Chapter Contents

Analog and Digital Systems

- Real world is analog but digital circuits are found in an astonishingly wide range of electronic systems.
- **Analog systems** process information that varies continuously . Examples of analog represented variables are:
  - a mercury thermometer
  - needle speedometer of cars
  - sine wave voltages indicated on a galvanometer
  - audio amplifier
  - simple light dimmer switch

Analog and Digital Systems

- **Digital systems** process discrete information. Discrete means distinct or separated as opposed to continuous or connected. The examples are:
  - telephone switching exchanges
  - Speedometer of cars with numerical readout
  - electronic calculators
  - digital computers

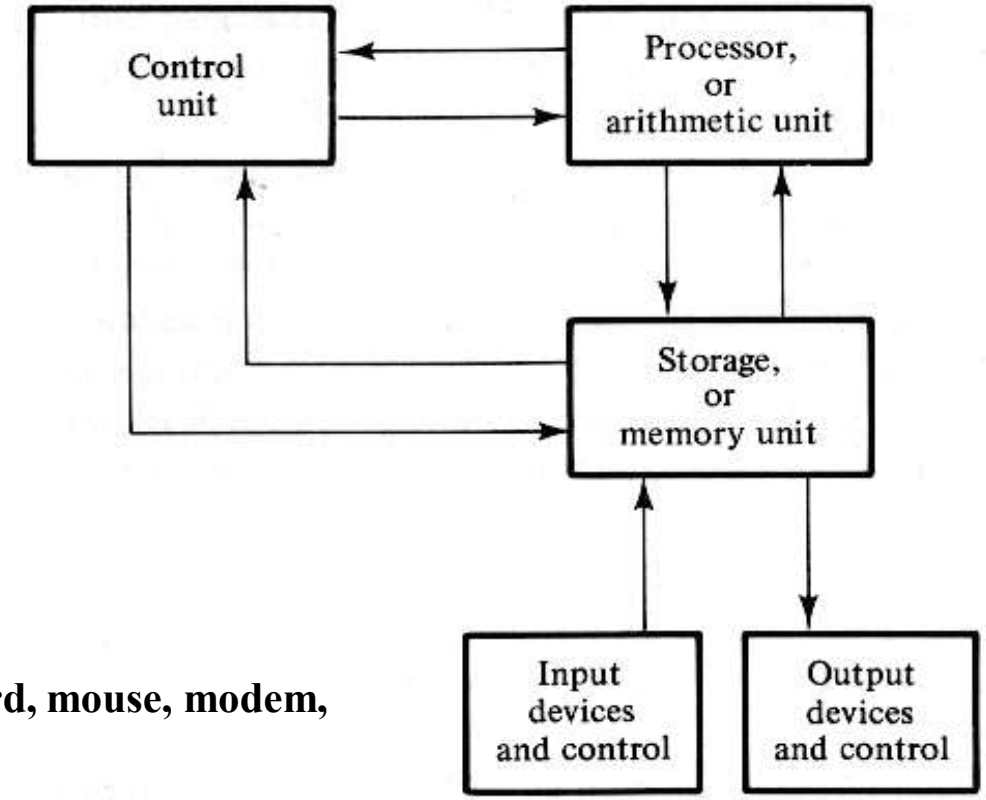
Digital Systems

- Digital Systems have such a prominent role in everyday life that we refer to the present technological period as the digital age.
- Digital systems manipulate discrete elements of information and have wide applications.
  - Digital systems are used in communication, business transactions, traffic control, space guidance, medical treatment, weather monitoring, the Internet, and many other commercial, industrial, and scientific enterprises.
  - We have digital telephones, digital television, digital versatile discs, digital cameras, and digital computers.
- The discrete elements of information are represented in a digital system by physical quantities called signals i.e voltage and current.
- The signals in present-day electronic digital systems use just two discrete values and are therefore said to be binary. A binary digit, called a bit, has two values: 0 and 1.
- **Why binary?**
  - reliability: a transistor circuit is either ON or OFF (two stable states)

Digital Computer

- **The digital computer is one of the most well known digital systems.**
- **The digital computer consists of the following components:**
  - **Memory unit**
  - **Central processing unit**
  - **Input and output units**
- **The digital computer can perform both arithmetic and logical operations.**

A digital computer



Inputs: **Keyboard, mouse, modem, microphone**

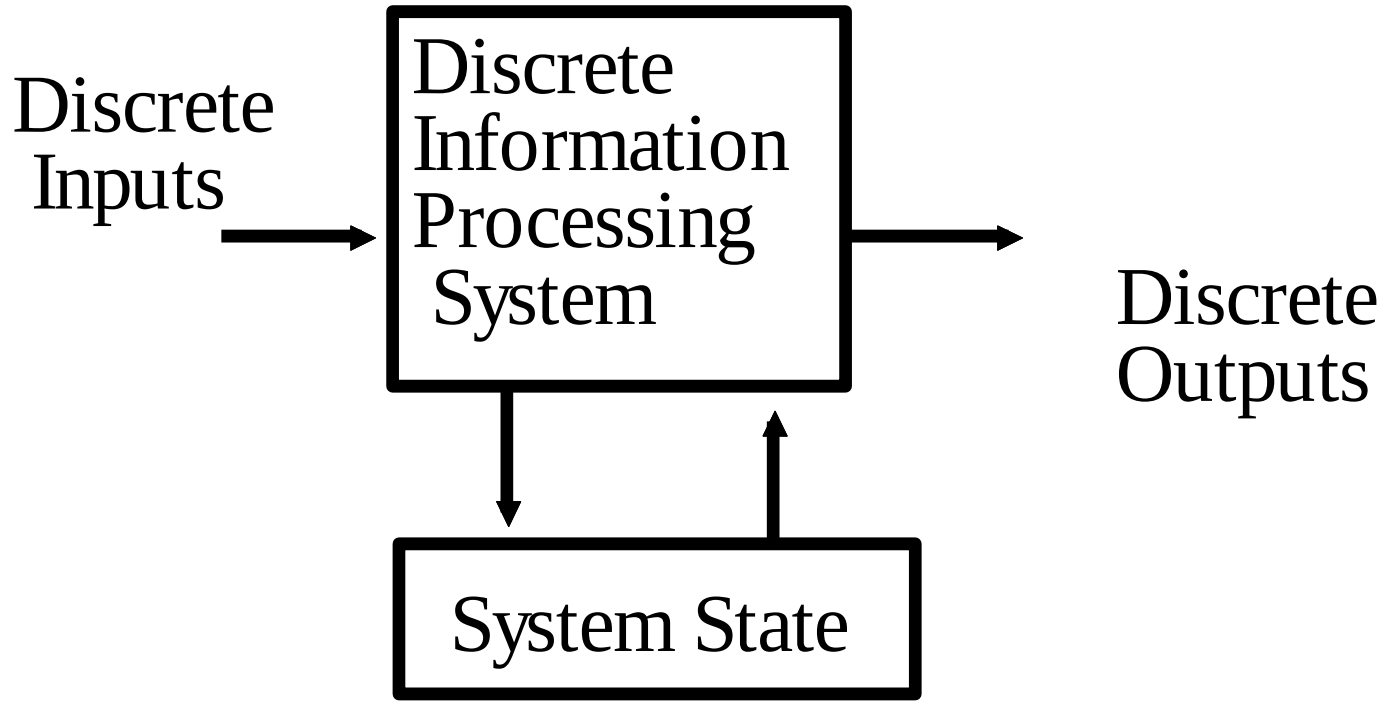
Outputs: **CRT, LCD, modem, speakers**

- **stored program**
- **control unit**
- **arithmetic computations and logical operations**

Digital Systems

- Digital Systems represent systems that understand, represent and manipulate discrete elements.
  - A discrete element is any set that has a finite number of elements, for example 10 decimal digits, 26 letters of the alphabet, etc.
- Discrete elements are represented by signals, such as electrical signals (voltages and currents)
- The signals in most electronic digital systems use two discrete values, termed binary.
- Digital Systems takes a set of discrete information inputs and discrete internal information (system state) and generates a set of discrete information outputs.

Digital Systems



Signals

- A collection of information variables mapped to some physical quantity.
- For digital systems, the quantities take on discrete values. Two level, or binary values are the most prevalent values in digital systems.
- The binary values are represented abstractly by digits 0 and 1.
- other physical signals represented by 1 and 0?
  - CPU — Voltage
  - Disk — Magnetic Field Direction
  - CD — Surface Pits/Light
  - Dynamic RAM — **Electrical Charge**

Why Digital Components?

- **Why do we choose to use digital components?**
  - **The main reason for using digital components is that they can easily be programmed, allowing a single hardware unit to be used for many different purposes.**
  - **Advances in circuit technology decrease the price of technology dramatically.**
  - **Digital integrated circuits can perform at speeds of hundreds of millions of operations per second.**
  - **Error-checking and correction can be used to ensure the reliability of the machine.**

Binary Digits

- **A binary digit, called a bit, is represented by one of two values: 0 or 1.**
  - **Discrete elements can be represented by groups of bits called binary codes. For example the decimal digits 0 to 9 are represented as follows:**

Decimal	Binary Code
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Different Bases

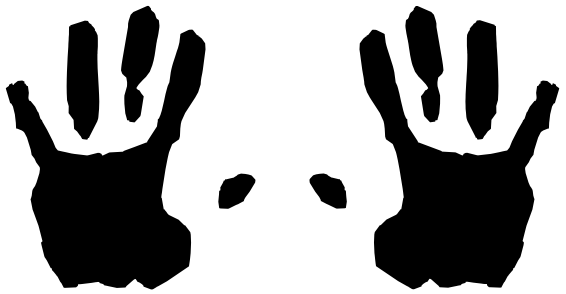
- In order to represent numbers of different bases, we surround a number in parenthesis and then place a subscript with the base of the number.
  - A decimal number $(9233)_{10}$
  - A binary number $(11011)_2$
  - A base 5 number $(3024)_5$
- Decimal number digits are 0 through 9
- Binary number digits are 0 through 1
- Base (radix) *r* number digits are 0 through *r* - 1

Commonly Used Bases

Name	Radix	Digits (0 through r-1)
Binary	2	0,1
Octal	8	0,1,2,3,4,5,6,7
Decimal	10	0,1,2,3,4,5,6,7,8,9
Hexadecimal	16	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

Decimal Numbers

- **A decimal number such as 5723 represents a quantity equal to:**
  - **5 thousands**
  - **7 hundreds**
  - **2 tens**
  - **3 ones**



- **Or, it can be written as:**
  - **$5 \text{ X } 10^3 + 7 \text{ X} 10^2 + 2 * 10^1 + 3 * 10^0$**
- **The 5, 7, 2, and 3 represent coefficients.**
- **The decimal number system is said to be of base or radix 10 because it uses the 10 digits (0..9) and the coefficients are multiplied by powers of 10.**

Binary Numbers

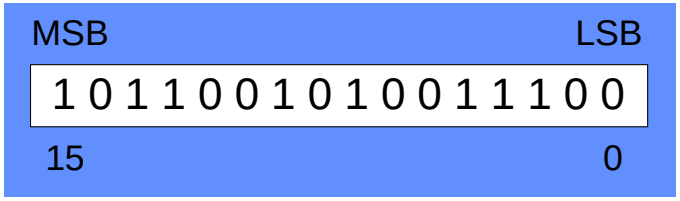
- **The binary system contains only two values in the allowed coefficients (0 and 1).**
- **The binary system uses powers of 2 as the multipliers for the coefficients.**
- **For example, we can represent the binary number 10111.01_2 as:**
  - $1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 0 \times 2^{-1} + 1 \times 2^{-2} = 23.25_{10}$

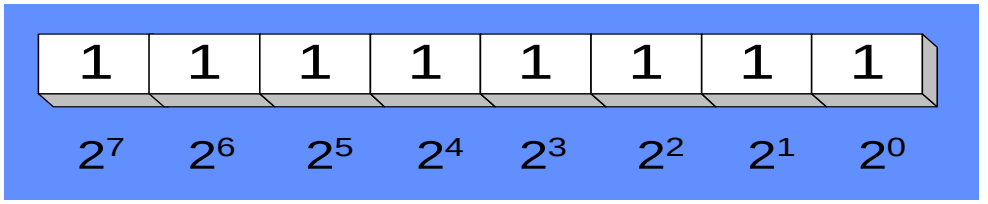
Understanding Binary Numbers

- **Binary numbers are made of binary digits (bits):**
  - **0 and 1**
- **How many items does an binary number represent?**
  - $(1011)_2 = 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0 = (11)_{10}$
- **What about fractions?**
  - $(110.10)_2 = 1x2^2 + 1x2^1 + 0x2^0 + 1x2^{-1} + 0x2^{-2}$
- **Groups of eight bits are called a *byte***
  - $(11001001)_2$
- **Groups of four bits are called a *nibble.***
  - $(1101)_2$

Understanding Binary Numbers (Cont…)

- Each digit (bit) is either 1 or 0
- Each bit represents a power of 2
- Bit numbering
- MSB: most significant bit
- LSB: least significant bit





Why Binary Numbers?

- Easy to represent 0 and 1 using electrical values.
- Possible to tolerate noise.
- Easy to transmit data
- Easy to build binary circuits.

Powers of Two

n	2^n	n	2^n	n	2^n
0	1	8	256	16	65,536
1	2	9	512	17	131,072
2	4	10	1,024	18	262,144
3	8	11	2,048	19	524,288
4	16	12	4,096	20	1,048,576
5	32	13	8,192	21	2,097,152
6	64	14	16,384	22	4,194,304
7	128	15	32,768	23	8,388,608

Important Powers of Two are:

- **2^{10} is referred to as Kilo, called "K"**
- **2^{20} is referred to as Mega, called "M"**
- **2^{30} is referred to as Giga, called "G"**
- **2^{40} is referred to as Tera, called "T"**

Octal Numbers

- **The octal number system is a base-8 system that contains the coefficient values of 0 to 7.**
- **The octal system uses powers of 8 as the multipliers for the coefficients.**
- **For example, we can represent the octal number 72032_8 as:**

$$7 \times 8^4 + 2 \times 8^3 + 0 \times 8^2 + 3 \times 8^1 + 2 \times 8^0 = (29722)_{10}$$

Hexadecimal Numbers

- **The hexadecimal number system is a base-16 system that contains the coefficient values of 0 to 9 and A to F.**
- **The letters A, B, C, D, E, F represent the coefficient values of 10, 11, 12, 13, 14, and 15, respectively.**
- **The hexadecimal system uses powers of 16 as the multipliers for the coefficients.**
- **For example, we can represent the hexadecimal number $C34D_{16}$ as:**
  - **$12 \times 16^3 + 3 \times 16^2 + 4 \times 16^1 + 13 \times 16^0 = (49997)_{10}$**

Your Turn

Find Decimal Equivalent of the following:-

$(1011.11)_2$
$(147.3)_8$
$(3301.13)_5$