Digital Engineering

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Lectures Info

- Lecturers:

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- Credit hours (3)
- Requirements & Grading (Total 150 marks)
  - Class work and attendance (40 marks)
  - Midterm exam (35 marks)
  - Final Exam (75 marks)

THE IMPORTANCE OF DIGITAL LOGIC

Most of electronic devices consist of two integrated systems

Hardware

Circuits that execute the program commands

To learn more about how to design this you need to study Digital Logic Design

Software

Programs that control hardware to execute user wishes

To learn how to design this you need to study Programming

APPLICATIONS OF DIGITAL LOGIC DESIGN

Conventional computer design

- CPUs, busses, peripherals

Networking and communications

- Phones, modems, routers

Embedded products

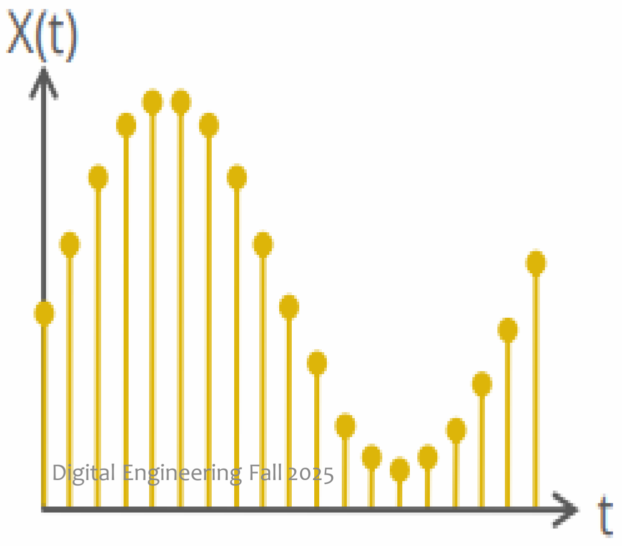
- Cars
- Toys
- Appliances
- Entertainment devices: MP3 players, gaming consoles (PlayStation, Xbox, etc...)

BUT WHAT IS THE MEANING OF DIGITAL LOGIC DESIGN?

DIGITAL SYSTEMS

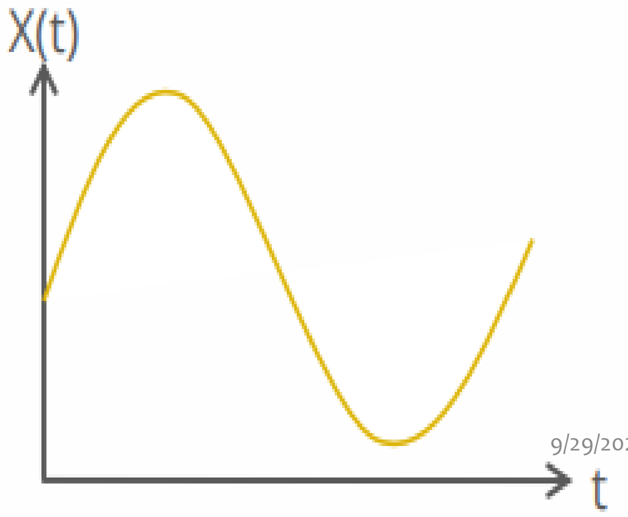
DIGITAL SIGNAL

- The physical quantities or signals can assume only discrete values.
- Greater accuracy



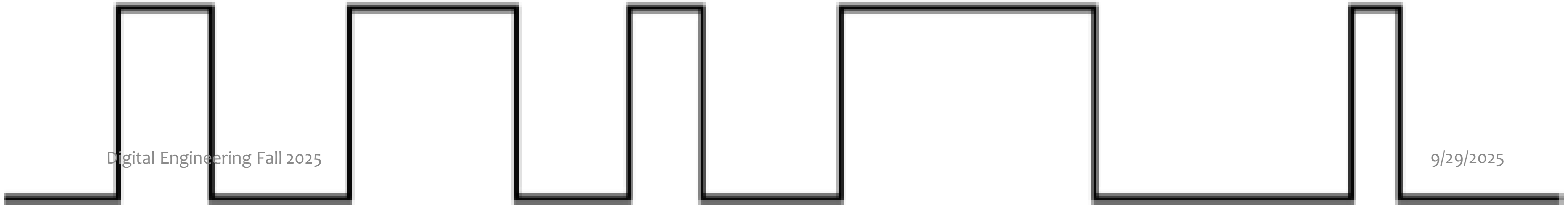
ANALOG SIGNAL

- The physical quantities or signals may vary continuously over a specified range.



WHAT IS DIGITAL?

- Digital describes any system based on discontinuous data or events
- Computers are digital machines because at their most basic level they can distinguish between just two values, 0s and 1s, or off and on
- There is no simple way to represent all the values in between, such as 0.25
- All data that a computer processes must be encoded digitally, as a sequence of 0s and 1s



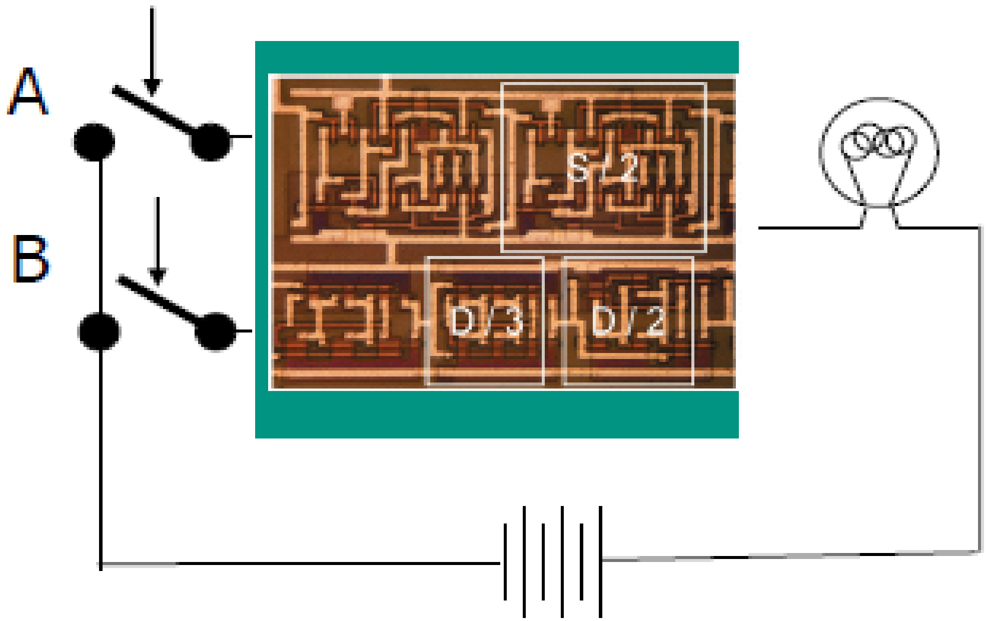
WHAT IS LOGIC DESIGN?

Given a specification of a problem, an engineer needs to come up with a way of solving it, choosing appropriately from a collection of available components, while meeting some criteria for size, cost or power.

WHAT ARE THE BASIC UNITS USED TO BUILD THESE DIGITAL CIRCUITS?

- Digital Logic Gates!
- These are the basic units used to build any digital circuit

DIGITAL LOGIC LEVELS



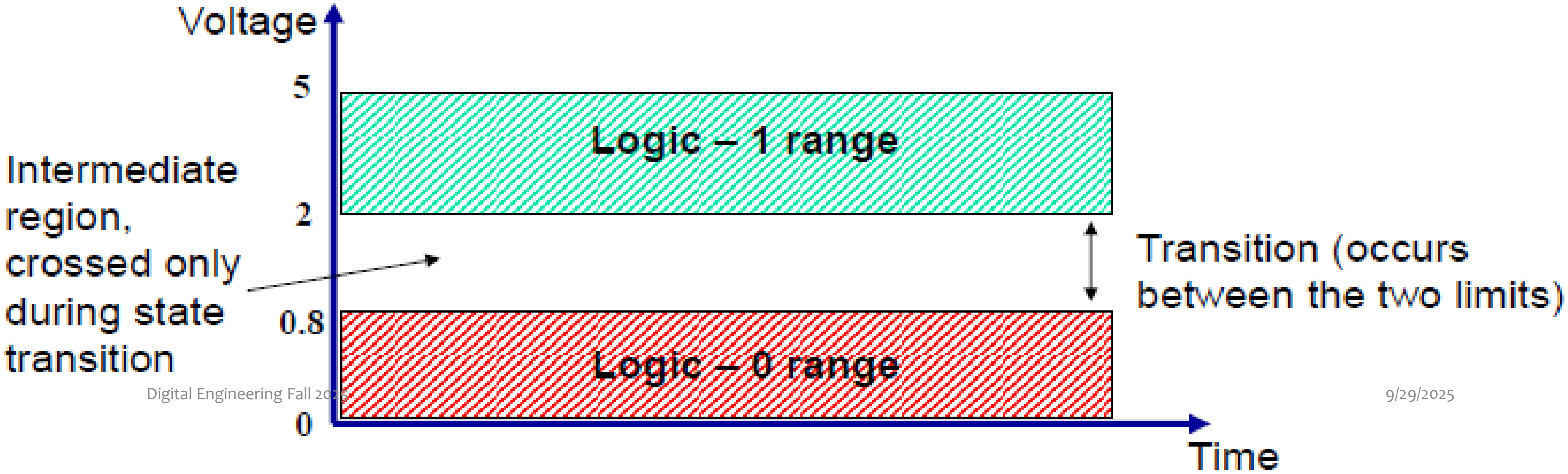
- Digital logic circuits are hardware components that manipulate binary information (we call these *gates*)
- A digital system is basically a black box with a minimum of one input and one output
- Inside this box, are millions of switches called *transistors*
- Transistors perform different functions according to inputs
- In *binary* logic circuits there are only two levels: 0 and 1

DIGITAL LOGIC LEVELS

- What is the physical meaning of logic 0 and logic 1?
- How can we recognize them?

DIGITAL LOGIC LEVELS

- Electrical signals (voltages or currents) that exist in a digital system are in either of two recognizable values (logic 1 or logic 0)



What is Digital Design?

- In this course, we will study the main building blocks of any digital circuit.
- In the electrical and electronic circuits, we have resistance, capacitance, inductance, transistors …
- In the digital circuits, we have the AND, OR, NOT, …
- In the electrical and electronic circuits, we deal with continuous voltage.

- In the digital circuits, we are dealing with either 1 or 0.

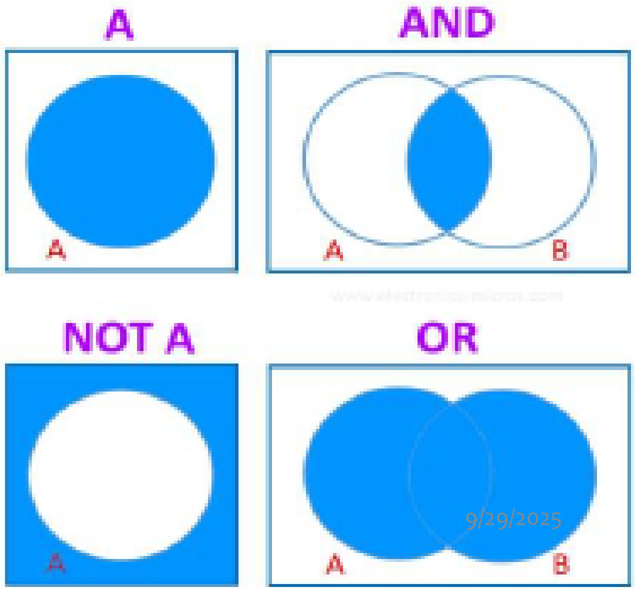
DIGITAL LOGIC GATES

There are three fundamental logical operations, from which all other functions, no matter how complex, can be derived. These Basic functions are named:

- *AND*
- *OR*
- *NOT (INVERTER)*

Each of these has a specific symbol

and a clearly-defined behavior



Numbering System

Revision: Types of Numerical Systems

- **Decimal (Base 10):** Uses digits 0-9.
- **Binary (Base 2):** Uses digits 0 and 1.
- **Octal (Base 8):** Uses digits 0-7.
- **Hexadecimal (Base 16):** Uses digits 0-9 and A-F.

The Decimal System

- Uses 10 digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

- **Description:** Base 10, most commonly used in everyday life.
- **Structure:** Each digit represents a power of 10 (e.g., $345 = 3\times10^2 + 4\times10^1 + 5\times10^0$).

The Binary System

- Uses 2 digits: 0 and 1.
- **Description:** Base 2, used primarily in computing.
- **Structure:** Each digit represents a power of 2 (e.g., $1011 = 1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0$).
- **Example:** The binary number 1101 represents 13 in decimal.

The Octal System

- Uses 8 digits: 0, 1, 2, 3, 4, 5, 6, 7.
- **Description:** Base 8, less common but used in some computing contexts.
- **Structure:** Each digit represents a power of 8 (e.g., $257 = 2\times8^2 + 5\times8^1 + 7\times8^0$).
- **Example:** The octal number 17 represents 15 in decimal.

The Hexadecimal System

- Uses 16 symbols: 0-9 and A-F (where A=10, B=11, C=12, D=13, E=14, F=15).
- **Description:** Base 16, commonly used in programming and digital electronics.
- **Structure:** Each digit represents a power of 16 (e.g., 2A3 = $2 \times 16^2 + 10 \times 16^1 + 3 \times 16^0$).
- **Example:** The hexadecimal number 1F represents 31 in decimal.

Decimal to Binary Conversion

- **Method:** Repeatedly divide by 2 and record the remainder.
- **Example:** Convert 13 decimal to binary:
- 13 ÷ 2 = 6, remainder 1
- 6 ÷ 2 = 3, remainder 0
- 3 ÷ 2 = 1, remainder 1
- 1 ÷ 2 = 0, remainder 1
- **Binary:** 1101

Binary to Decimal Conversion

- **Method:** Sum the powers of 2 for each digit.
- **Example:** Convert 1101 binary to decimal:

$1\times 2^3 + 1\times 2^2 + 0\times 2^1 + 1\times 2^0$

$= 8 + 4 + 0 + 1 = \mathbf{13}$

Decimal to Octal Conversion

- **Method:** Repeatedly divide by 8 and record the remainder.
- **Example:** Convert 65 decimal to octal:
- 65 ÷ 8 = 8, remainder 1
- 8 ÷ 8 = 1, remainder 0
- 1 ÷ 8 = 0, remainder 1
- **Octal:** 101

Octal to Decimal Conversion

- **Method:** Sum the powers of 8 for each digit.
- **Example:** Convert 17 octal to decimal:
  - $1 \times 8^1 + 7 \times 8^0$
  - = 8 + 7 = **15 decimal**

Decimal to Hexadecimal Conversion

- **Method:** Repeatedly divide by 16 and record the remainder.
- **Example:** Convert 31 to hexadecimal:
- 31 ÷ 16 = 1, remainder 15 (F)
- 1 ÷ 16 = 0, remainder 1
- **Hexadecimal:** 1F

Hexadecimal to Decimal Conversion

- **Method:** Sum the powers of 16 for each digit.
- **Example:** Convert 2A3 to decimal:
- $2 \times 16^2 + 10 \times 16^1 + 3 \times 16^0$
- $= 512 + 160 + 3 =$ **675**

Summary

1. What is Digital Design?

- Digital design involves creating circuits that operate using discrete values, primarily binary (0s and 1s).
- Focuses on the design of systems that process digital signals.

2. Importance of Digital Systems

- Digital systems are more reliable and flexible than analog systems.
- Commonly used in computers, smartphones, and embedded systems

3. Binary Number System

- Digital systems use the binary number system (base-2), which employs two symbols: 0 and 1.
- Understanding binary representation is essential for working with digital circuits.

4. Logic Levels

- Represents binary values with specific voltage levels: typically, a high voltage for 1 and a low voltage for 0.

5. Logic Gates:

- Basic building blocks (AND, OR, NOT, NAND, NOR, XOR, XNOR) that perform logical operations.

Practice Problems (Left to student to read)

- **Exercise 1:** Convert 45 to binary.
- **Exercise 2:** Convert 1010 to decimal.
- **Exercise 3:** Convert 23 to octal.
- **Exercise 4:** Convert 7F to decimal.

Exercise 1: Convert 45 to Binary (Left to student to read)

- **Method:** Divide by 2 and record the remainders.
- 45 ÷ 2 = 22, remainder **1**
- 22 ÷ 2 = 11, remainder **0**
- 11 ÷ 2 = 5, remainder **1**
- 5 ÷ 2 = 2, remainder **1**
- 2 ÷ 2 = 1, remainder **0**
- 1 ÷ 2 = 0, remainder **1**
- **Binary:** Reading the remainders from bottom to top, **45 in binary is 101101**.

Exercise 2: Convert 1010 to Decimal (Left to student to read)

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1. $1 \times 2^3 = 1 \times 8 = 8$
2. $0 \times 2^2 = 0 \times 4 = 0$
3. $1 \times 2^1 = 1 \times 2 = 2$
4. $0 \times 2^0 = 0 \times 1 = 0$

Decimal: 8+0+2+0=10

Exercise 4: Convert 23 to Octal (Left to student to read)

- **Method:** Divide by 8 and record the remainders.
- 23 ÷ 8 = 2, remainder **7**
- 2 ÷ 8 = 0, remainder **2**
- **Octal:** Reading the remainders from bottom to top, **23 in octal is 27**.

Exercise 4: Convert 7F to Decimal (Left to student to read)

1. $7 \times 16^1 = 7 \times 16 = 112$
2. $F \times 16^0 = 15 \times 1 = 15$ (since F = 15)

- **Decimal:** 112+15=127112 + 15 = 127112+15=127