Al-Azhar University
.,Faculty of Eng
.,Systems and Computer Eng., Dept

ENG 041: Digital & Logic Design (1)

Grade 1, 1st Semester

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Course Objectives

- Studying logic design introduces students to binary numbers, logic gates, and Boolean algebra to understand and design combinational and sequential digital circuits for computers and other systems.
- Key objectives include learning to simplify logic functions, designing basic components, and using hardware description languages (HDLs) for modern design with tools for simulation and testing.
- This knowledge provides a foundation for computer architecture and practical skills in digital hardware development.

Text Books

- **“Logic and Computer Design Fundamentals”, by:** M. Morris Mano Charles Kime, Fifth Edition

Syllabus

- Introduction
- Number Systems
- Combinational Logic Circuits.
- Boolean Algebra.
- Circuit Optimization
- Combinational Logic Design.
- Combinational Logic Devices.

Course Plan

- Final Exam: 40
- Mid Term : 30
- Practical Lab: 30

- Total 100

Lecture 1

Introduction

Introduction

- The term logic is applied to circuits that operate on a set of just two elements with values True (1) and False (0).
- Since computers are based on logic circuits, they operate on patterns of elements from these two-valued sets, which are used to represent, among other things, the decimal digits.
- Today, the term “digital circuits” is viewed as synonymous with the term “logic circuits”.
- The general-purpose digital computer is a digital system that can follow a stored sequence of instructions, called a program, that operates on data.

Information Representation

- Most physical parameters are **continuous** (Analog), typically capable of taking on all possible values over a defined range.
- The physical world is characterized by parameters such as weight, temperature, pressure, velocity, flow, and sound intensity and frequency.
- In contrast, The digital computer system deals only with discrete inputs (countable) called **discrete** (Digital) in nature.
- A devices' like Analog To Digital Converter (ADC), and Digital to Analog Converter (DTA) converters are used to convert information from one form into another.

Analog Signal Vs. Digital Signal

- Suppose that temperature, which is continuous, is measured by a sensor and converted to an electrical voltage, which is likewise continuous.
- We refer to such a continuous voltage as an **analog** signal, which is one possible way to represent temperature.

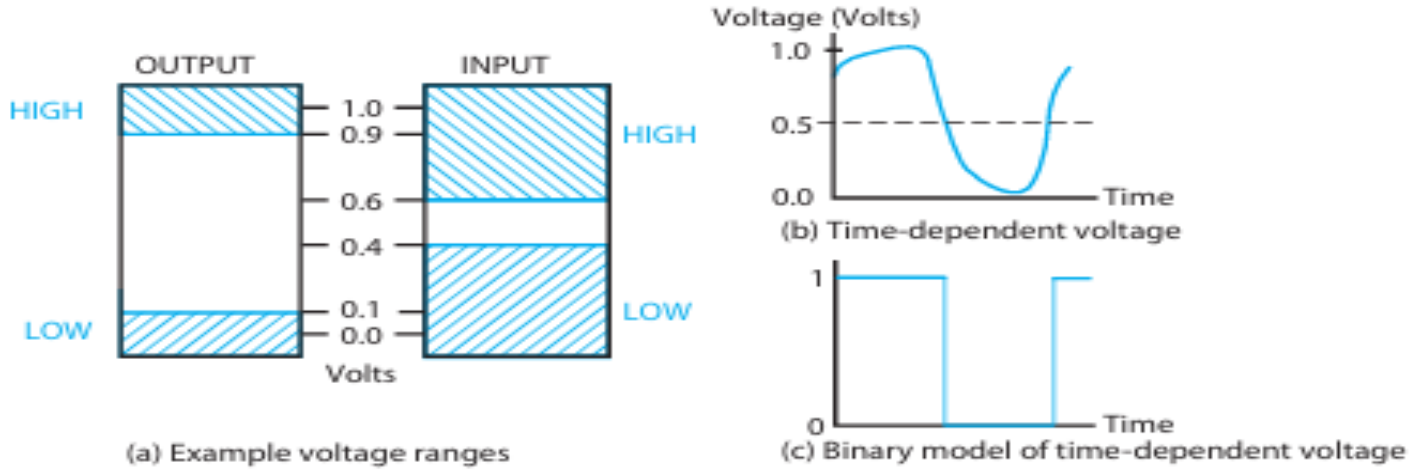
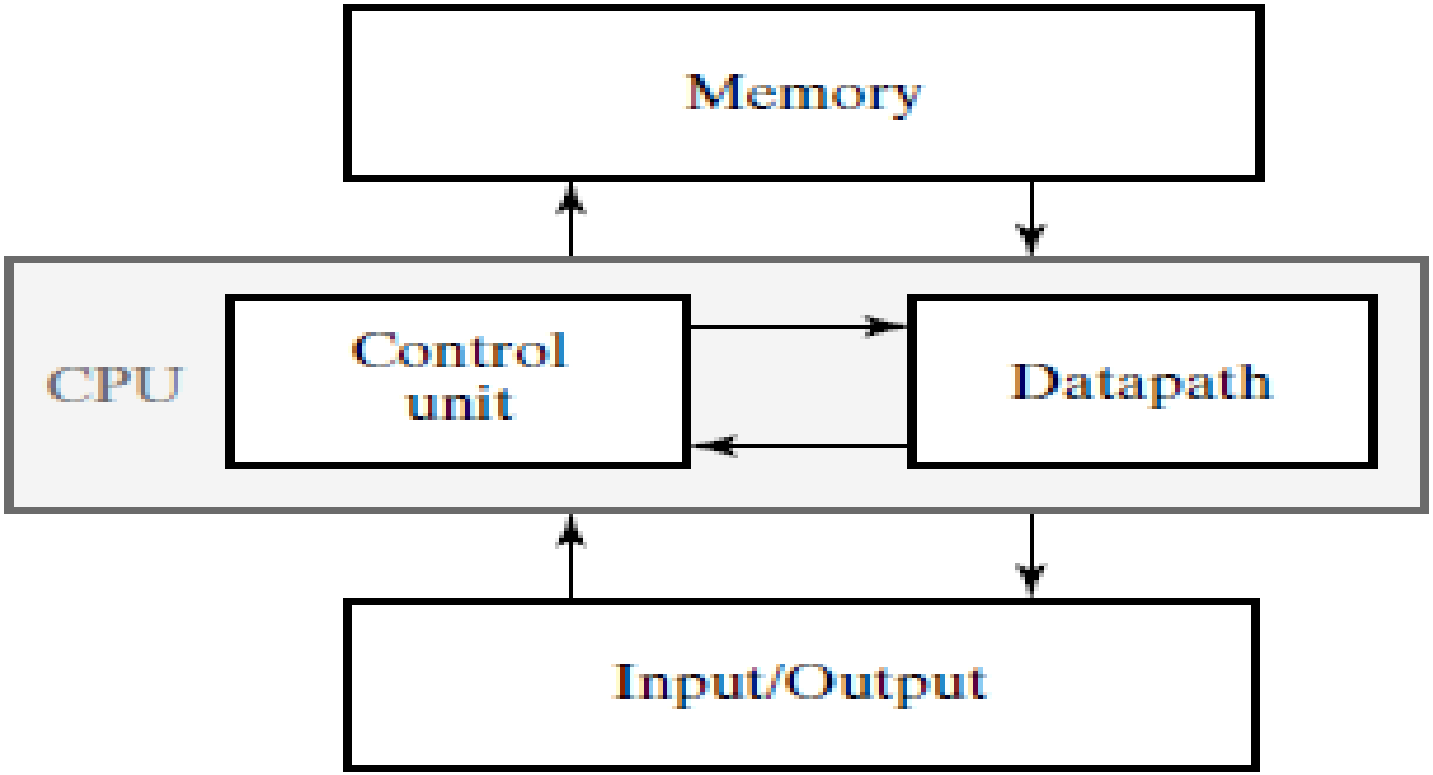


FIGURE 1-1
Examples of Voltage Ranges and Waveforms for Binary Signals

Did You Know?

- What are the main components of digital computer system?
  - Processor and Memory.
- How are the processor and memory designed ?
  - by using Integrated circuits (IC's)
- The IC's made of :
  - logic circuits (combinational & sequential circuits)
- The logic circuits consisting of :
  - logic gates (AND, OR, NOT,….)
- The logic gates made of :
  - transistor (Bipolar, and Unipolar)
- The Transistor made of: Semiconductors (Si, Ge)

The Digital Computer: Von-Neumann Architecture

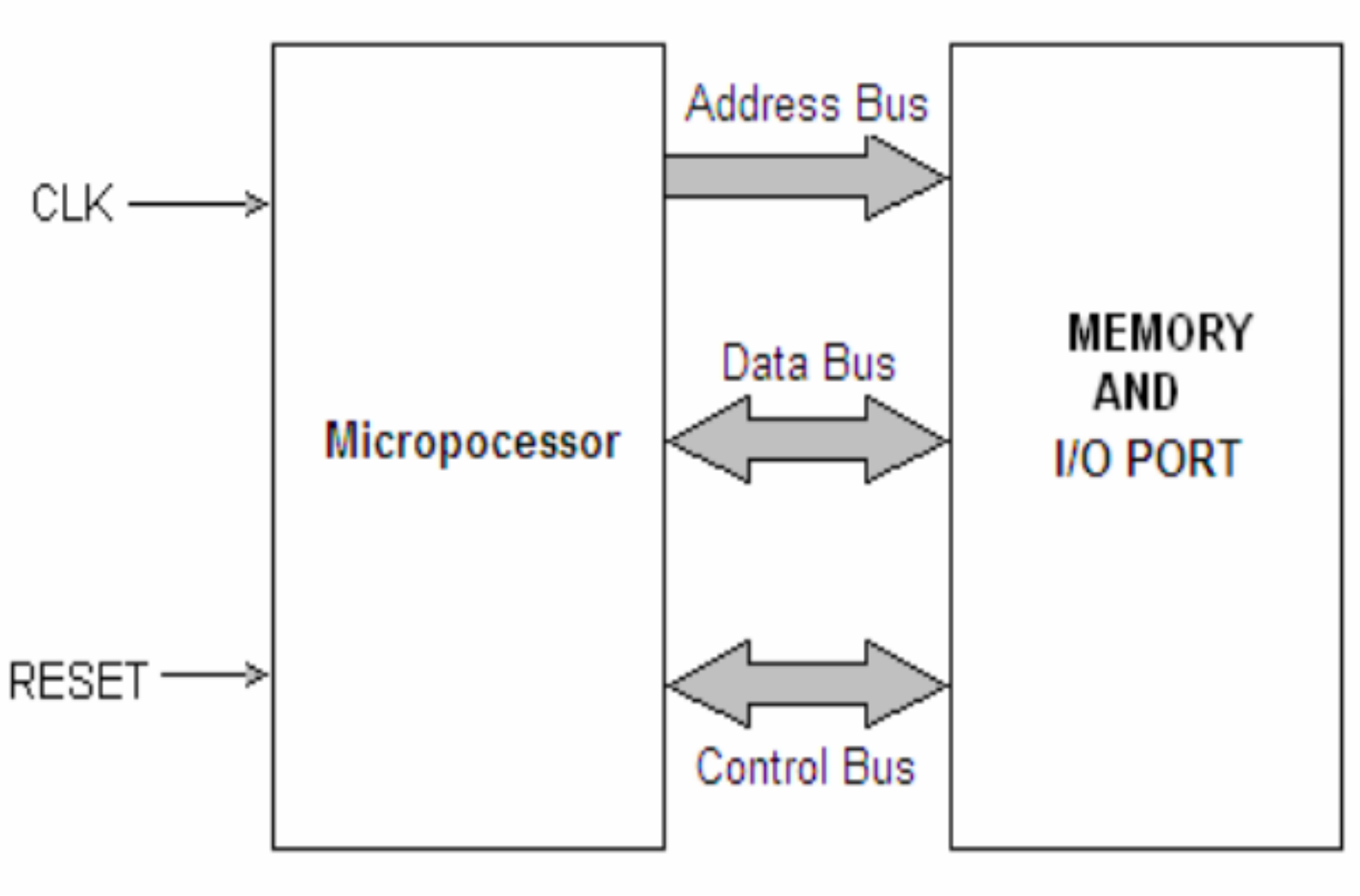


The main Features of Von-Neumann Arch.,

- The computer consists of memory, I/O, and CPU
- The computer structure is independent of the problem
- Binary signals are used for representing data and instructions
- The memory is divided into cells of equal size
- Instructions and Data are stored in the same memory
- The program is a sequence of instructions (control flow)

BASIC MICROPROCESSOR SYSTEM

- The Microprocessor alone does not serve any useful purpose unless it is supported by memory and I/O ports.
- The combination of memory and I/O ports with microprocessor is known as microprocessor-based system.
- The microprocessor executes the program stored in the memory and transfer data to and from the outside world through I/O ports.
- The microprocessor is interconnected with memory and I/O ports by busses called: the data bus, the Address bus and the control bus.
- A bus is basically a communication link between the processing unit and the peripheral devices.


CLK
RESET
Micropocessor
Address Bus
Data Bus
Control Bus
MEMORY
AND
I/O PORT

Control Unit

- The control unit performs the most important function in a computer.
- It controls all other units and controls the flow of data from one unit to another for performing computations.
- It also sequences the operations.
- It instructs all the units to perform the task in a particular sequence with the help of clock pulses.

Arithmetic Logic Unit (ALU)

- Microprocessors (Datapath) are defined by their registers and the operations performed on binary data stored in the registers.
- This operation unit (ALU) is used for performing arithmetic operations such as Addition, Subtraction, Multiplications, division and other logical operations on the data.
- The control unit guides ALU which of the operations are to be performed.
- The sequence of the instructions is controlled by the control unit.

Address Bus

- The **address** bus is unidirectional and is to be used by the CPU to send out address of the memory location to be accessed.
- It is also used by the CPU to select a particular input or output port.
- It may consist of 8, 12, 16, 20 or even more number of parallel lines.
- Number of bits in the address bus determines the minimum number of bytes of data in the memory that can be accessed.
- A 16-bit address bus for instance can access 2^{16} bytes of data.

Data Bus

- Data bus is bidirectional, that is, data flow occurs both to and from CPU and peripherals.
- A microprocessor is characterized by the width of its data bus.
- The size of the internal data bus determines the largest number that can be processed by a microprocessor, for instance, having a 16-bit internal data bus is 65536 (64K).
- A microprocessor is specified by its ‘Word Size’, e.g. 4-bit, 8-bit, 16-bit etc.
- By the term ‘word size” means the number of bits of data that is processed by the microprocessor as a unit.
- It also specifies the width of the data bus.

Control Bus

- Control bus contains a number of individual lines carrying synchronizing signals.
- The control bus sends out control signal to memory, I/O ports and other peripheral devices to ensure proper operation.
- For instance, if it is desired to read the contents of a particular memory location, the CPU first sends out address of that very location on the address bus and a ‘Memory Read’ control signal on the control bus.
- The memory responds by outputting data stored in the addressed memory location on the data bus.

Summary

What are the three main units of a digital computer?

- **Ans.** The three main units of a digital computer are: the central processing unit (CPU), the
  - memory unit and the input/output devices.

How does the microprocessor communicate with the memory and input/output devices?

- **Ans.** The microprocessor communicates with the memory and the Input/ Output devices via
  - the three buses, data bus, address bus and control bus.

What are the different jobs that the CPU is expected to do at any given point of time?

- **Ans.** The CPU may perform a memory read or write operation, ALU operations, an I/O read or write operation or an internal activity.

Beyond the Computer

- In terms of world impact, computers, such as the PC, are not the end of the story.
- Smaller, often less powerful, single-chip computers called *microcomputers* or *microcontrollers*, or special-purpose computers called *digital signal processors* (DSPs) actually are more prevalent in our lives.
- These computers are parts of everyday products (Embedded systems).

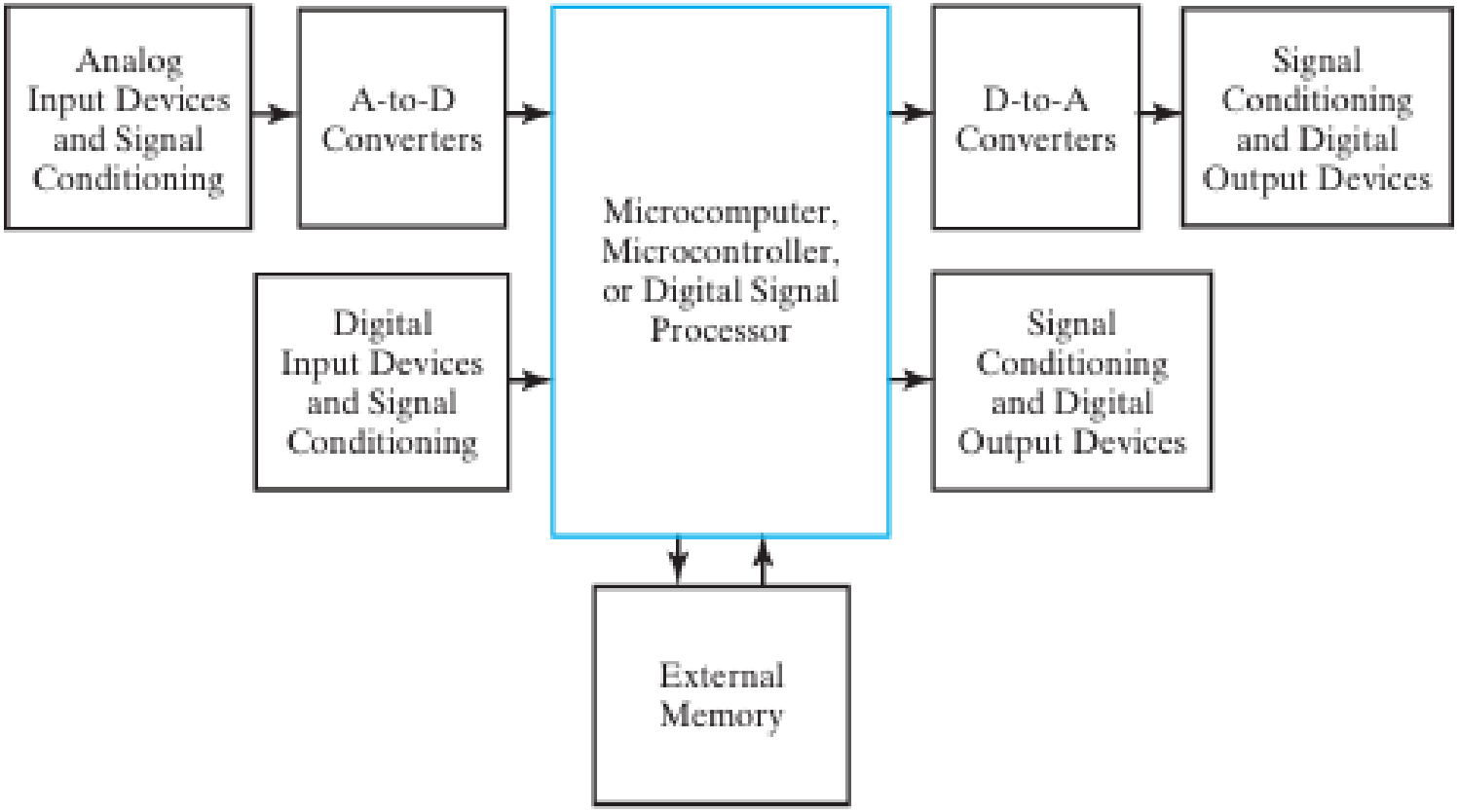


FIGURE 1-3
Block Diagram of an Embedded System

The Task of computer Designer

- Determine what attributes are important for a new computer, then design a computer to maximize performance and energy efficiency while staying within cost, power, and availability constraints.
- This task has many aspects, including instruction set design, functional organization, logic design, and implementation.
- The implementation may encompass integrated circuit design, packaging, power, and cooling.
- Optimizing the design requires familiarity with a very wide range of technologies, from compilers and operating systems to logic design and packaging.

Abstraction Layers Design

- Design is the process of understanding all the relevant constraints for a problem and arriving at a solution that balances those constraints.
- In computer systems, typical constraints include functionality, speed, cost, power, area, and reliability.
- Computer systems design is typically performed in a “top down” approach, where the system is specified at a high level and then the design is decomposed into successively smaller blocks until a block is simple enough that it can be implemented.
- These blocks are then connected together to make the full system.

Cont.,

- A fundamental aspect of the computer systems design process is the concept of "***layers of abstraction***."

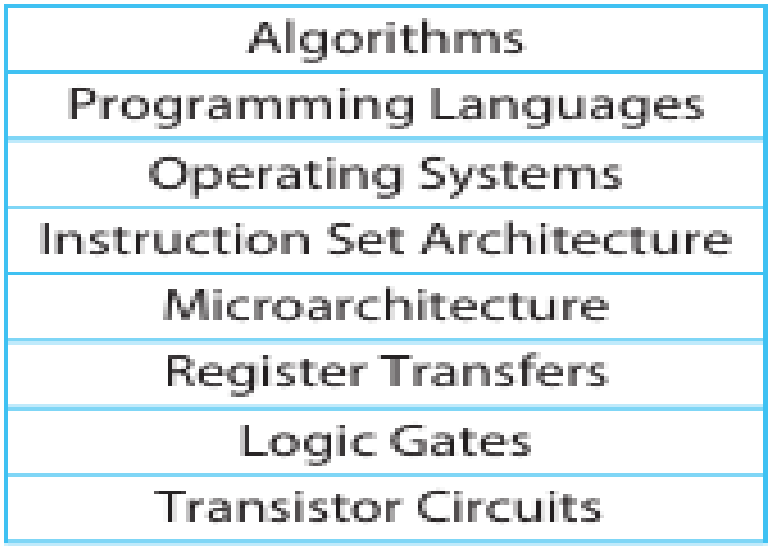


FIGURE 1-5
Typical Layers of Abstraction in Modern Computer Systems

Where:

- At the top of the abstraction layers, algorithms describe a series of steps that lead to a solution.
- These algorithms are then implemented as a program in a high level programming language such as C++, Python, or Java.
- When the program is running, it shares computing resources with other programs under the control of an **operating system.**
- Both the operating system and the program are composed of sequences of **instructions** that are particular to the processor running them.

Cont.,

- The processor hardware is a particular implementation of the instruction set architecture, referred to as the microarchitecture;.
- A microarchitecture can be described as underlying sequences of transfers of data between registers.
- These register transfers can be decomposed into logic operations on sets of bits performed by logic gates, which are electronic circuits implemented with transistors.

Note:

- An important feature of abstraction is that lower layers of abstraction can usually be modified without changing the layers above them.
- For example, a program written in C++ can be compiled on any computer system with a C++ compiler and then executed.
- As another example, an executable program for the Intel™ x86 instruction set architecture can run on any microarchitecture (implementation) of that architecture, whether that implementation is from Intel™ or AMD.
- Consequently, abstraction allows us to continue to use solutions at higher layers of abstraction even when the underlying implementations have changed.

Assignment #1

Give a brief about :

"HARVARD Computer Architecture".