Digital System Design

Lecture 1

Digital Concepts

Objectives:

- **Introduction (digital system design concepts and definitions).**
- **Advantages and drawbacks of digital techniques compared with analog.**
- **Digital Abstraction.**
- **Synchronous and Asynchronous Systems.**
- **Specification of Digital Systems.**
- **Implementation of Digital Systems.**
- **Switching Networks Types: Combinational and Sequential.**
- **Digital System examples.**

Introduction (concepts and definitions)

***System*:** A set of related components work together to achieve a goal.

A system contains (see figure 1):

- ✓ Input
- ✓ Behavior
- ✓ Output

Figure 1: System Architecture

Behavior is a function that translates input to output.

Components are electronic components: ***digital***, ***analog*** and ***mixed*** signals.

Digital system is a system in which signals have a ***finite number*** of discrete values (see figure 2).

Analog system contains devices that manipulate ***continuous set*** of values (Analog from representation, see figure 3).

Mixed system (hybrid) mixed systems can manipulate both signals (digital and analog forms).

- ✓ In analog systems, for any input value, the set of infinite output values can be obtained.
- ✓ In mixed systems, they can contain both finite and infinite values for inputs and/ or outputs.

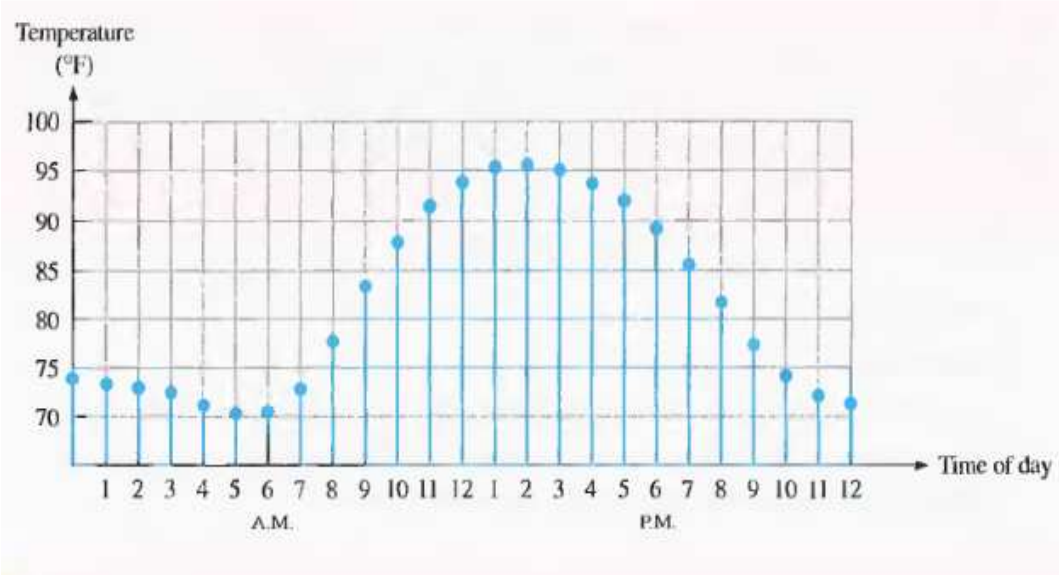


Figure 2: digital signal

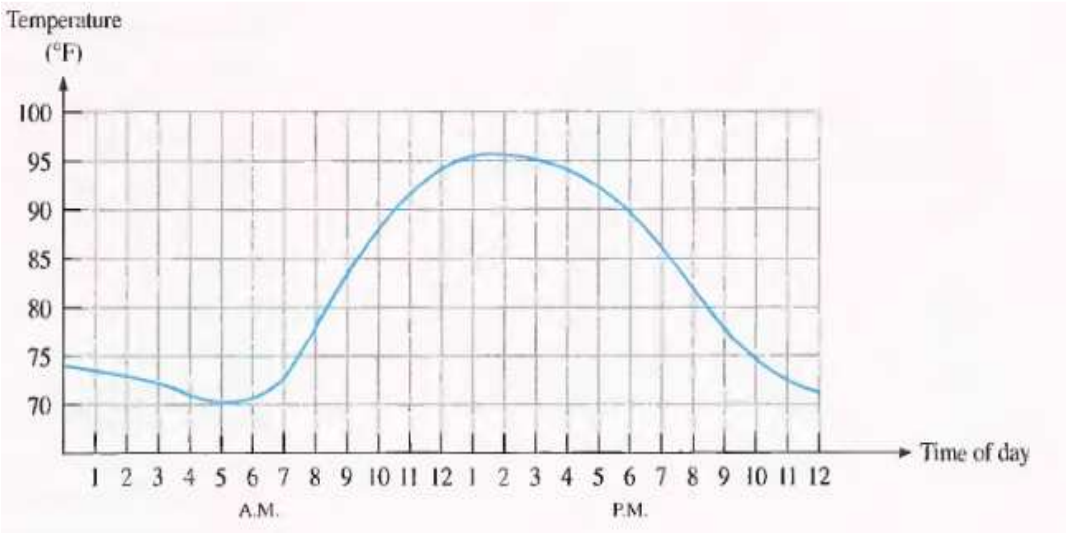


Figure 3: Analog signal

Advantages and Drawbacks of digital techniques compared with analog

***Advantages*:**

- ➢ Digital systems are generally ***easier to design*** (automated design and fabrication on IC chips).
- ➢ Information storage is ***easy***.

- Digital representation is very ***well suited*** for ***numerical*** and ***non-numerical*** information processing.
  - ***Numerical information***:
    The digital representation is simple: 0, 100, 130.53
  - ***Non-numerical information***:
    The character can be represented digital in easy way.
- Accuracy and precision are ***greater***:
  - Digital system can handle as many digits of precision as you need simply by adding more switching circuit.
  - In analog systems, precision is usually 3-4 digits.
- Operations can be ***programmed***.
- Digital circuits are less affected by ***noise***.
- Low cost.
- Easy to ***duplicate*** similar circuits (regular structures).
- The main advantages: ***Easily controllable by computer***, the finite number of values in a digital system can be represented by a vector of signals with just two values (Binary signals) e.g. **2** is **0010** and **10** is **1010**. So the device which processes the signal is very simple say a **switch- open/close**.
  Finite values- 0 and 1 (Binary values).

Example:

0-10 decimal numbers:

0 = 0000 **1 = 0001** **2 = 0010**

3 = 0011 **4 = 0100** **....** **10 = 1010**

Disadvantages of Digital Techniques:

- Lower speed (extra time required to perform conversions)
- The major drawback is

The physical world is analog

Such as temperature, pressure, talk, etc

So we need to convert digital to analog and vice versa to communicate with real world.

Three steps must be followed

1. *Convert the real- world analog inputs to digital form.*
2. *Process the digital information.*
3. *Convert the digital outputs back to real-world analog form.*

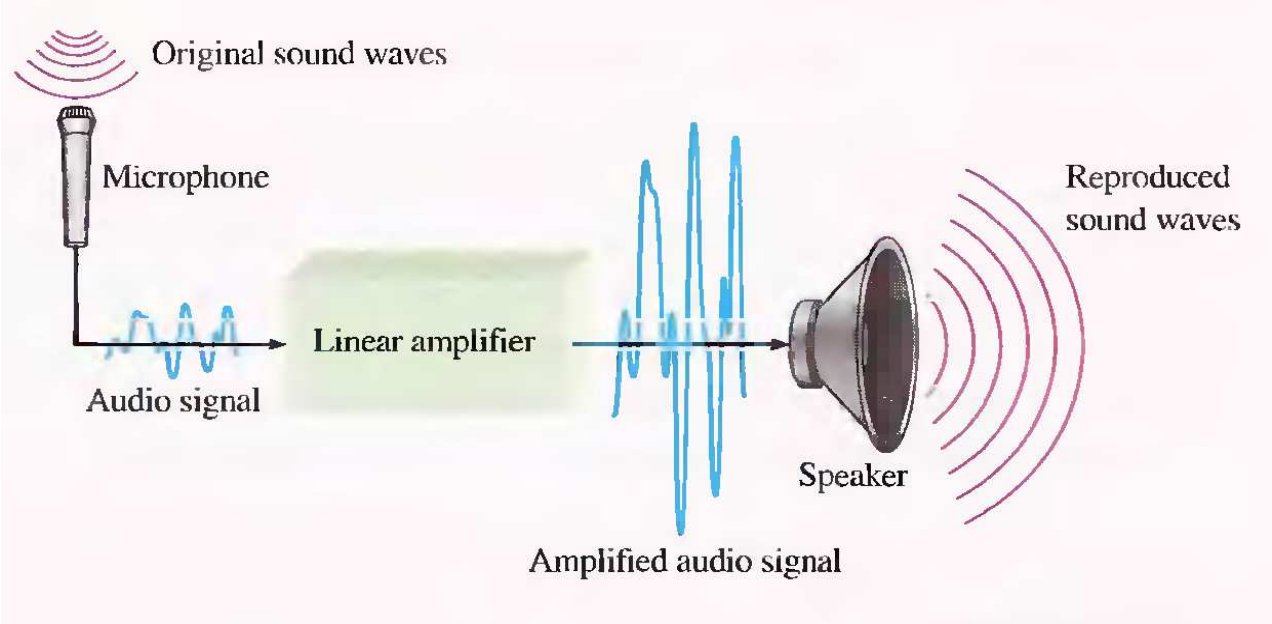


Figure 4: Analog System

Figure 5: Mixed System

Digital Abstraction

- Digital circuits actually deal with analog signals (current or voltage: 0-10 volts).
- **Example 1: analog values: 10v power supply**

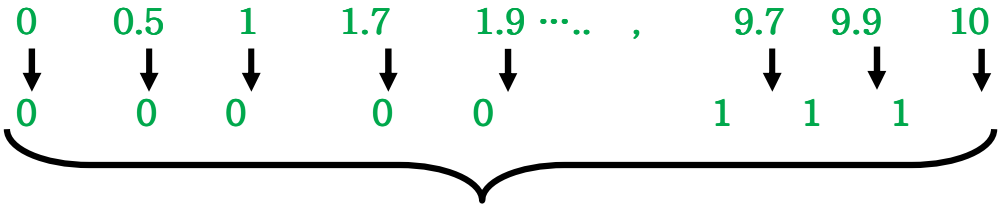
0 0.5 1 1.7 1.9 2.3, ⋯ , 9.7, 9.9 , 10

To represent these values digitally using just two values 0 and 1, we first define one range for 0 and another range for 1:

For example:

range 1: 0 – 4.8 v ⟶ 0
range 2: 4.8 – 10 v ⟶ 1

So the digital representation for the above sequence is:



Digital Abstraction

- Digital abstraction allows analog signals to be ignored and allows some discrete values to be used.

Example 2: Binary system, only two values are allowed: 1 and 0

1 means high value or logic "TRUE"

0 means low value or logic "FALSE"

Synchronous and Asynchronous Systems

Synchronous system: elements change their values at certain specified times (***clocked***).

Asynchronous system: output can change at any instant of time.

Example: Digital clock

- ✓ If a digital clock is set to alarm at every minute: 11:15, 11:16, 11:17, 11:18, etc, then the system is ***synchronous***.
- ✓ If a digital clock is set to alarm at any time: 10:10, 10:70, 13:35, 22:15, etc, then the system is ***Asynchronous***.

Specification of Digital Systems

Specification of system is the description of the system functions and another characteristics required for designing it such as ***speed, cost*** **and** ***power*****, (requirements)** they are related, when construct a system.

Implementation of Digital System

Implementation means how the system is constructed from smaller and simpler components called modules.

- ✓ The modules can vary from simple gates to complex processors.
- ✓ Digital system follows some ***hierarchical implementation***.

Hierarchical implementation:

- ➢ ***Modular design:***
  - o *Divide and conquer*
  - o *Modules are designed and built separately and then assembled to form the system.*
  - o *Simplifies implementation and testing*

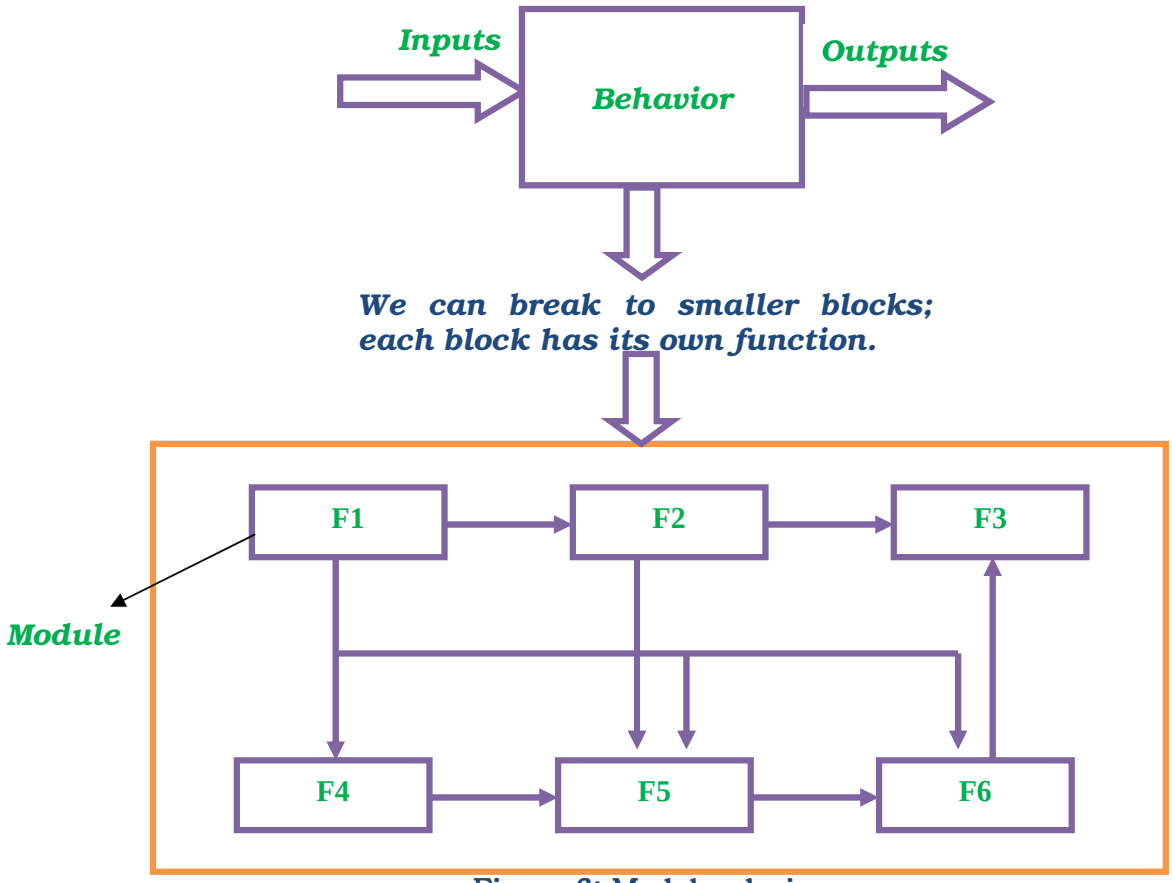


Figure 6: Modular design

- ***Design approaches:***
  - ***Top-down design:***
    - Starts at the top and works down.
    - Decomposes the system into subsystem and then subsystems into simpler and smaller subsystems and so on.
    - Stop when subsystems can be realized by directly available module.

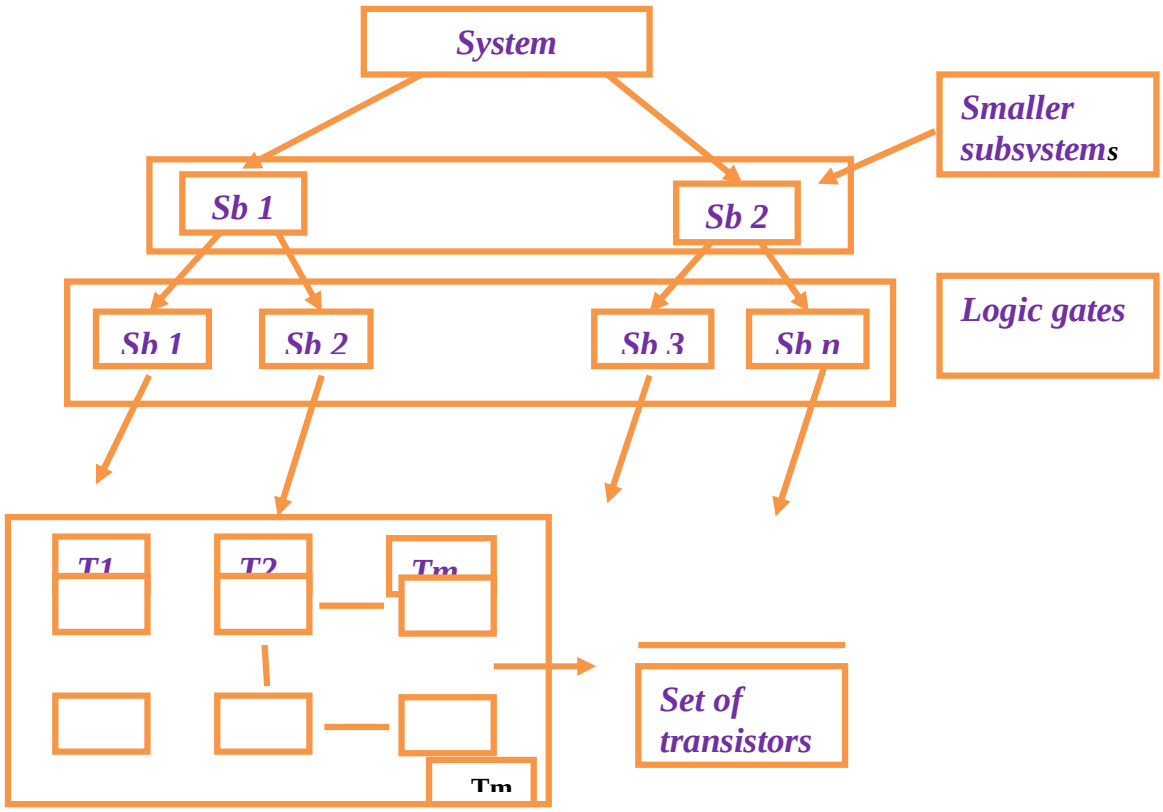


Figure 7: Top-down design

  - ***Bottom-up Design***
    - Starts at the leaves and put pieces together to build up the design.
    - Subsystems are assembled to form a bigger subsystem.
    - Stop when required functional specification is achieved.

Switching Networks Types: Combinational and Sequential

Switching network: Many of the subsystems of a digital system take the form of switching network.

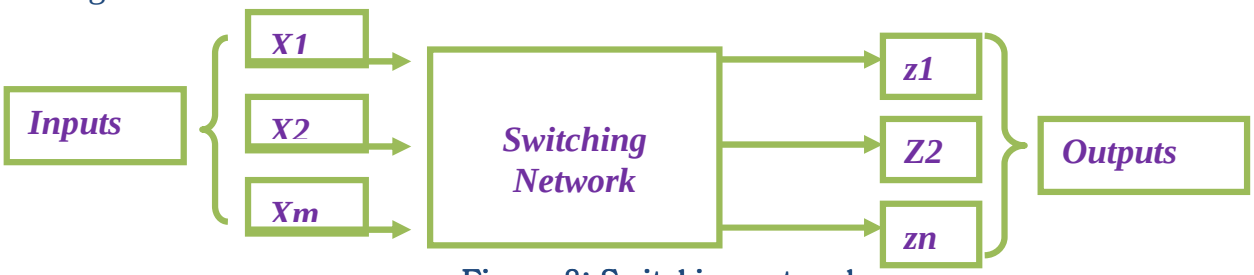


Figure 8: Switching network

- ***Switching networks types***
  - ***Combinational***
  - ***Sequential***

In ***combinational network***: the output values depend only on the present value of the inputs and not on past values.

In ***sequential network*** the output depend on both the present and the past input values (we need a ***memory***).

> ***In general, a sequential network is composed of a combinational network with added memory elements.***

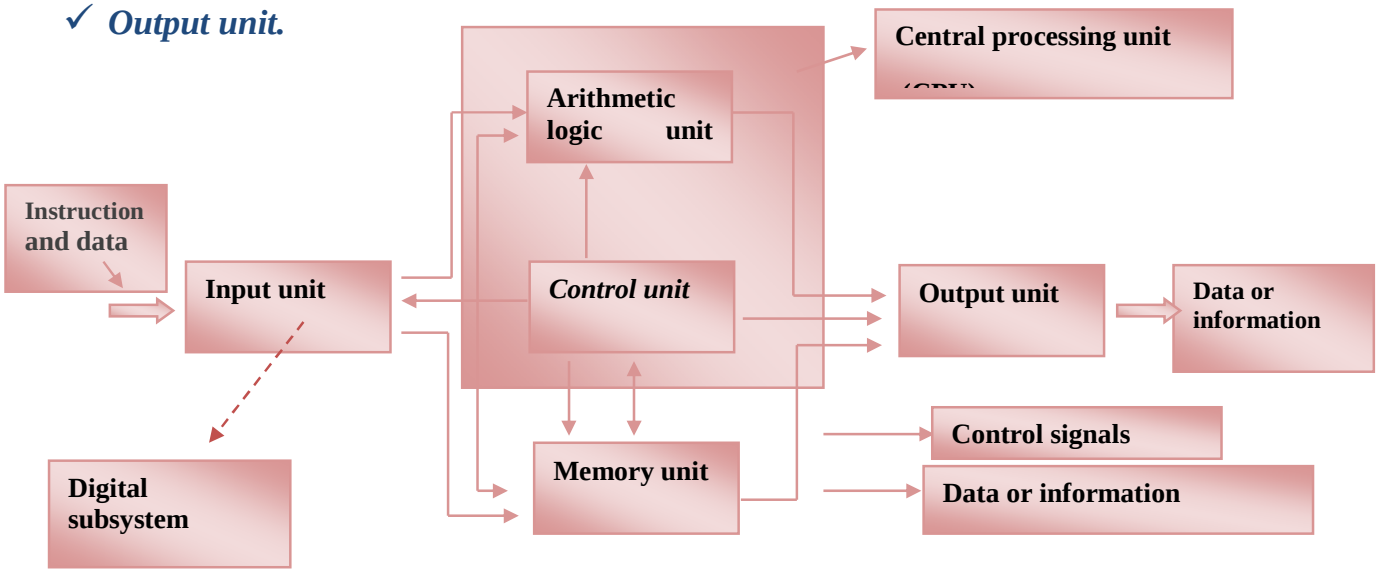
- The basic building blocks used to construct combinational network are ***logic gates***
- The relationship between the input and output signal of the logic gates can be described mathematically using ***Boolean algebra***

Digital system examples

- ***Digital calculator.***
- ***Digital watch.***
- ***Digital computer.***

Functional parts of a digital computer:

- ✓ ***Input unit:*** enter a set of instructions and data.
- ✓ ***Memory unit:*** Stores the instructions and data received from the input unit.
- ✓ ***Control unit:*** Send appropriate signals to all the other units to cause the specific instruction to be executed.
- ✓ ***Arithmetic/ logic unit (ALU)***.
- ✓ ***Output unit.***



General diagram of a digital computer

- ✓ Each component (input/ output/ memory/ CPU) is a digital subsystem.