.)

- Other computer components can
  - get the information held at a particular address in memory, known as a **READ,**
  - or store information at a particular address in memory, known as a **WRITE**.
- Writing to a memory location alters its contents.
- Reading from a memory location does not alter its contents.

Main Memory (cont.)

- All addresses in memory can be accessed in the same amount of time.
- We do not have to start at address 0 and read everything until we get to the address we really want (**sequential access**).
- We can go directly to the address we want and access the data (**direct** or **random access**).
- That is why we call main memory **RAM** (**Random Access Memory**).

Secondary Storage Media

- Disks -- floppy, hard, removable (random access)
- Tapes (sequential access)
- CDs (random access)
- DVDs (random access)
- Secondary storage media store files that contain
  - computer programs
  - data
  - other types of information
- This type of storage is called persistent (permanent) storage because it is non-volatile.

I/O (Input/Output) Devices

- Information input and output is handled by I/O (input/output) devices.
- More generally, these devices are known as peripheral devices.
- Examples:
  - monitor
  - keyboard
  - mouse
  - disk drive (floppy, hard, removable)
  - CD or DVD drive
  - printer
  - scanner

Bits, Bytes, and Words

- A bit is a single binary digit (a 1 or 0).
- A byte is 8 bits
- A word is 32 bits or 4 bytes
- Long word = 8 bytes = 64 bits
- Quad word = 16 bytes = 128 bits
- Programming languages use these standard number of bits when organizing data storage and access.
- What do you call 4 bits?
  (hint: it is a small byte)

Number Systems

- The on and off states of the capacitors in RAM can be thought of as the values 1 and 0, respectively.
- Therefore, thinking about how information is stored in RAM requires knowledge of the binary (base 2) number system.
- Let’s review the decimal (base 10) number system first.

The Decimal Number System

- The decimal number system is a positional number system.
- Example:

5 6 2 1

10^3 10^2 10^1 10^0

$1 \times 10^0 = 1$

$2 \times 10^1 = 20$

$6 \times 10^2 = 600$

$5 \times 10^3 = 5000$

The Decimal Number System

- The decimal number system is also known as base 10. The values of the positions are calculated by taking 10 to some power.
- Why is the base 10 for decimal numbers?
  - Because we use 10 digits, the digits 0 through 9.

The Binary Number System

- The binary number system is also known as base 2. The values of the positions are calculated by taking 2 to some power.
- Why is the base 2 for binary numbers?
  - Because we use 2 digits, the digits 0 and 1.

The Binary Number System

- The binary number system is also a positional numbering system.
- Instead of using ten digits, 0 - 9, the binary system uses only two digits, 0 and 1.
- Example of a binary number and the values of the positions:

1	0	0	1	1	0	1
2^6	2^5	2^4	2^3	2^2	2^1	2^0
64	32	16	8	4	2	1

Converting from Binary to Decimal

1 0 0 1 1 0 1

2^6 2^5 2^4 2^3 2^2 2^1 2^0

$2^0 = 1$	$2^4 = 16$
$2^1 = 2$	$2^5 = 32$
$2^2 = 4$	$2^6 = 64$
$2^3 = 8$	

$1 \times 2^0 = 1$

$0 \times 2^1 = 0$

$1 \times 2^2 = 4$

$1 \times 2^3 = 8$

$0 \times 2^4 = 0$

$0 \times 2^5 = 0$

$1 \times 2^6 = \underline{64}$

77_{10}

Converting from Binary to Decimal

Practice conversions:

<u>Binary</u>	<u>Decimal</u>
11101	
1010101	
100111	

Converting from Decimal to Binary

- Make a list of the binary place values up to the number being converted.
- Perform successive divisions by 2, placing the remainder of 0 or 1 in each of the positions from right to left.
- Continue until the quotient is zero.
- Example: 42_{10}

2^5	2^4	2^3	2^2	2^1	2^0
32	16	8	4	2	1
1	0	1	0	1	0

Converting from Binary to Decimal

Practice conversions:

Decimal	Binary
59	
82	
175	

Working with Large Numbers

0 1 0 1 0 0 0 0 1 0 1 0 0 1 1 1 = ?

- Humans can’t work well with binary numbers; there are too many digits to deal with.
- Memory addresses and other data can be quite large. Therefore, we sometimes use the **hexadecimal number system**.

The Hexadecimal Number System

- The hexadecimal number system is also known as base 16. The values of the positions are calculated by taking 16 to some power.
- Why is the base 16 for hexadecimal numbers ?
  - Because we use 16 symbols, the digits 0 through 9 and the letters A through F
  - Computer bus and computer graphics are just two of many that use hexadecimal.

The Hexadecimal Number System

Binary	Decimal	Hexadecimal	Binary	Decimal	Hexadecimal
0	0	0	1010	10	A
1	1	1	1011	11	B
10	2	2	1100	12	C
11	3	3	1101	13	D
100	4	4	1110	14	E
101	5	5	1111	15	F
110	6	6			
111	7	7			
1000	8	8			
1001	9	9			

The Hexadecimal Number System

- Example of a hexadecimal number and the values of the positions:

C	8	B	0	5	1
16^5	16^4	16^3	16^2	16^1	16^0

Often used with red-green-blue coloring in a two pair format

F	4	B	0	5	1
16^1	16^0	16^1	16^0	16^1	16^0

Hexadecimal: Colors

Decimal	Hexadecimal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

Examples:

F4B051=F4 30 5C
red green blue

F4 (red) = 15x16 + 4 = 240 + 4 = 244
30 (green) = 3x16 + 0 = 48 + 0 = 48
5C (blue) = 5x16 + 12 = 80 + 12 = 92

FFFF00 = FF FF 00
red green blue

FF (red) = 15x16 + 15 = 240 + 15 = 255
FF (green) = 15x16 + 15 = 240 + 15 = 255
00 (blue) = 0x16 + 0 = 0 + 0 = 0
which produces the color yellow!

Example of Equivalent Numbers

Binary: 1 0 1 0 0 0 0 1 0 1 0 0 1 1 1_2

Decimal: 20647_{10}

Hexadecimal: $50A7_{16}$

Notice how the number of digits gets smaller as the base increases.

Converting from Binary to Hex

- Because 16 is the equivalent of 2^4, it is easy to convert from binary to hex and vice-versa.
- Binary: 1101 0010 1111 0000
- Hex: 0x D 2 F 0

Converting from Binary to Octal

- Octal is another number system that is base 8.
- Because 8 is the equivalent of 2^3, it is easy to convert from binary to octal and vice-versa.
- Convert the following binary number to octal:
  - 01 101 001 011 110 000