Professional Diploma of Software Engineering

Computer Systems Principles & Programming (SE102)

Lecture 1

Course Administration

Dr. Ahmed Hamza

Department of Information Systems and Technology

Faculty of Graduate Studies for Statistical Research (FGSSR)

Cairo University

- Email: ah_Hamza@cu.edu.eg
- Office: FGSSR Main Building, 5th Floor, Room No. 521
- Office Hours: Monday (3-5 pm), Thursday (7-9 pm)

Course Motivation

☞ Learn students the principles of computer systems and their programming.

What Is A Computer?

- A computer is a **programmable machine** that receives input, stores and manipulates data, and provides output in a useful format

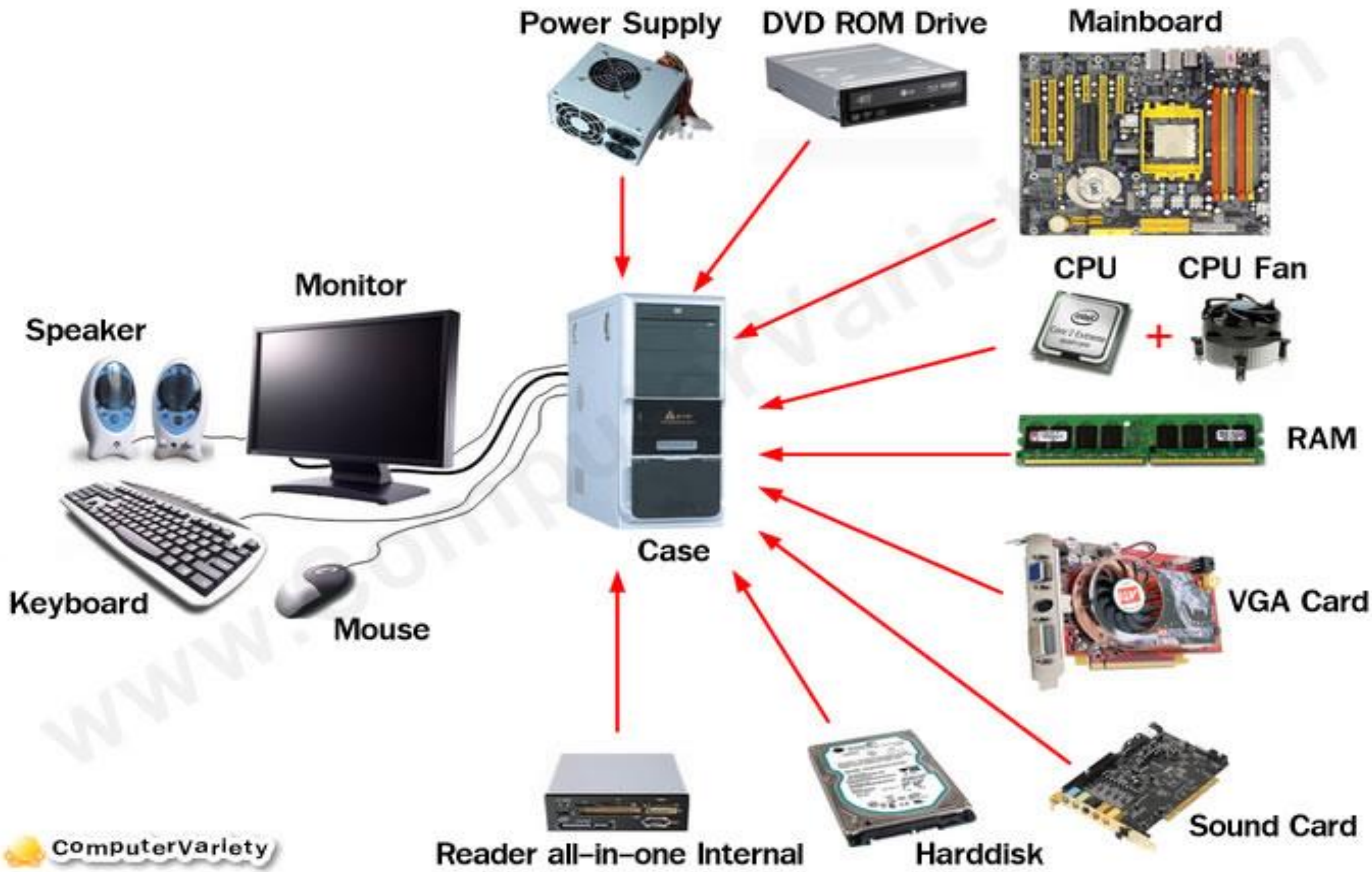
- The **“machine”** part of the computer is called the **hardware**, while the **“programmable”** part is called the **software**

- The specialization field of **computer systems engineering** primarily focus on the design and manufacturing of computer hardware

- The specialization field of **computer software engineering** primarily focus on the design and implementation of software

Hardware Versus Software

- The term hardware refers to the physical components of a computer



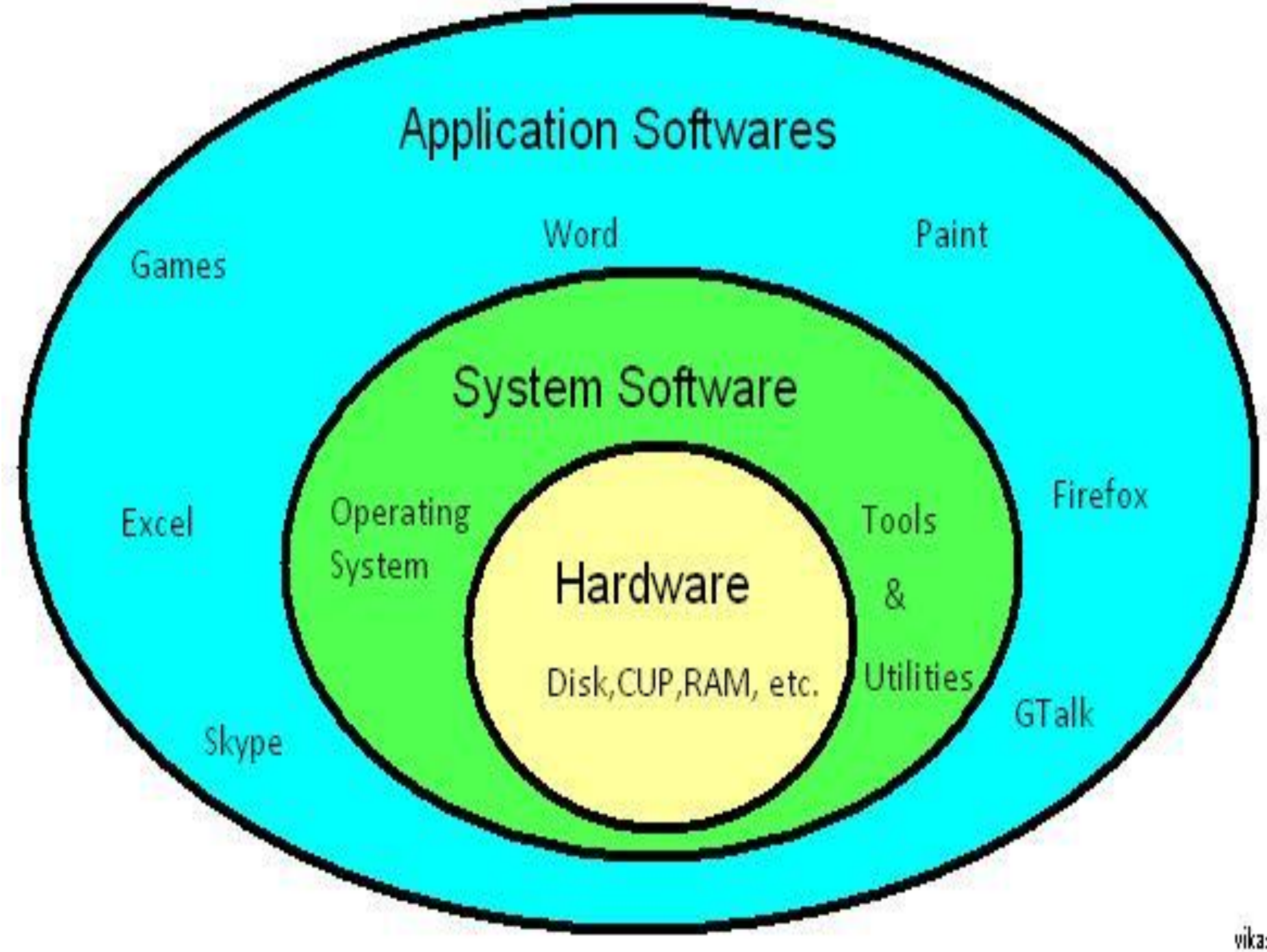
Hardware Versus Software (2)

- The term software refers to the programs that execute on a computer

1. **System Software (Operating System):** is designed to operate the computer's hardware and to provide and maintain a platform for running applications

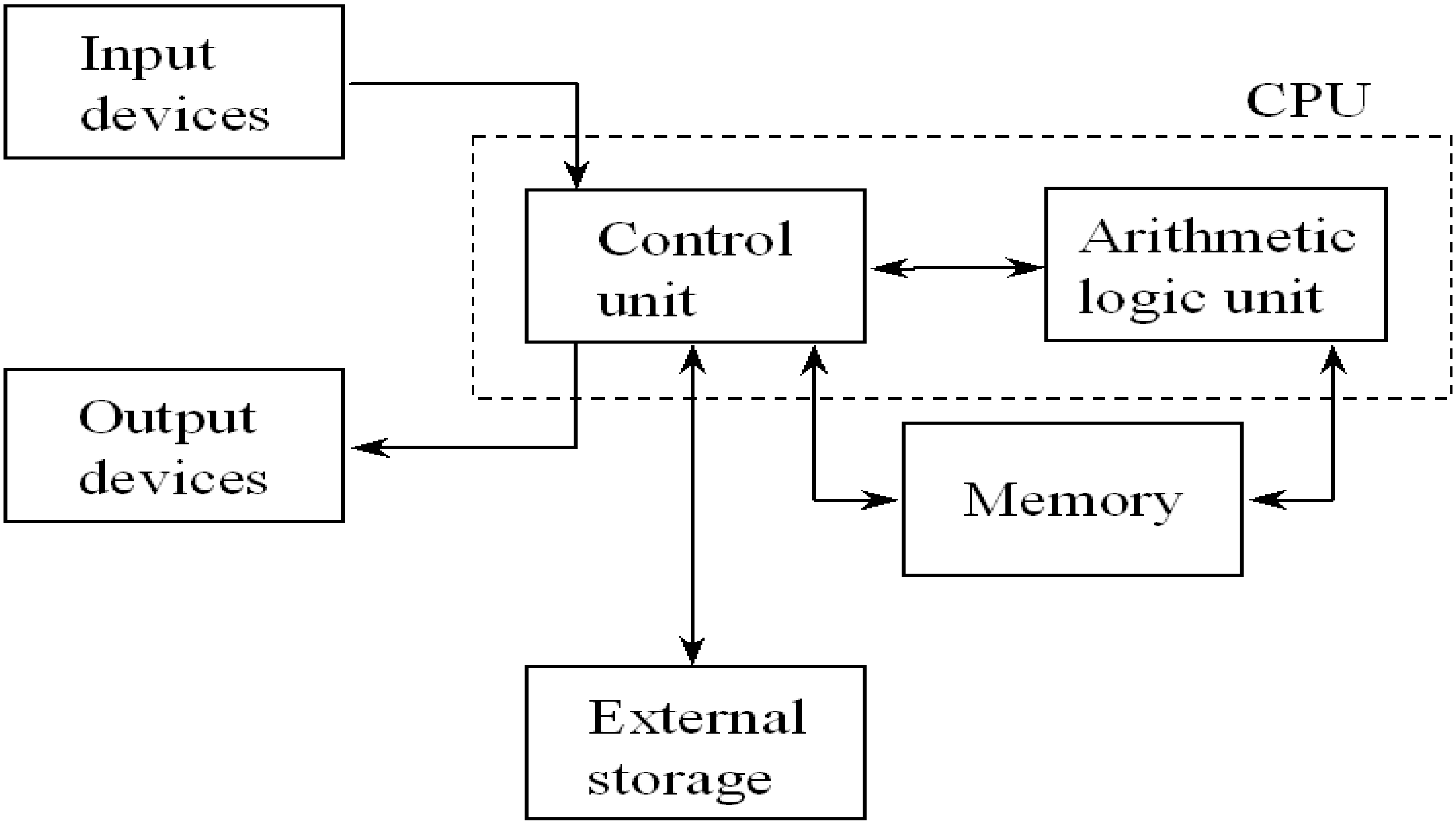
2. **Application Software:** is designed to help the user perform one or more related specific tasks

Hardware Versus Software (3)



Architecture Of Modern Computer

- Although specific components may vary, **virtually all modern computers have the same underlying structure** which is known as the **Von-Neumann architecture**



Categories Of Modern Computers

- Different types of computers have different characteristics:
  - **Supercomputers:** powerful but expensive; used for complex computations (e.g., weather forecasting, engineering design and modeling)
  - **Desktop Computers:** less powerful but affordable; used for a variety of user applications (e.g., email, web browsing, document processing)
  - **Laptop Computers:** similar functionality to desktops, but mobile
  - **Palmtop Computers:** portable, but limited applications and screen size




What Is Computer Science?

- Computer science is fundamentally about **computational problem solving** that is, solving problems by the use of computation

- In order to solve a problem computationally, two things are needed:
  1. A representation captures all the relevant aspects of the problem
  2. An algorithm solves the problem by use of this representation

- A representation that leaves out details of what is being represented is a form of **abstraction**

- **<u>Example</u>**: The man, cabbage, goat and wolf problem

  Start State: [E, E, E, E]

  Goal State: [W, W, W, W]

  E=East, W=West

What Is An Algorithm?

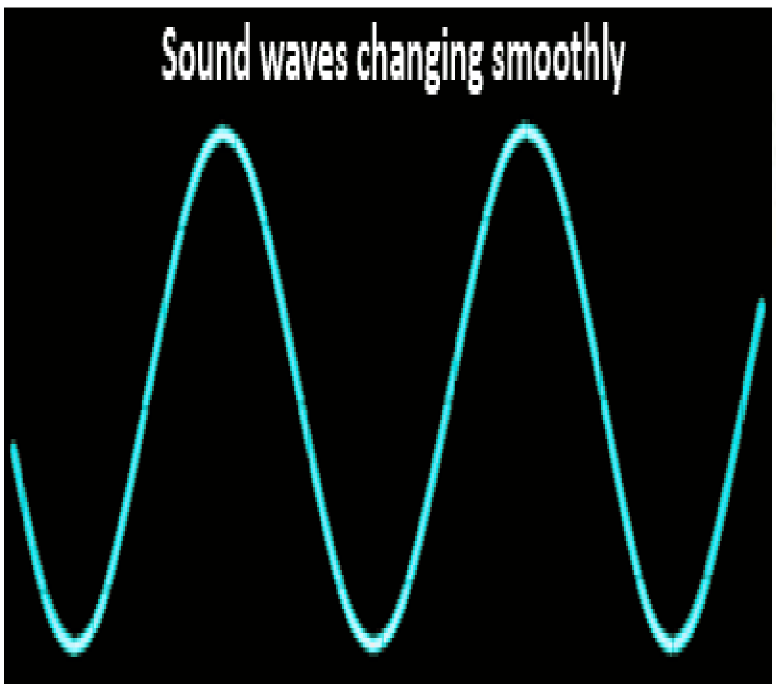
- Algorithm **is a finite set of ordered, unambiguous and executable instructions that terminates with a desired output(s) for given input(s) in a finite amount of time**
- The input(s) and output(s) are data
- **Example:** find the average of two numbers

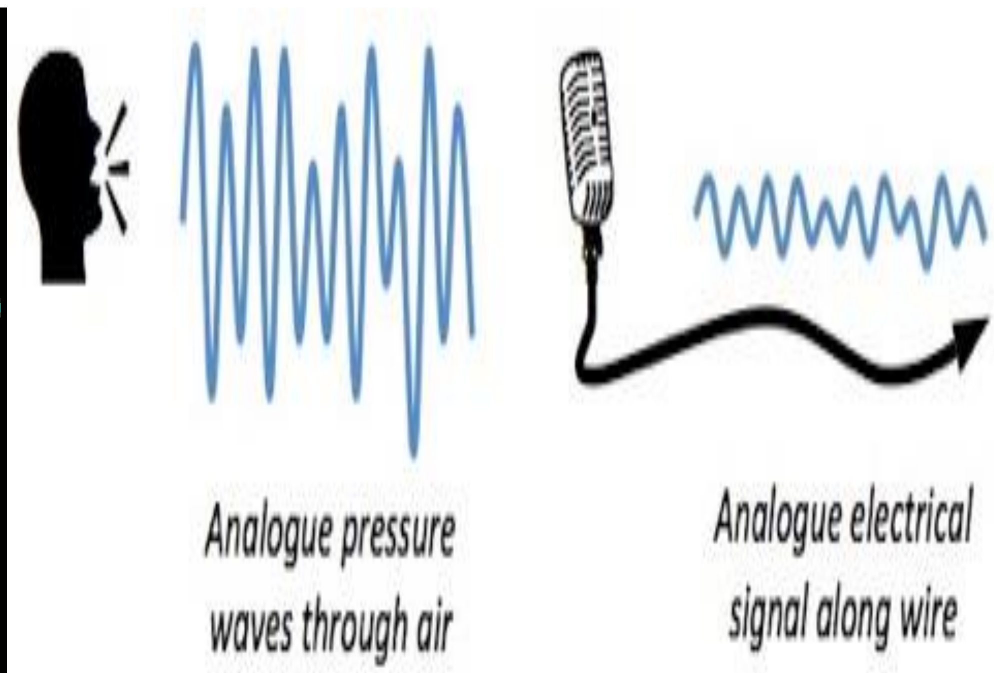
  Solution Algorithm

1. Read the two number (inputs)
2. Sum the two numbers
3. Divide the sum by 2
4. Store the division quotient
5. Display the stored quotient (output)

Analog Data Versus Digital Data

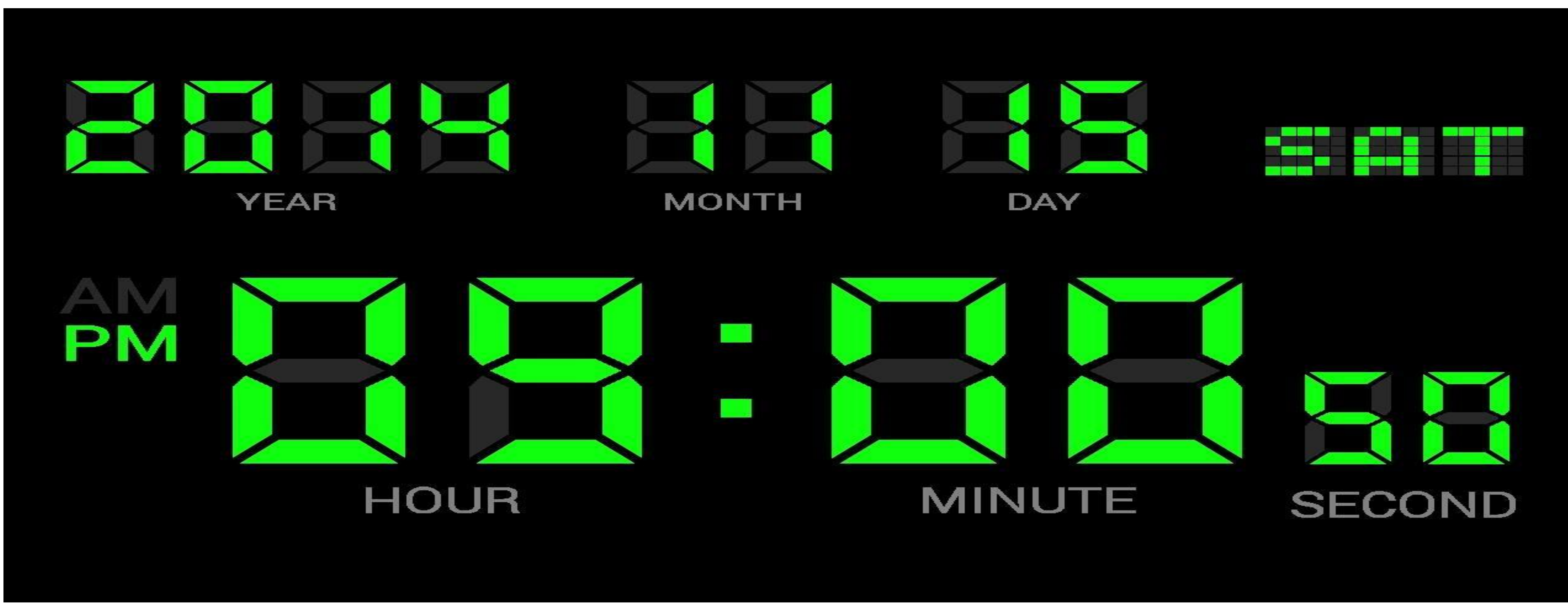
- Analog means continuous
- An analog parameter **has continuous range of values**
- **<u>Example:</u>** Temperature is an analog parameter
- Temperature increases/decreases continuously
- **What are other examples of analog data?**





Analog Data Versus Digital Data (2)

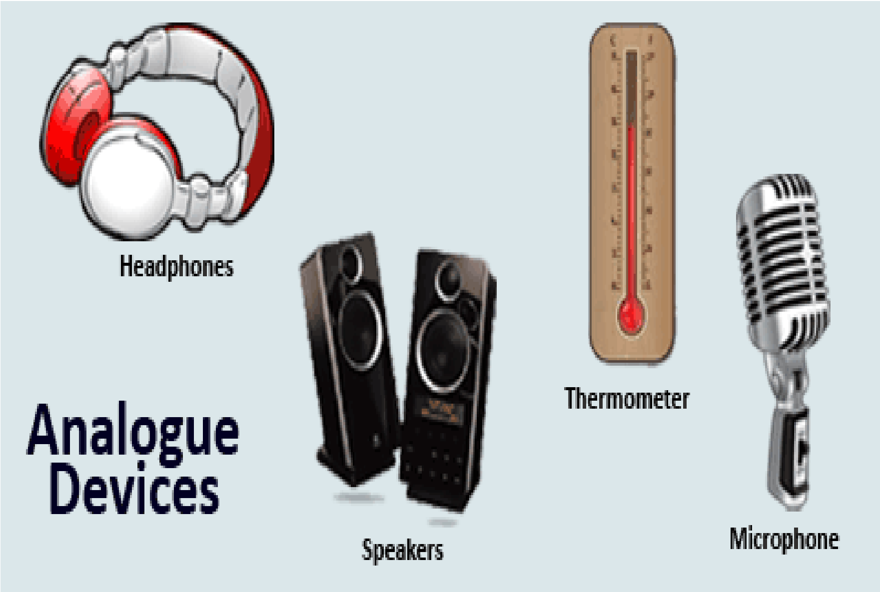
- Digital means discrete
- A digital parameter **has fixed set of discrete values**
- **<u>Example:</u>** Month number is a digital parameter (cannot be 1.5!)
- Month number $\in \{1, 2, 3, \ldots, 12\}$
- **What are other examples of digital data?**



Analog Device Versus Digital Device

- **Which is easier to design an analog device or a digital device?**

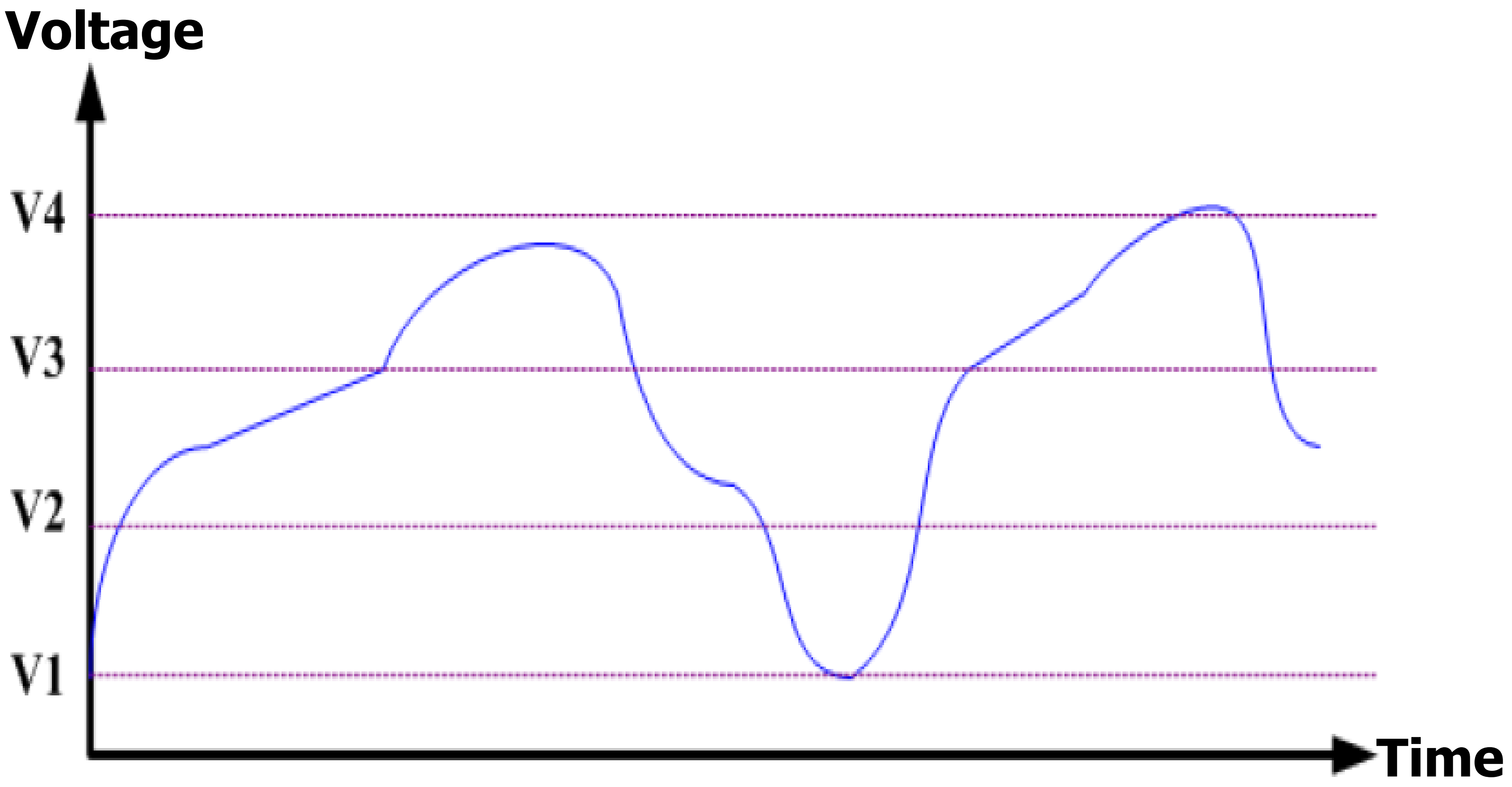
  Digital device is easier to design, because it deals with a limited set of values rather than an infinitely large range of continuous values



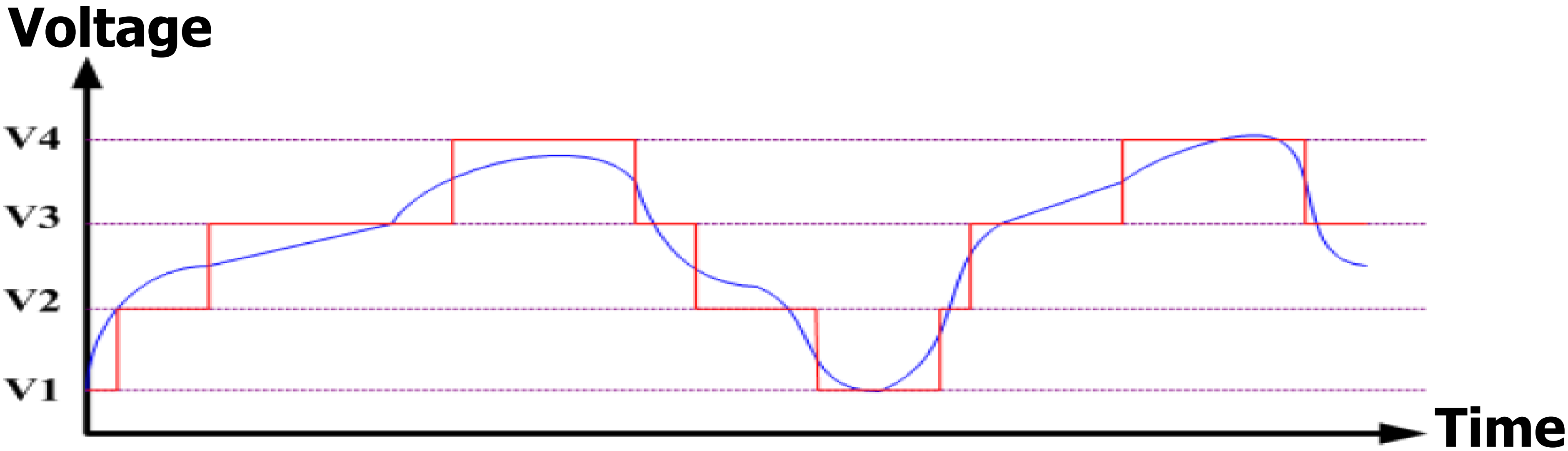
- But the world around us is analog
- It is common to convert analog parameters into a digital form by the **digitization process**

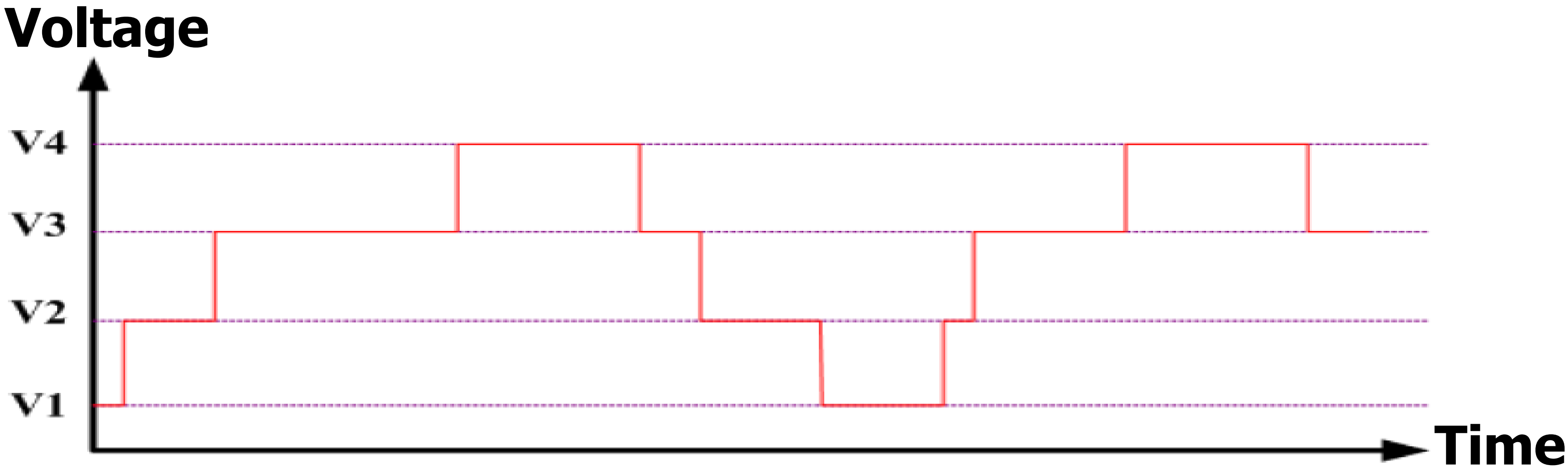
Digitization Of Analog Signals

- Example: consider digitizing an analog voltage signal
- Digitized output is limited to four values = {V1,V2,V3,V4}



Digitization Of Analog Signals (2)





- Some loss of accuracy, why?
- How to improve accuracy? **Add more voltage values**

Data Representation In Modern Computers

- The main characteristics of modern digital computers is its manipulation of discrete elements of information. Such discrete elements are represented physically by **“electrical signals” in form of varying values of voltages**

- The main memory of modern digital computers consists of millions of electrical devices called **transistors**, each of which can only have **two possible states: on or off**

- The transistor circuit in main memory acts as an electronic switch with two states according to its input voltage

Data Representation In Modern Computers (2)

- Since main memory can only store data in the form of 0 and 1, therefore, modern digital computers can only deal with information represented as binary values.

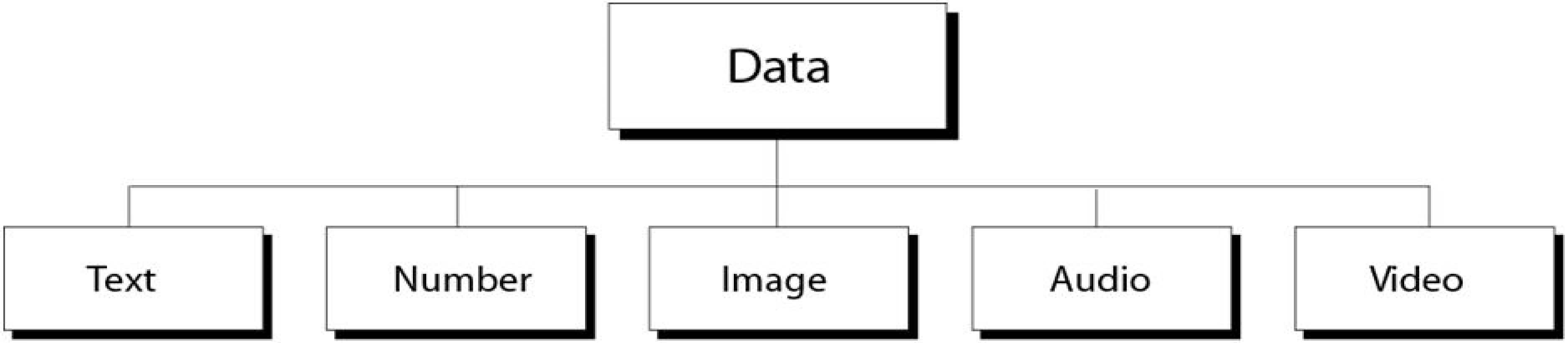
- All information entered to the modern digital computers, (regardless of being numbers, characters, symbols, colors,…), should be represented as a sequence of binary digits.

- Binary digit is usually abbreviated as ***bit*** and it has one of <u>***Just two values based on the electrical signal levels: (0-0.2 Volt) represented by 0 and (3-5 Volt) represented by 1***</u>

Data Representation In Modern Computers (3)

Figure 2-1

Different types of data



Numbering System

- To define new number system, it‘s needed to define its base (radix) and its list of adopted symbols

Number System	**Base/Radix**	**Symbols**
Decimal	10	0,1,2,3,4,5,6,7,8,9
Binary	2	0,1
Ternary	3	0,1,2
Octal	8	0,1,2,3,4,5,6,7
Hexadecimal	16	0,1,2,3,4,5,6,7,8,9, A, B, C, D, E, F

Decimal Number System

In general, a number expressed in a base-*r* number system has coefficients multiplied by powers of *r* to convert it to decimal number system that is used in the normal life

$$a_n \cdot r^n + a_{n-1} \cdot r^{n-1} + \cdots + a_2 \cdot r^2 + a_1 \cdot r + a_0$$
$$+ a_{-1} \cdot r^{-1} + a_{-2} \cdot r^{-2} + \cdots + a_{-m} \cdot r^{-m}$$

r is called ***base*** or ***radix***.

Example (1) (Decimal system)

The number 724.53 is calculated in the decimal system as follows:

$$(724.53)_{10} = 7*10^2 + 2*10^1 + 4*10^0 + 5*10^{-1} + 3*10^{-2}$$
$$= 700 + 20 + 4 + 0.5 + 0.03$$

Conversion From Decimal To Binary (Integer Part)

Example (2): Convert $(41)_{10}$ to the binary system.

Integer	Remainder
41	
20	1
10	0
5	0
2	1
1	0
0	1

101001

The conversion from decimal integers to any base-*r* system is similar to the example, except that division is done by *r* instead of 2.

Conversion From Decimal To Binary(Fraction Part)

Example (3): Convert $(0.6875)_{10}$ to the binary system.

	Integer		Fraction	Coefficient
$0.6875 \times 2 =$	1	+	0.3750	$a_{-1} = 1$
$0.3750 \times 2 =$	0	+	0.7500	$a_{-2} = 0$
$0.7500 \times 2 =$	1	+	0.5000	$a_{-3} = 1$
$0.5000 \times 2 =$	1	+	0.0000	$a_{-4} = 1$

$$(0.6875)_{10} = (0.a_{-1}a_{-2}a_{-3}a_{-4})_2 = (0.1011)_2$$

To convert a decimal fraction to a number expressed in base r, a similar procedure is used. Multiplication is by r instead of 2, and the coefficients found from the integers may range in value from 0 to $r - 1$ instead of 0 and 1.

Conversion From Decimal To Binary

Example (4): Convert $(174.390625)_{10}$ to the binary system.

$2 \div$	Integer part	remainder
	174	
	87	0
	43	1
	21	1
	10	1
	5	0
	2	1
	1	0
	0	1

$2 \times$	Fraction part	integer part
	0.390625	
	0.781250	0
	0.562500	1
	0.125000	1
	0.250000	0
	0.500000	0
	0.000000	1

$\boxed{1\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ .\ 0\ 1\ 1\ 0\ 0\ 1}$

Conversion From Decimal To Binary (2)

<u>Example (5):</u> Get the equivalent binary number of the decimal number 47.763 with a precision of 7-binary digits.

	Integer part	remainder
2 ÷	47	
	23	1
	11	1
	5	1
	2	1
	1	0
	0	1

	Fraction part	integer part
2 ×	0.763	
	0.526	1
	0.052	1
	0.104	0
	0.208	0
	0.416	0
	0.832	0
	0.664	1

1 0 1 1 1 1 . 1 1 0 0 0 0 1

Conversion From Decimal To Binary (3)

- Therefore, the number $(10101110.011001)_2$ is the **exact** binary equivalent to the decimal number $(174.390625)_{10}$

- Therefore, the number $(10111.1100001)_2$ is the **approximate** binary equivalent to the decimal number $(47.763)_{10}$

- ***Don't worry if the binary representation of the fractional part doesn't end, just stop when reaching the required precision***

Conversion From Binary To Decimal

Example (6):

The decimal equivalent of the binary number $(1001.0101)_2$ is determined as follows:

- The integer part = 1001
- The decimal equivalent $= 1 \times 2^0 + 0 \times 2^1 + 0 \times 2^2 + 1 \times 2^3 = 1 + 0 + 0 + 8 = 9$
- The fractional part = .0101
- Therefore, the decimal equivalent $= 0 \times 2^{-1} + 1 \times 2^{-2} + 0 \times 2^{-3} + 1 \times 2^{-4} = 0 + 0.25 + 0 + 0.0625 = 0.3125$
- Therefore, the decimal equivalent of $(1001.0101)_2 = 9.3125$

Example (7):

$$(1010.011)_2 = 2^3 + 2^1 + 2^{-2} + 2^{-3} = (10.375)_{10}$$

Conversion From Decimal To Octal

Example (10): Convert the decimal number $(167.390625)_{10}$ to its equivalent octal number.

	Integer part	remainder
8 ÷	167	
	20	7
	2	4
	0	2

	Fraction part	integer part
8 ×	0.390625	
	0.125	3
	0	1

$\boxed{2\,4\,7\,.\,3\,1}$

Therefore, the number $(247.31)_8$ is the **exact** octal equivalent to the decimal number $(167.390625)_{10}$.

Conversion From Decimal To Octal (2)

Example (11): Convert the decimal number $(95.236)_{10}$ to its equivalent octal number with a precision up to 4 octal digits.

	Integer part	remainder
$8 \div$	95	
	11	7
	1	3
	0	1

	Fraction part	integer part
$8 \times$	0.236	
	0.888	1
	0.104	7
	0.832	0
	0.656	6

Conversion From Decimal To Octal (3)

Example (12): Convert the decimal number $(153.513)_{10}$ to its equivalent octal number with a precision up to 6 octal digits.

$$
\begin{array}{r|l}
153 & \\
19 & 1 \\
2 & 3 \\
0 & 2
\end{array}
\quad = (231)_8
$$

$$
\begin{aligned}
0.513 \times 8 &= 4.104 \\
0.104 \times 8 &= 0.832 \\
0.832 \times 8 &= 6.656 \\
0.656 \times 8 &= 5.248 \\
0.248 \times 8 &= 1.984 \\
0.984 \times 8 &= 7.872
\end{aligned}
$$

$$(0.513)_{10} = (0.406517\ \ldots)_8$$

$$(153.513)_{10} = (231.406517)_8$$

Conversion From Octal To Decimal

Example (13):

The decimal equivalent of the octal number $(137.21)_8$ is determined as follows:

- The integer part = 137
- The decimal equivalent = $7 \times 8^0 + 3 \times 8^1 + 1 \times 8^2 = 7 + 24 + 64 = 95$
- The fractional part = .21
- The decimal equivalent = $2 \times 8^{-1} + 1 \times 8^{-2} = 0.265$
- Therefore, the decimal equivalent of $(137.21)_8 = (95.265)_{10}$

Example (14):

$$(630.4)_8 = 6 \times 8^2 + 3 \times 8 + 4 \times 8^{-1} = (408.5)_{10}$$

Conversion From Decimal To Hexadecimal

Example (15): Convert the decimal $(247.390625)_{10}$ to its equivalent hexadecimal number.

		Integer part	remainder
16	÷	247	
		15	7
		0	$15 \equiv F$
		Fraction part	**integer part**
16	×	0.390625	
		0.250	6
		0.0	4

Therefore, the number $(F7.64)_{16}$ is the **exact** hexadecimal equivalent to the decimal number $(247.390625)_{10}$

Conversion From Decimal To Hexadecimal (2)

<u>Example (16)</u>: *determine the hexadecimal equivalent of* $(82.25)_{10}$.

- The integer part = 82

Divisor	Dividend	Remainder
16	82	—
16	5	2
—	0	5

- The hexadecimal equivalent of $(82)_{10} = (52)_{16}$
- The fractional part = 0.25
- $0.25 \times 16 = 0$ with a carry of 4
- Therefore, the hexadecimal equivalent of $(82.25)_{10} = (52.4)_{16}$

Conversion From Hexadecimal To Decimal

Example (17):

The decimal equivalent of the hexadecimal number $(1E0.2A)_{16}$ is determined as follows:

- The integer part = 1E0
- The decimal equivalent $= 0 \times 16^0 + 14 \times 16^1 + 1 \times 16^2 = 0 + 224 + 256 = 480$
- The fractional part = 2A
- The decimal equivalent $= 2 \times 16^{-1} + 10 \times 16^{-2} = 0.164$
- Therefore, the decimal equivalent of $(1E0.2A)_{16} = (480.164)_{10}$

Example (18):

$$(B65F)_{16} = 11 \times 16^3 + 6 \times 16^2 + 5 \times 16^1 + 15 \times 16^0 = (46687)_{10}$$

Binary–Octal and Octal–Binary Conversions

- There are two ways:
  - **Indirect conversion:**

$$B \longrightarrow D \longrightarrow O$$

$$O \longrightarrow D \longrightarrow B$$

<u>Example (19):</u> Using the indirect way, convert the binary number $(1001101.1011)_2$ to octal

$$(1001101.1011)_2 = 1*2^6 + 0*2^5 + 0*2^4 + 1*2^3 + 1*2^2 + 0*2^1 + 1*2^0 + 1*2^{-1} + 0*2^{-2} + 1*2^{-3} + 1*2^{-4}$$

$$= 64 + 8 + 4 + 1 + 0.5 + 0.125 + 0.0625$$

$$= (77.6875)_{10}$$

Binary–Octal and Octal–Binary Conversions (2)

- **Indirect conversion:**

		Integer part	remainder
8	$\div$	77	
		9	5
		1	1
		0	1
		Fraction part	**integer part**
8	$\times$	0.6875	
		0.5	5
		0	4

Thus, $(1001101.1011)_2 = (77.6875)_{10} = (115.54)_8$

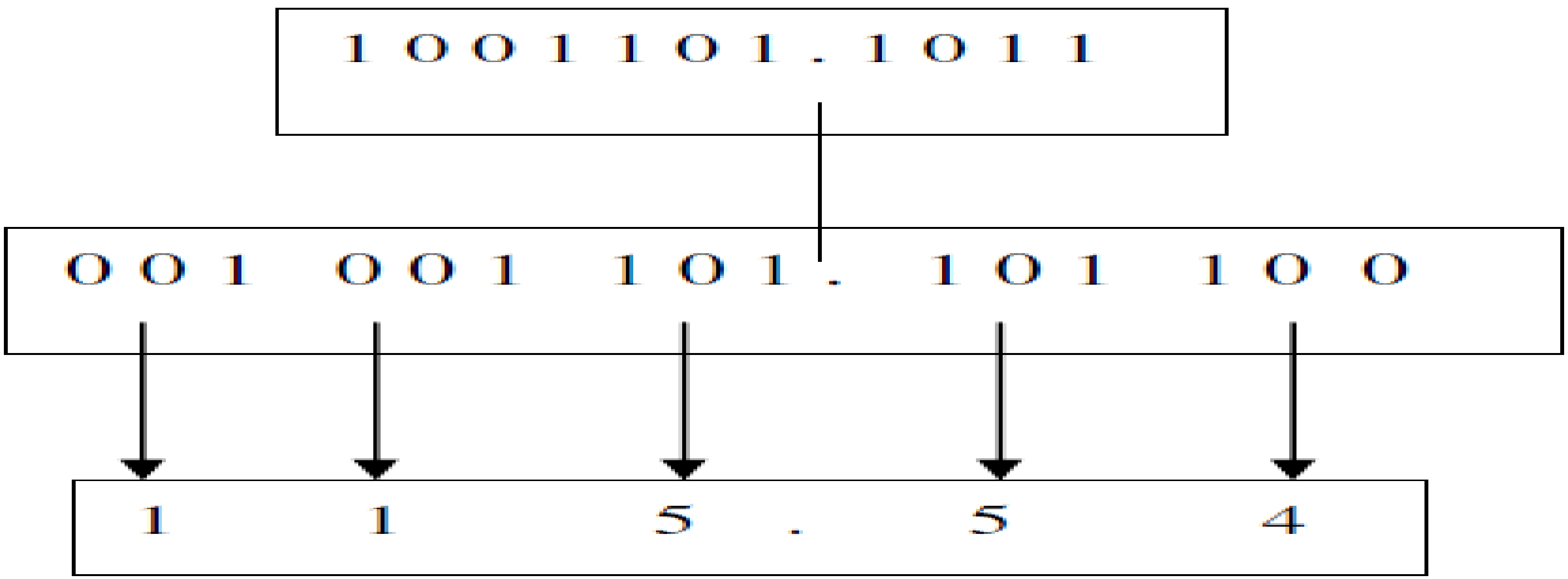
Binary–Octal and Octal–Binary Conversions (3)

- **Direct conversion:**
  Each 3-binary digits are replaced by one octal digit , and vice versa , using the following table:

Octal	0	1	2	3	4	5	6	7
Binary	000	001	010	011	100	101	110	111

Example (20): Using the direct way, convert the binary number

$(1001101.1011)_2$ to octal



Binary–Octal and Octal–Binary Conversions (4)

Example (21):

$$(\underbrace{10}_{2}\ \underbrace{110}_{6}\ \underbrace{001}_{1}\ \underbrace{101}_{5}\ \underbrace{011}_{3}\ .\ \underbrace{111}_{7}\ \underbrace{100}_{4}\ \underbrace{000}_{0}\ \underbrace{110}_{6})_2 = (26153.7460)_8$$

Example (22):

find the binary equivalent of $(374.26)_8$ and the octal equivalent of $(1110100.0100111)_2$.

Solution

- The given octal number $= (374.26)_8$
- The binary equivalent $= (011\ 111\ 100.010\ 110)_2 = (011111100.010110)_2$
- Any 0s on the extreme left of the integer part and extreme right of the fractional part of the equivalent binary number should be omitted. Therefore, $(011111100.010110)_2 = (11111100.01011)_2$
- The given binary number $= (1110100.0100111)_2$
- $(1110100.0100111)_2 = (1\ 110\ 100.010\ 011\ 1)_2$

$$= (001\ 110\ 100.010\ 011\ 100)_2 = (164.234)_8$$

Binary–Hexa and Hexa–Binary Conversions

- There are two ways:
  - **Indirect conversion:**

    B ⟶ D ⟶ H

    H ⟶ D ⟶ B

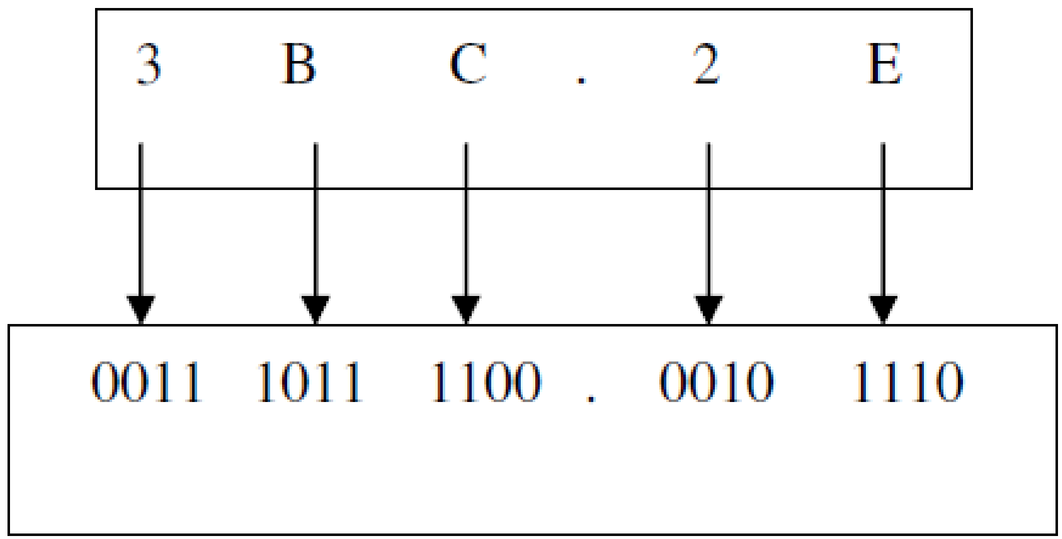
  - **Direct conversion:** Each 4-binary digits are replaced by one hexadecimal digit , and vice versa , using the following table:

Hexa	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**A**	**B**	**C**	**D**	**E**	**F**
Binary	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Binary–Hexa and Hexa–Binary Conversions (2)

- **Direct conversion:** Each 4-binary digits are replaced by one hexadecimal digit , and vice versa.

Example (23): Convert the hexadecimal $(3BC.\ 2E)_{16}$ directly to its equivalent binary number.



Thus, $(3BC.2E)_{16} = (001110111100.00101110)_2$

Binary–Hexa and Hexa–Binary Conversions (3)

Example (24): Convert the binary number $(111010.11011)_2$ directly to its equivalent hexadecimal number.

Solution: Start from the binary point and move to the right (for fraction part) and to the left (for the integral part) grouping each 4-binary digits as one hexadecimal digit. Adding 0's to the extreme right (or left) is allowed. Thus, we have:

$$(111010.11011)_2 = (00111010.11011000)_2 = (3A.D8)_{16}$$

Binary–Hexa and Hexa–Binary Conversions (4)

Example (25): $(\underbrace{10}_{2}\ \underbrace{1100}_{C}\ \underbrace{0110}_{6}\ \underbrace{1011}_{B}\ .\ \underbrace{1111}_{F}\ \underbrace{0010}_{2})_2 = (2C6B.F2)_{16}$

Example (26):

find the binary equivalent of $(17E.F6)_{16}$ and the hex equivalent of $(1011001110.011011101)_2$.

Solution

- The given hex number $= (17E.F6)_{16}$
- The binary equivalent $= (0001\ 0111\ 1110.1111\ 0110)_2$

$$= (000101111110.11110110)_2$$

$$= (101111110.1111011)_2$$

- The 0s on the extreme left of the integer part and on the extreme right of the fractional part have been omitted.
- The given binary number $= (1011001110.011011101)_2$

$$= (10\ 1100\ 1110.0110\ 1110\ 1)_2$$

- The hex equivalent $= (0010\ 1100\ 1110.0110\ 1110\ 1000)_2 = (2CE.6E8)_{16}$

Hex–Octal and Octal–Hex Conversions

- For ***Hexadecimal–Octal*** conversion, the given hex number is firstly converted into its binary equivalent which is further converted into its octal equivalent.

- An alternative approach is firstly to convert the given hexadecimal number into its decimal equivalent and then convert the decimal number into an equivalent octal number. The former method is definitely more convenient and straightforward.

- For ***Octal–Hexadecimal*** conversion, the octal number may first be converted into an equivalent binary number and then the binary number transformed into its hex equivalent.

- The other option is firstly to convert the given octal number into its decimal equivalent and then convert the decimal number into its hex equivalent. The former approach is definitely the preferred one.

Hex–Octal and Octal–Hex Conversions (2)

Example (27):

find the octal equivalent of $(2F.C4)_{16}$ and the hex equivalent of $(762.013)_8$.

Solution

- The given hex number $= (2F.C4)_{16}$.
- The binary equivalent $= (0010\ 1111.1100\ 0100)_2 = (00101111.11000100)_2$
  $= (101111.110001)_2 = (101\ 111.110\ 001)_2 = (57.61)_8$.
- The given octal number $= (762.013)_8$.
- The octal number $= (762.013)_8 = (111\ 110\ 010.000\ 001\ 011)_2$
  $= (111110010.000001011)_2$
  $= (0001\ 1111\ 0010.0000\ 0101\ 1000)_2 = (1F2.058)_{16}$.

Octal and Hexadecimal Numbers

Table 1.2
Numbers with Different Bases

Decimal (base 10)	Binary (base 2)	Octal (base 8)	Hexadecimal (base 16)
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

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The End

Questions?