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Electrical Engineering Department

DESIGN AND IMPLEMENTATION OF A COMPREHENSIVE SYSTEM FOR SECOND-YEAR LOGIC LAB EXPERIMENTS

A graduation project is submitted to the Electrical Engineering Department in partial fulfillment the requirements for the degree of Bachelor of Science in College of Engineering - Electrical Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged.

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Abstract

The rapid advancement of digital logic and computing systems has necessitated the development of practical and interactive learning tools for university students. This project focuses on the **design and implementation of a comprehensive system for second-year logic lab experiments**. The system includes a custom-designed board integrating fundamental logic gates and complex combinational circuits such as **Full Adder, Half Subtractor, Multiplexer, Demultiplexer, and Flip-Flop**.

The primary objective of this project is to enhance students' understanding of digital logic principles through hands-on experiments. The system provides a user-friendly platform that enables students to construct, test, and analyze various logic circuits efficiently. The board is designed to be cost-effective, and easily adaptable to different educational settings.

By implementing this system, we aim to bridge the gap between theoretical knowledge and practical application, making logic circuit experimentation more accessible and engaging for students. The proposed system will serve as a valuable educational tool for universities, fostering a deeper comprehension of digital logic design.

الخلاصة

شهدت الأنظمة الرقمية وتكنولوجيا الحوسبة تطورًا سريعًا، مما أدى إلى الحاجة إلى أدوات تعليمية عملية وتفاعلية لطلاب الجامعات. يهدف هذا المشروع إلى **تصميم وتنفيذ نظام شامل لتجارب مختبر المنطق لطلاب السنة الثانية**، حيث يتضمن لوحة إلكترونية مخصصة تحتوي على **البوابات المنطقية الأساسية والدوائر المنطقية المركبة** مثل **المجمع الكامل، الطارح النصفي، الملتبلكسر، الديمولتبلكسر، والفلب-فلوب**.

يهدف هذا النظام إلى تعزيز فهم الطلاب لمبادئ المنطق الرقمي من خلال التجارب العملية. كما يوفر منصة سهلة الاستخدام تتيح للطلاب بناء واختبار وتحليل الدوائر المنطقية بكفاءة. تم تصميم اللوحة بحيث تكون **وحدوية، منخفضة التكلفة، وسهلة التكيف** مع البيئات التعليمية المختلفة.

من خلال تنفيذ هذا النظام، نسعى إلى سد الفجوة بين المعرفة النظرية والتطبيق العملي، مما يجعل تجارب الدوائر المنطقية أكثر سهولة وتفاعلية للطلاب. سيسهم هذا النظام المقترح في تحسين جودة التعليم في الجامعات من خلال توفير أداة تعليمية فعالة لفهم تصميم الدوائر الرقمية بشكل أعمق.

Table of content

Table of figure

Table of Tables

CHAPTER ONE

1.1 Introduction

The rapid advancements in digital electronics and computing have significantly influenced various fields, including education, automation, and embedded systems. Understanding digital logic circuits is fundamental for students pursuing degrees in electrical engineering, computer science, and related disciplines. Logic circuits form the backbone of modern digital systems, enabling functions ranging from basic arithmetic operations to complex decision-making processes in microcontrollers and processors. However, learning digital logic can often be challenging due to its abstract nature, requiring students to develop both theoretical knowledge and practical skills.

To address these challenges, this research focuses on designing and implementing a comprehensive system for second-year logic lab experiments. The proposed system is a custom-built logic circuit board that incorporates fundamental logic gates and complex combinational circuits such as Full Adder, Half Subtractor, Multiplexer, Demultiplexer, and Flip-Flop. This board will serve as an interactive and user-friendly platform that enables students to construct, modify, and test various logic circuits efficiently. By providing hands-on experience, the system enhances students' comprehension of logic design concepts and bridges the gap between theoretical learning and real-world applications.

Traditional methods of teaching logic circuits often rely on theoretical explanations and software simulations, which may not fully engage students in the learning process. While simulations provide insights into circuit behavior, they lack the tangible experience that physical hardware offers. The proposed logic lab board integrates both hardware and software elements, allowing students to experiment with real components while simultaneously analyzing circuit behavior through digital tools. This hybrid approach ensures a more comprehensive understanding of digital logic principles.

Furthermore, the designed system is cost-effective, modular, and adaptable to different educational settings. It can be used in classroom environments, laboratories, or even for self-learning purposes. By implementing this system, we aim to provide an innovative educational tool that simplifies logic circuit experiments and fosters a deeper understanding of digital electronics among students. The research also explores potential improvements in teaching methodologies through interactive and practical approaches.

This study will outline the design, implementation, and evaluation of the proposed logic lab board. Through a detailed analysis, we will demonstrate how this system enhances students' learning experiences and contributes to the development of more effective digital logic education methodologies. The following sections of this paper will discuss the theoretical framework, system design, experimental setup, results, and conclusions drawn from the research.[1][2]

1.2 Digital Logic

Digital logic is the foundation of electronic circuit design, forming the core of modern computing systems. It operates on binary signals (0s and 1s) to represent and process data, playing a crucial role in designing processors, control units, and embedded systems.[3]

1.2.1 Components of Digital Logic

Logic Gates: Basic building blocks such as AND, OR, NOT, NAND, NOR, XOR, and XNOR, which perform fundamental logical operations.

1. Combinational Circuits: Circuits whose outputs depend only on current inputs, including adders, multiplexers, and decoders.
2. Sequential Circuits: Circuits that rely on both current and previous inputs, such as flip-flops and registers.

3. Counting and Storage Systems: Components like registers and counters used for storing and processing data.
4. Microprocessors and Microcontrollers: Devices that execute instructions and perform various computing tasks based on digital logic principles.[4]

1.2.2 Applications of Digital Logic:

1. Computer and smartphone design.
2. Embedded systems in electronic devices.
3. Memory and storage unit development.
4. Industrial and medical electronic circuits.[5]

1.3 Digital Logic Laboratories

Digital logic laboratories are essential for students and engineers to gain hands-on experience in designing and analyzing digital circuits. These labs provide a practical environment for experimenting with fundamental digital logic concepts, helping learners bridge the gap between theory and real-world applications.[6]

1.4 Importance of Digital Logic Labs

1. Enhances problem-solving and critical thinking skills.
2. Provides practical exposure to real-world circuit implementation.
3. Prepares students for advanced courses in computer architecture and embedded systems.
4. Helps in developing industry-relevant technical skills.[7]

1.5 System Design

The proposed system is a custom-built logic circuit board designed to facilitate second-year university students in performing various digital logic experiments. This board integrates fundamental and complex logic components, enabling students to construct, test, and analyze different logic circuits in a practical manner. The system aims to enhance hands-on learning by providing an interactive platform that replicates real-world applications of digital logic. [8]

1.5.1 Components of the System

The system consists of the following key components:

1. Logic Gates: AND, OR, NOT, NAND, NOR, XOR, XNOR gates for basic logic operations.
2. Combinational Circuits: Full Adder, Half Subtractor, Multiplexer, Demultiplexer.
3. Sequential Circuits: Flip-Flops (SR, D, JK, T) for memory and state storage.
4. Power Supply Unit: Provides stable voltage levels required for circuit operation.
5. Input and Output Interfaces: Switches, push buttons, and LED indicators for user interaction and circuit visualization.
6. PCB Design: A modular and compact printed circuit board layout for easy integration and usability.[9]

1.5.2 Functional Design

The system is designed to allow students to construct and experiment with digital circuits using plug-and-play modularity. The board consists of dedicated sections for each circuit type, allowing users to connect inputs, observe outputs, and modify configurations easily.

1. Interactive Learning: Users can manually toggle switches and buttons to test different input conditions.
2. Real-Time Observation: LED indicators provide immediate feedback on circuit outputs.
3. Scalability: Additional logic modules can be attached to expand the system's capabilities.[10]

1.5.3 Implementation Approach

The implementation of the system follows these stages:

1. Circuit Design and Simulation: Using software tools like Proteus or Logisim to validate circuit functionality.

2. Hardware Development: Assembling the PCB, soldering components, and ensuring proper connectivity.

3. Testing and Calibration: Verifying the accuracy of logic operations and debugging any electrical issues.

4. User Testing and Feedback: Evaluating the system with students to assess usability and effectiveness.[11]

1.5.4 Advantages of the System

1. Hands-on Experience: Encourages practical application of digital logic theories.
2. Cost-Effective: Reduces reliance on expensive lab equipment.
3. Enhanced Understanding: Provides a direct and intuitive method for experimenting with logic circuits.
4. Portable and Modular: Can be easily transported and expanded for more advanced experiments.[10][11]

1.6 Importance of the Project

1. Enhanced Learning – Provides an interactive and structured platform for better understanding of digital logic concepts.
2. Error Reduction – Automates key processes to minimize mistakes in circuit design and implementation.
3. Improved Troubleshooting – Offers real-time feedback and guided simulations to help students resolve issues efficiently.
4. Time Efficiency – Speeds up grading and feedback, reducing instructors' workload and accelerating student progress.

5. Industry Alignment – Prepares students for real-world engineering roles by aligning with modern digital circuit design practices.

1.7 Objectives of the Project

1. Enhancing Practical Learning – Provide an interactive environment for better understanding of digital logic concepts.
2. Reducing Errors – Automate processes to minimize mistakes in circuit design and execution.
3. Improving Troubleshooting – Utilize real-time feedback and simulations for efficient issue resolution.
4. Increasing Efficiency – Automate evaluations to optimize workflow and reduce grading efforts.
5. Facilitating Documentation – Implement data logging for systematic tracking and analysis of experiments.
6. Bridging Theory and Practice – Strengthen the link between theoretical knowledge and practical application.
7. Industry Alignment – Equip students with skills relevant to modern digital circuit design.

1.8 Reasons for Choosing This Project

1. Bridging the Gap Between Theory and Practice
2. Enhancing Digital Logic Education
3. Cost-Effective and Accessible Solution
4. Encouraging Active Learning
5. Adaptability for Various Learning Levels
6. Preparation for Industry Applications
7. Promoting Research and Innovation

CHAPTER TWO

Tools and equipment

2.1 Logic gates

Are fundamental building blocks of digital circuits and are used in electronic devices to perform logical operations. They take one or more binary inputs and produce a single output based on a specific logical function. These operations follow the principles of Boolean algebra.[12] Below are the most common types of logic gates:

2.1.1 AND Gate

- Symbol: A.B

Operation: The AND gate outputs 1 (true) only if all of its inputs are 1. Otherwise, the output is 0.[13]

Table 2-1 Truth Table AND Gate

A	B	Output (A.B)
0	0	0
0	1	0
1	0	0
1	1	1

- **Equation**: Output=A.B

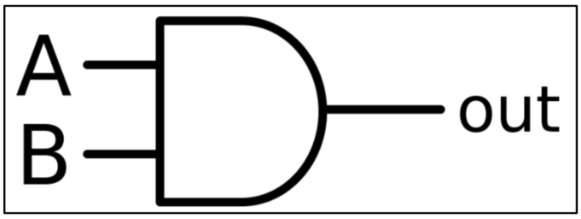

Figure 2–1 AND Gate

2.1.2 OR Gate

- **Symbol**: A+B
- **Operation**: The OR gate outputs 1 if **at least one** of its inputs is 1. The output is 0 only when all inputs are 0.[14]

Table 2-2 Truth Table OR Gate

A	B	Output (A + B)
0	0	0
0	1	1
1	0	1
1	1	1

- **Equation**: Output=A+B

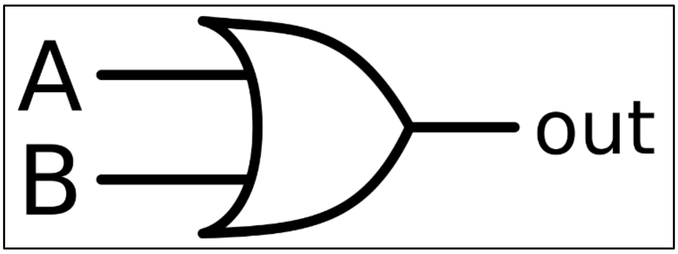

Figure 2–2 OR Gate

2.1.3 NOT Gate (Inverter)

- Symbol: $\bar{A}$

Operation: The NOT gate, or inverter, outputs the opposite of its input. If the input is 1, the output will be 0, and vice versa.[14]

Table 2-3 Truth Table NOT Gate

A	Output ($\bar{A}$)
0	1
1	0

- **Equation**: Output=$\bar{A}$

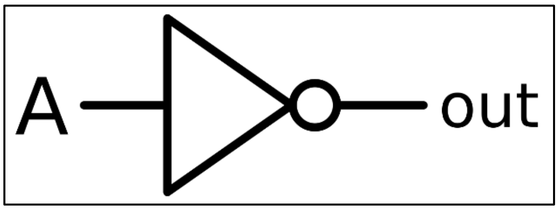

Figure 2–3 NOT Gate

2.1.4 NAND Gate

- Symbol: $\overline{A.B}$
- Operation: The NAND gate is the inverse of the AND gate. It outputs 0 only when all inputs are 1. Otherwise, the output is 1.[14]

Table 2-4 Truth Table NAND Gate

A	B	Output ($\overline{A.B}$)
0	0	1
0	1	1
1	0	1
1	1	0

- **Equation**: Output= $\overline{A.B}$

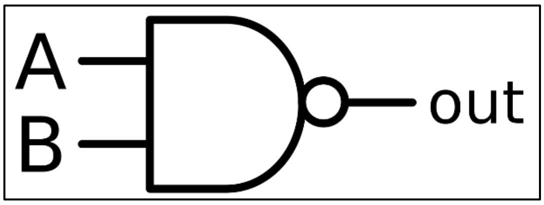

Figure 2–4 NAND Gate

2.1.5 NOR Gate

- Symbol: $\overline{A + B}$
- Operation: The NOR gate is the inverse of the OR gate. It outputs 1 only when all of its inputs are 0. Otherwise, it outputs 0.[14]

Table 2-5 Truth Table NOR Gate

A	B	Output ($\overline{A + B}$)
0	0	1
0	1	0
1	0	0
1	1	0

- **Equation**: Output=$\overline{A + B}$

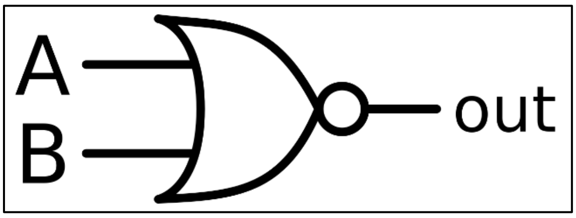

Figure 2–5 NOR Gate

2.1.6 XOR Gate (Exclusive OR)

- Symbol: A⊕B
- Operation: The XOR gate outputs 1 if only one of its inputs is 1. If both inputs are the same (either both 0 or both 1), the output is 0.[14]

Table 2-6 Truth Table XOR gate

A	B	Output (A ⊕ B)
0	0	0
0	1	1
1	0	1
1	1	0

- **Equation**: Output=A⊕B

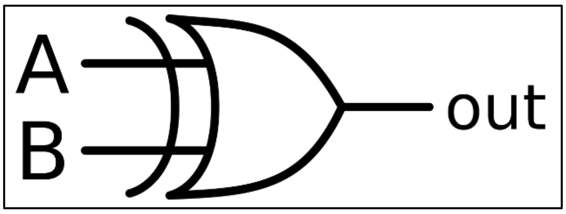

Figure 2–6 XOR Gate

2.1.7 XNOR Gate (Exclusive NOR)

- Symbol: $\overline{A \oplus B}$
- Operation: The XNOR gate is the inverse of the XOR gate. It outputs 1 when both inputs are the same (either both 0 or both 1), and 0 when the inputs differ.[14]

Table 2-7 Truth Table XNOR gate

A	B	Output ($\overline{A \oplus B}$)
0	0	1
0	1	0
1	0	0

1	1	1

- **Equation**: Output=$\overline{A \oplus B}$

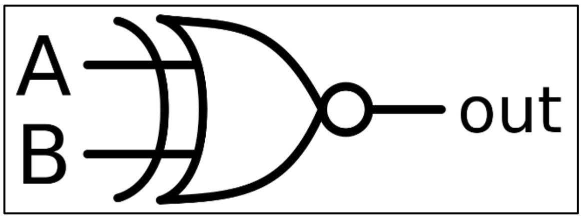

Figure 2–7 XNOR Gate

2.2 Combinational Circuit

A combinational circuit is a type of digital logic circuit whose output depends on the present input values only and does not depend on past input and output values. Therefore, a combinational circuit is considered to not have a memory element in its circuit that stores previous inputs and outputs. Instead, it consists of a certain number of input lines to apply current input values and a certain number of output lines.

The most important characteristic of a combinational circuit is that it does not have any feedback path between input and output. Therefore, the combinational circuits can be categorized as open-loop systems.[15]

2.2.1 Types of Combinational Circuits

2.2.1.1 Binary Adders

A binary adder is a combinational circuit that performs the addition of binary digits or bits. Depending on the design and configuration, there are two types of binary adders namely, Half Adder and Full Adder.

2.2.1.2 Half Adder

The half adder is a combinational logic circuit with two inputs and two outputs. The half adder circuit is designed to add two single-bit binary numbers A and B.

It is the basic building block for the addition of two single-bit numbers. This circuit has two outputs namely, sum and carry.[15]

2.2.1.3 Full Adder

The full adder is designed to overcome the drawback of a half adder which is the ability to add only two bits. Therefore, the full adder is a three-input and two-output combinational circuit. Where, the inputs are two one-bit numbers A and B, and a carry C from the previous addition. The outputs are sum and carry output.[15]

2.2.1.4 Binary Subtractors

A binary subtractor is a combinational logic circuit used to subtract one binary number from another. Similar to binary adder, there are two types of binary subtractors namely, half-subtractor and full-subtractor.

2.2.1.5 Half Subtractor

A half subtractor is a combination circuit with two inputs (A and B) and two outputs (difference and borrow). It produces the difference between the two binary bits at the input and also produces an output (Borrow) to indicate if a 1 has been borrowed. In binary subtraction (A-B), A is called a Minuend bit and B is called a Subtrahend bit.

2.2.1.6 Full Subtractor

The full subtractor is also a combinational circuit with three inputs A, B, and Bin, and two outputs D and Bout.

2.2.1.7 Multiplexers (MUX)

A multiplexer is a special type of combinational logic circuit. It consists of n-data input lines, one output, and m-select lines. For a multiplexer, n = 2m.

A multiplexer is a digital circuit that selects one of the n data inputs and routes it to the output line. The selection of one of the n data inputs is done by the select lines. Depending on the digital code applied at the select lines, one out of "n" data inputs is selected and transmitted to the output line.

In some multiplexers, there is also an enable input E which is useful in cascading of multiple multiplexers.

Depending on the number of input lines, there can be several types of multiplexers. Some common types of multiplexers include 2:1 Multiplexer, 4:1 Multiplexer, 16:1 Multiplexer, and 32:1 Multiplexer.

2.2.1.8 4x1 Multiplexer

4x1 Multiplexer has four data inputs D0, D1, D2 & D3, two selection lines S0 & S1 and one output Y. The block diagram of 4x1 Multiplexer is shown in the following figure. One of these 4 inputs will be connected to the output based on the combination of inputs present at these two selection lines. Truth table of 4x1 Multiplexer is shown below.[15]

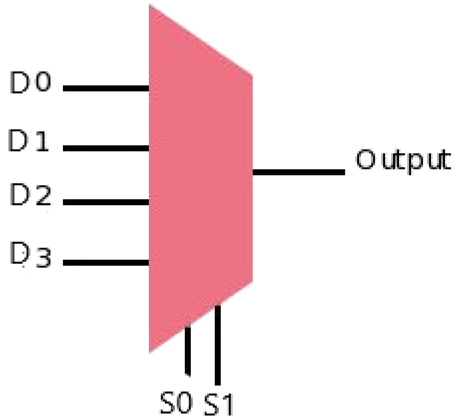

Figure 2–8: Block diagram of 4x1 Multiplexer

Table 2-8 : Truth table of 4x1 Multiplexer

Selection Lines		Output
S0	**S1**	**Y**
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

2.2.1.9 Demultiplexers (DEMUX)

A demultiplexer performs a distribution operation i.e., it receives one data input and distributes it over several output lines.

A demultiplexer has only one input line, "n" output lines, and "m" select lines. At a time, only one output line is selected by the digital code applied to the select lines and the data input is transmitted to the selected output line.

Demultiplexers can be classified into various types depending on the number of output lines. Some commonly used types of demultiplexers include: 1:2 Demultiplexer, 1:4 Demultiplexer, 1:16 Demultiplexer, and 1:32 Demultiplexer.

2.2.1.10 1x4 De-multiplexer

1x4 De-Multiplexer has one input Data(D), two selection lines, S0 & S1 and four outputs Y0, Y1, Y2 & Y3. The block diagram of 1x4 De-Multiplexer is shown in the following figure [15]

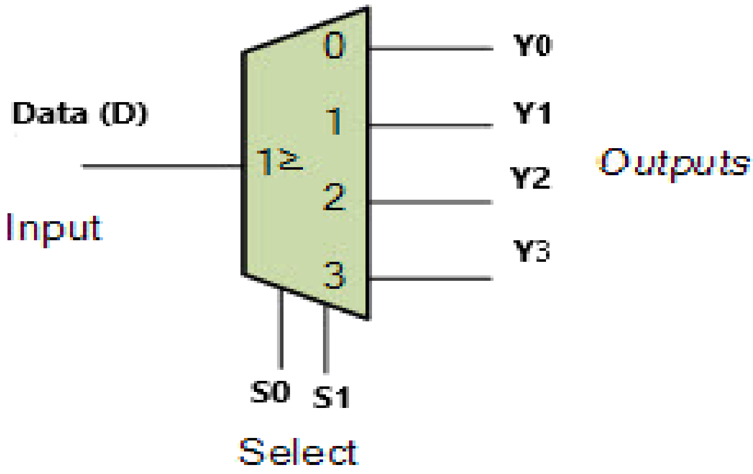

Figure 2–9:Block diagram of 1x4 De-Multiplexer

Table 2-9: Truth table of 1x4 De-Multiplexer

Selection Inputs		Outputs			
S0	S1	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	**D**
0	1	0	0	**D**	0
1	0	0	**D**	0	0
1	1	**D**	0	0	0

2.2.1.11 Flip Flop

Its name comes from its ability to "flip" or "flop" between two stable states. By latching a value and changing it when triggered by a clock signal, flip-flops can store data over time. They are called flip-flops because they have two stable states and switch between them based on a triggering event.

It is the basic storage element in sequential logic. But first, let's clarify the difference between a latch and flip-flops.

Types of Flip-flops

There are 4 types of flip-flops in digital electronics:

1. SR Flip Flop
2. JK Flip Flop
3. D Flip Flop
4. T Flip Flop

1. SR Flip Flop

This is the most common flip-flop among all. This simple flip-flop circuit has a set input (S) and a reset input (R). In this system, when you Set “S” as active, the output “Q” would be high, and “Q‘” would be low.

Once the outputs are established, the wiring of the circuit is maintained until “S” or “R” goes high, or power is turned off.

As shown above, it is the simplest and easiest to understand. The two outputs, as shown above, are the inverse of each other.

SR Flip Flop is also known as a master-slave flip-flop.

The truth table of SR Flip-Flop is given below.[16]

Table 2-10: truth table of SR Flip-Flop

S	R	Q	Q’
0	0	0	1
0	1	0	1
1	0	1	0
1	1	∞	∞

2. JK Flip-Flop

Due to the undefined state in the SR flip-flops, another flip-flop is required in electronics.

The JK flip-flop is an improvement on the SR flip-flop where S=R=1 is not a problem.

The input condition of J=K=1 gives an output inverting the output state. However, the outputs are the same when one tests the circuit practically.

In simple words, If J and K data input are different (i.e. high and low), then the output Q takes the value of J at the next clock edge. If J and K are both low, then no change occurs.

If J and K are both high at the clock edge, then the output will toggle from one state to the other. JK Flip-Flops can function as Set or Reset Flip-flops.[17]

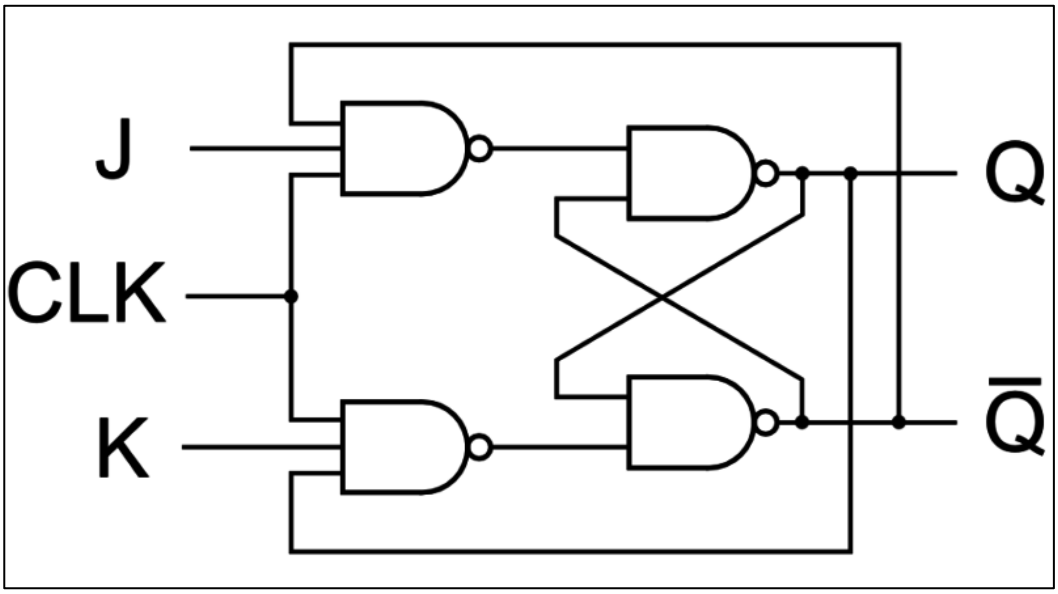

Figure 2–10: JK Flip Flop Circuit

Table 2-11: JK Flip-flop Truth Table

J	K	Q	Q’
0	0	0	0
0	1	0	0
1	0	0	1
1	1	0	1
0	0	1	1
0	1	1	0
1	0	1	1
1	1	1	0

3. D Flip-Flop

Delay or D flip-flop is a better alternative that is very popular with digital electronics. They are commonly used for counters, shift registers, and input synchronization**.**

In the D flip-flops, the output can only be changed at the clock edge, and if the input changes at other times, the output will be unaffected.

The change of state of the output is dependent on the rising edge of the clock. The output (Q) is the same as the input and can only change at the rising edge of the clock.[18]

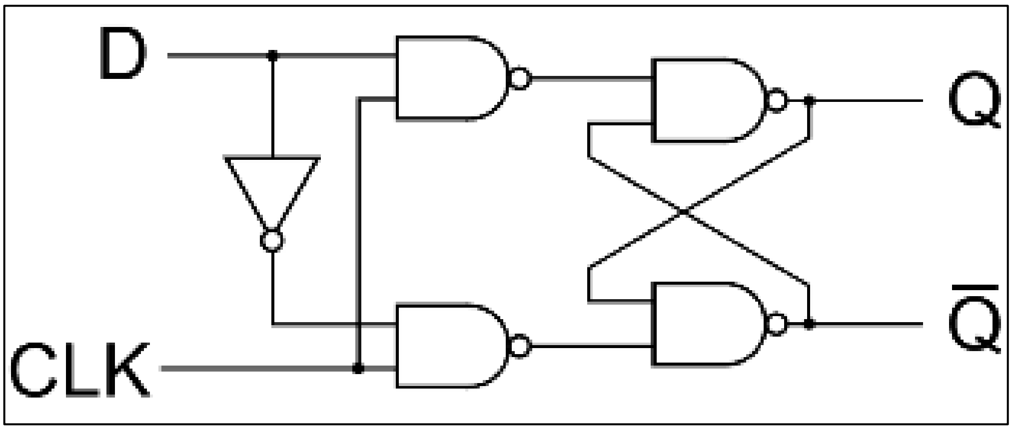

Figure 2–11: D Flip-Flop Circuit

Table 2-12: Truth Table D Flip-Flop

Clock	D	Q	Q’
↓ » 0	0	0	1
↑ » 1	0	0	1
↓ » 0	1	0	1
↑ » 1	1	1	0

4. T Flip-Flop

A T flip-flop is like a JK flip-flop. These are single-input versions of JK flip-flops. This modified form of the JK is obtained by connecting inputs J and K together. It has only one input along with the clock input.

These flip-flops are called T flip-flops because of their ability to complement their state i.e. Toggle; hence they are named Toggle flip-flops.[19]

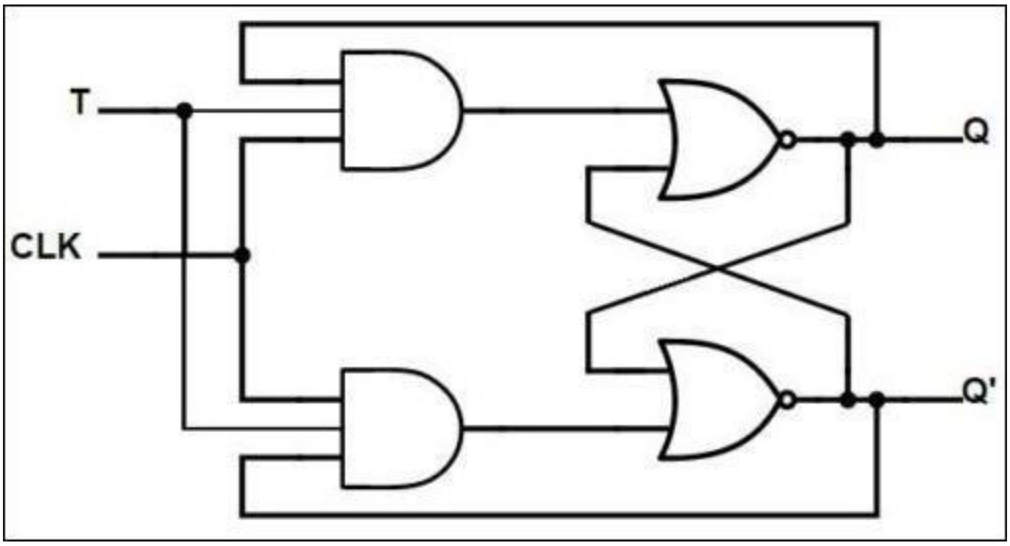

Figure 2–12: T Flip Flop Circuit

Table 2-13: Truth Table T Flip Flop

T	Q	Q (t+1)
0	0	0
1	0	1
0	1	1
1	1	0

CHAPTER THREE

Board building

3.1 Steps for Building the Experimental Board

1. **Identifying Experiment Components:**

   The first step involved selecting the types of logic gates and combinational circuits to be integrated into the board, along with determining the required number of inputs and outputs for each.

2. **Designing the Board Layout:**

   A preliminary schematic was drawn to indicate the placement of each logic gate, switches, and LEDs. This helped ensure an organized setup and ease of assembly. Tools like Canva, or manual sketches were used during this phase. Canva was particularly helpful due to its user-friendly drag-and-drop interface, which allowed the team to create clear and visually appealing schematic diagrams. Although Canva is typically used for graphic design, it proved effective in planning the layout of the board by enabling the representation of circuit elements and their connections in a clean, illustrative format.

The board design template that was designed and approved:

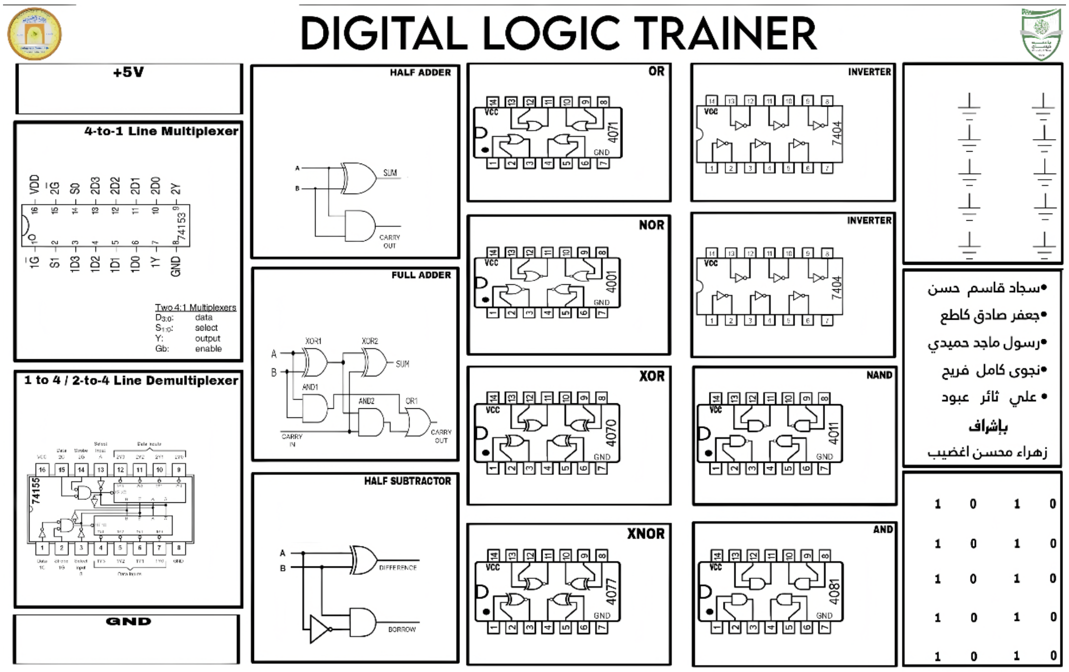

Figure 3–1 The board design 1

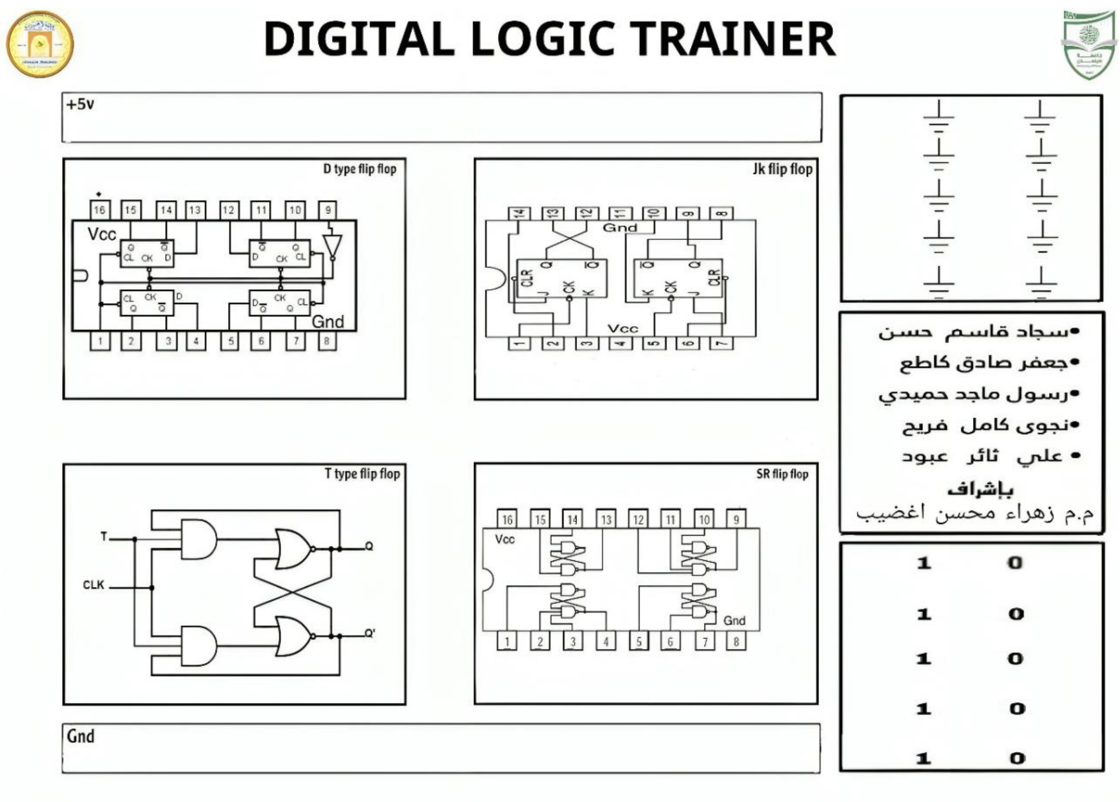

Figure 3–2 The board design 2

3. **Choosing the Type of Board:**

   A breadboard was used in the initial prototype to test the connections. Later, the components were transferred to a fixed board (such as a PCB or Dot Board) to achieve higher reliability and better mechanical stability.

4. **Installing Logic Gates and Components:**

   Logic gate ICs were mounted in their designated positions. The input pins were connected to toggle switches, and output pins were wired to LEDs through appropriate resistors.

5. **Organizing Wires and Connections:**

   Multi-colored wires were used to distinguish between inputs, outputs, and power lines, simplifying troubleshooting and modifications.

6. **Powering the Board:**

   A stable 5V power supply was connected to the logic gate circuits. VCC and GND lines were properly distributed across all components. Additionally, a 10µF electrolytic capacitor and a 100nF ceramic capacitor were added between +5V and GND to reduce electrical noise and improve voltage stability.

   A microfarad capacitor was also included to minimize ripple factor in the power line.

7. **Reverse Polarity Protection:**

   A diode (1N4007 or 1N5819 for faster response) was connected in reverse polarity across the +5V and GND lines.

   A fuse (250mA–300mA) was placed in series with the +5V line. In case of reverse polarity, the diode would conduct and blow the fuse, effectively protecting the entire board.

8. **Overvoltage Protection:**

   A 5.6V Zener diode (1W) was connected in parallel with the supply line, through a series resistor of 470Ω–1kΩ.

   This setup helps clamp any voltage exceeding 5.6V, preventing damage to the logic components.

3.2 Board Performance Testing

After completing the construction of the experimental board and connecting all components, a series of performance tests were conducted to ensure the system's efficiency and stability under various operating conditions. These tests aimed to verify that each logic gate and combinational circuit functions correctly and that all electrical connections are safe and reliable.

3.2.1 Performance Testing Steps:

1. **Basic Logic Gate Testing:**

   Each logic gate (AND, OR, NOT, NAND, NOR, XOR, XNOR) was individually connected to input switches and output LEDs. All possible binary input combinations (0 and 1) were tested, and the output results were compared to the corresponding truth tables to confirm accuracy.

2. **Combinational Circuit Testing:**

   Circuits such as the half Adder and Multiplexer were tested using different input conditions. The output values were then compared to theoretical expectations, confirming the correctness of the circuit's internal connections.

3. **Response and Interaction Testing:**

   The system's response to changes in switch states was evaluated. It was observed that transitions between logic states occurred quickly and without delay or output errors, indicating reliable wiring and stable circuit operation.

4. **Stability Under Continuous Operation:**

   The board was operated for extended periods (over an hour), during which its performance was monitored for signs of overheating, signal degradation, or circuit failure. The results showed excellent stability throughout the test.

5. **Power Supply Testing:**

   The voltage supplied to the board (5V) was verified for consistency. Appropriate resistors were used to protect the circuits and LEDs from potential damage due to overcurrent.

3.2.2 Test Results

All tests demonstrated that the board operates with high efficiency and accuracy, with no errors in logic operations or faults in the outputs. The organized layout of the board also facilitated easy verification and experimentation, making it an effective tool for applying theoretical concepts in a hands-on and practical manner.

3.3 Board Operating Mechanism

The experimental board was designed with a simple and practical approach, allowing students to conduct experiments easily and clearly without requiring advanced technical skills. The operation mechanism aims to enable direct interaction with the system components, reinforcing theoretical concepts through hands-on practice.

3.3.1 Steps for Using the Board During an Experiment:

1. **Selecting the Circuit to Test:**

   The student begins by choosing the logic gate or combinational circuit they wish to test, such as an AND gate or a half Adder. Each circuit is clearly labeled on the board and is isolated from any external power source.

2. **Connecting Power:**

   The student powers the selected gate by connecting it to an onboard power source. The power connection points are color-coded to match the power terminals, making it easier to identify.

3. **Setting Input Switches:**

   Toggle switches are used to define input values (0 or 1). The student connects these switches to the inputs of the logic gates. These simulate digital signals (Low/High voltage levels) typically used in digital systems.

4. **Reading Outputs via LEDs:**

   Once the input values are set, the logic circuit processes the data automatically, and the result is immediately displayed through LEDs connected by the student to the output terminals. Each LED represents a logic state (ON = 1, OFF = 0).

5. **Repeating the Process for All Input Combinations:**

   Students can change the switch states and test all possible input combinations, comparing the results with the theoretical truth table to understand the relationship between inputs and outputs.

6. **Recording and Analyzing Results:**

   Results can be documented in a table to compare theoretical versus practical outcomes, and to discuss special cases such as edge conditions or potential errors.

3.4 Board pictures

Initial Stage – Applying the Design and Drilling the Board:

The process begins with placing the circuit layout on the board, followed by drilling the required holes for component installation and mounting the connectors.

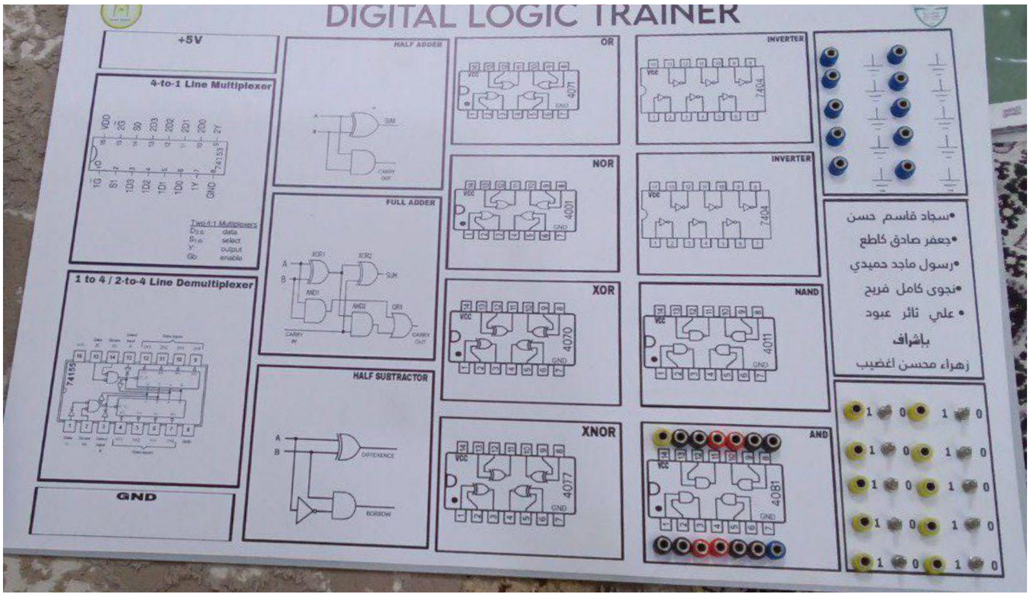

Figure 3–3 Design step bord 1

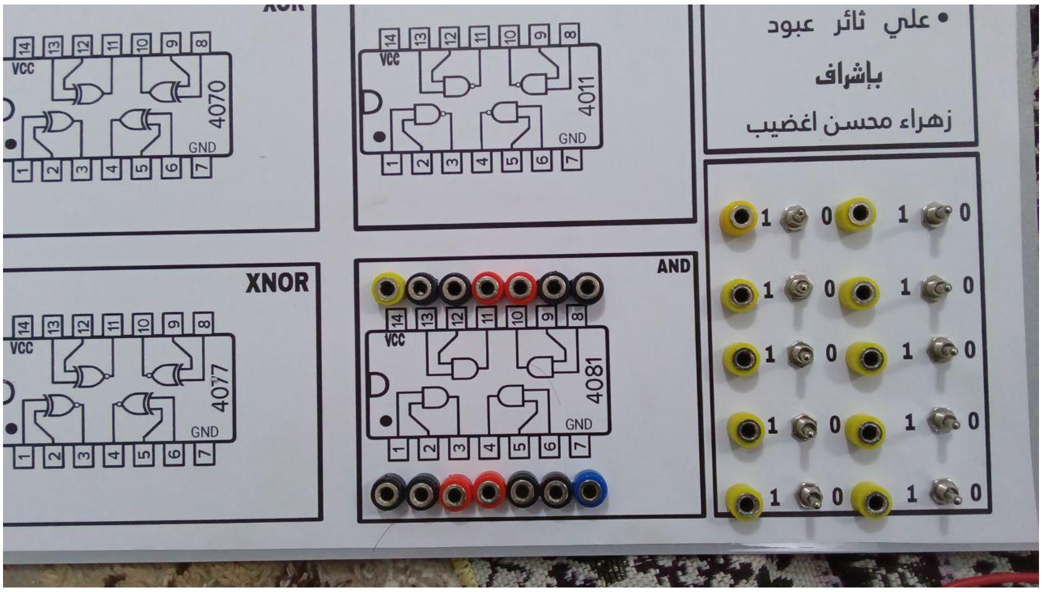

Figure 3–4 Perforation step bord 1

Completing All Drilling and Mounting Steps:

All holes are drilled and components are fixed in place, including installing the input/output connectors and LED indicators.

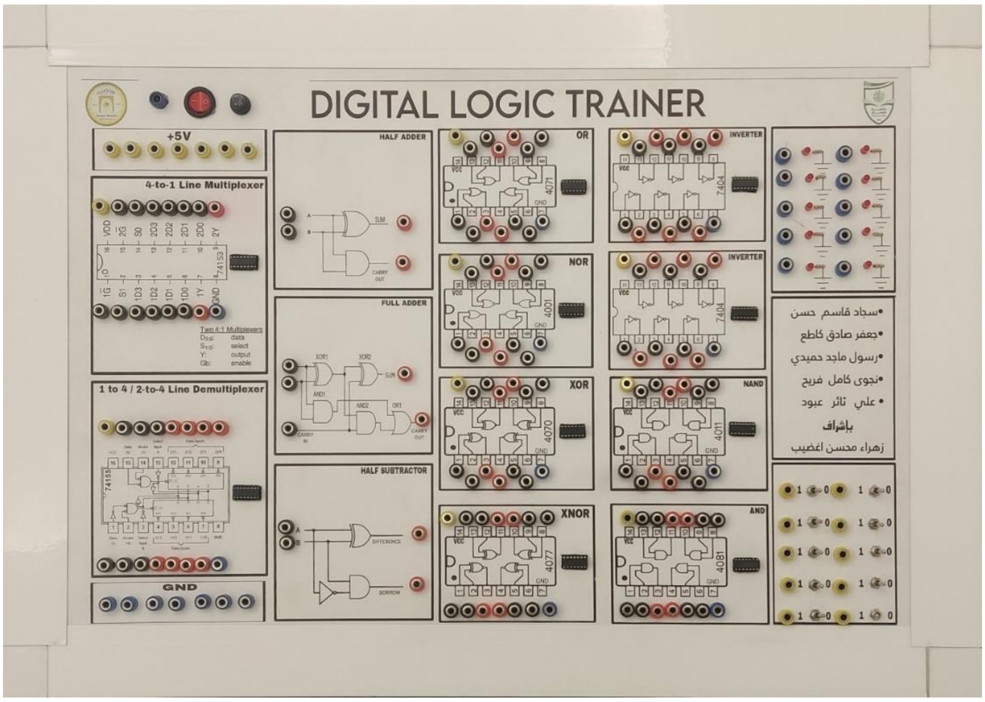

Figure 3–5 Drilling and Mounting Steps bord 1

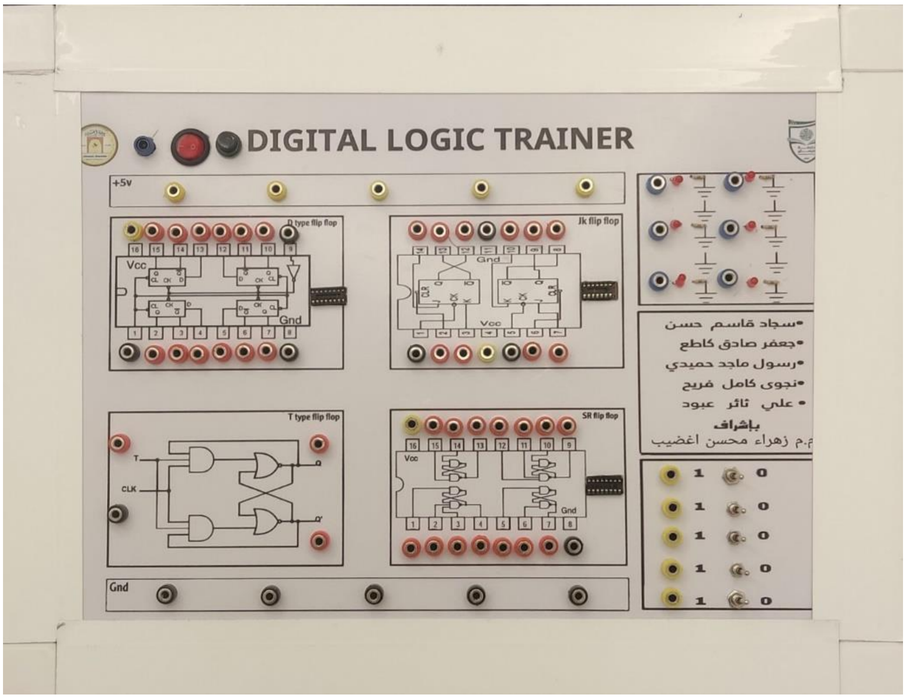

Figure 3–6 Drilling and Mounting Steps bord 2

Connecting the Components – Gates and Connectors:

Each connector is wired to one of the IC pins, as illustrated in Figure (3-6). The logic gates are carefully connected to ensure correct signal routing.

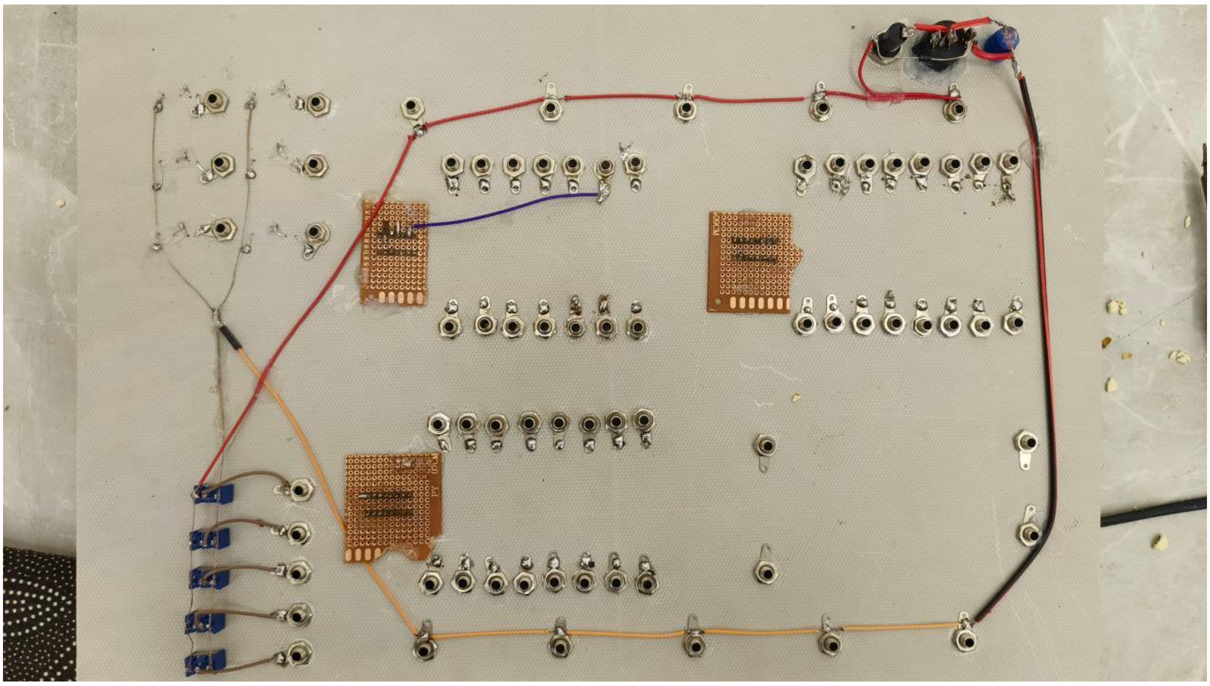

Figure 3–7 Connecting the Components bord 2

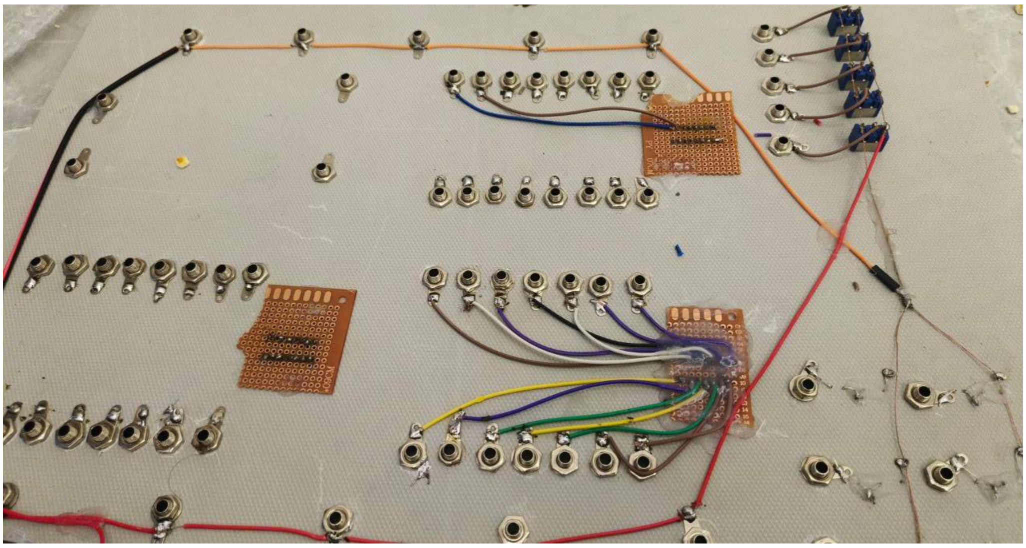

Figure 3–8 Gates and Connectors bord 2

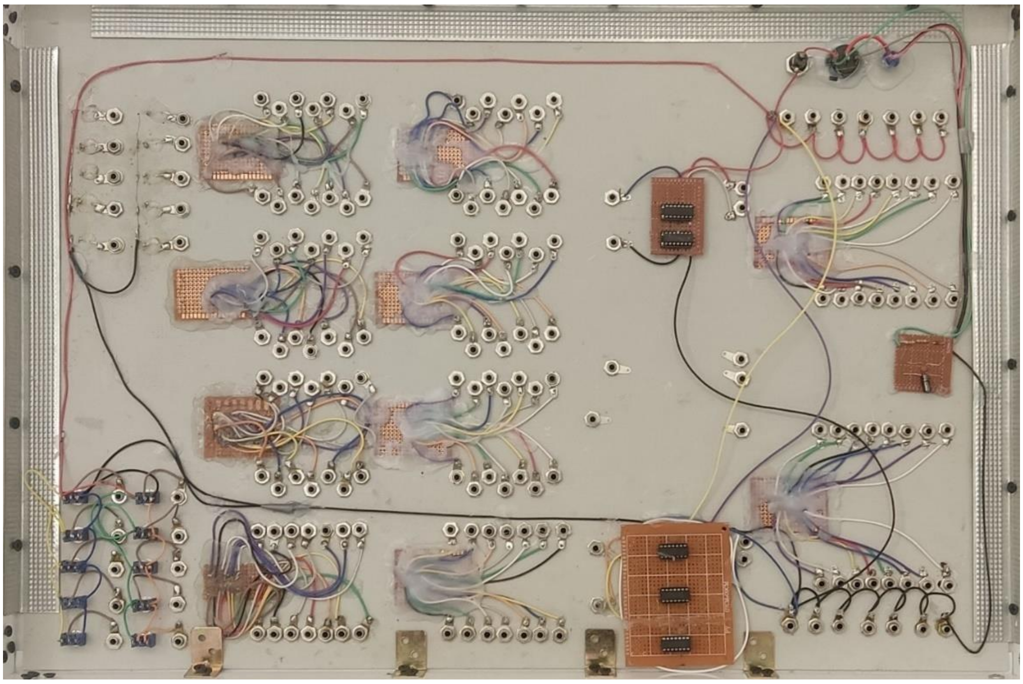

Figure 3–9 Gates and Connectors bord 1

Final Stage – Completing Connections:

This involves finalizing all connections between the logic gates and their corresponding connectors, in addition to wiring the power supply terminals.

Transition to the Experiment Phase:

Once the board assembly is complete, the system is ready for testing and conducting the logic experiments.

CHAPTER FOUR

4.1 conclusion

At the conclusion of this project, we successfully designed and implemented a comprehensive system for second-year logic lab experiments that meets the practical and educational needs of university students. This system serves as an interactive educational tool that enhances theoretical understanding through hands-on experimentation, allowing students to build and test basic and complex logic circuits using a well-organized and user-friendly electronic board. Through this project, the gap between theoretical concepts and practical application was bridged by providing a stimulating learning environment that relies on immediate interaction with the outputs of logic circuits.

Performance tests demonstrated the system's efficiency and stability, and the board's flexible and expandable design makes it suitable for future development. Therefore, the proposed system is not only an educational tool, but also a foundation for the advancement of more complex projects in digital logic and electrical engineering, directly contributing to the improvement of education quality in university laboratories.

Scan the QR Code below to watch a step-by-step video tutorial on how to use and experiment with the logic lab board:

4.2 Recommendations

Based on the results of this project and the experience of using the system in an educational environment, several recommendations can be made to improve the system's performance and expand its future applications. One key recommendation is to integrate programmable microcontrollers such as Arduino or Raspberry Pi to implement logic circuits through software. This approach would enhance the variety of experiments and deepen students' understanding of the difference between hardware logic and software logic.

Additionally, it is recommended to prepare a comprehensive instructional guide to accompany the board, including simplified explanations of truth tables and clear wiring instructions for each circuit. This would enable students to conduct experiments independently and with greater confidence. The introduction of a graphical interface through a small display screen can also be considered, offering a more interactive way to visualize logic operations and their results.

Finally, we encourage the adoption of this system across other university laboratories and recommend updating it regularly to align with advanced academic curricula. This will help ensure its continued effectiveness as a valuable educational tool for understanding digital and logical circuits.

4.3 Future work

This project represents a first step toward the development of practical educational tools in the field of digital logic. It can serve as a foundation for future enhancements and the addition of more advanced features to improve its educational capabilities. One of the key proposed directions for future work is the design of an interactive digital version of the system, using software simulators or by integrating a touchscreen interface that allows students to select and perform experiments electronically, with real-time result visualization.

The system could also be expanded to support the implementation of programmable logic circuits using technologies such as FPGA, enabling students to design complex circuits and learn advanced concepts in digital systems design. Furthermore, Internet of Things (IoT) technologies can be integrated to store experiment results in a cloud-based database, facilitating performance analysis and tracking students' academic progress.

Additionally, a companion mobile or desktop application could be developed to provide theoretical explanations and guide users step-by-step during the experiments on the board, thus enhancing interactivity and self-learning. With these extensions, the system can evolve from a simple lab tool into a comprehensive educational platform covering a wide range of modern digital concepts.

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