BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 304 (January 2023)

Digital Electronics Laboratory

Final Project Report

Section: A2 Group: 07

Tic Tac Toe using Digital Logic Design

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Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. *You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.*

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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1 Abstract

This project aims to implement the very popular turn-based game Tic Tac Toe using digital logic circuits Leveraging digital logic components and circuitry, this project offers a unique and interactive solution for playing Tic Tac Toe. The focus of the project is to develop a system that enables players to engage in the game, providing a challenging and enjoyable experience.

2 Introduction

Most Tic Tac Toe games have always been implemented using software or code. While this provides a virtual experience of playing the game, a game can only be truly interactive and beneficial to society if we are able to improve human relationships through it. This is best done if this game is transferred from virtual platform to hardware. By preparing an interactive hardware gaming interface, the Tic Tac Toe project uses digital logic circuitry to prepare a game board where the users provide their input through push buttons and the response is processed by the digital circuitry. The use of bicolored LEDs and a separate interface for inputs make the game visually stimulating and offers the opportunity for improving human interactions.

3 Design

Each player has been designated a single color of the bicolored LEDs. Total 9 Bicolor LEDs have been used. Player one has been designated red and player two has been designated yellow. When a certain player pushes a pushbutton, that particular LED is turned on with the color designated for that player. When a pushbutton is pressed once, it cannot be pressed again allowing the players not to be able to cheat in the game.

When a winning combination is found i.e., when a particular player wins, the bicolor winning LED is lit with the color designated for that player. If all buttons are pressed and no player wins, the unicolor draw LED is turned on. When the WIN LED or DRAW LED is turned on, the game is ended and no other pushbutton pressing works. The game can only be restarted with the press of the reset button

3.1 Problem Formulation

3.1.1 Identification of Scope

This game intends to enhance the arcade gaming experience and take Tic-Tac-Toe to arcade gaming hubs across the country. Educational campuses can have the arcade version of this scalable game of Tic-Tac-Toe in the recess or common rooms so that students can have a fun pastime.

3.1.2 Literature Review

This game requires flipflops and combinations of multiple logic gates and ICs to be implemented. Research was done on how flipflops can be used to store the data by players and stop the same button from getting pressed multiple times. (Chapter 5: Fundamentals of Digital Logic with Verilog Design by Brown). The winning LED combination logic and implementation was taken from YouTube. Further studies were done on XOR gates and flip-flop combination implementation from research papers.

3.1.3 Formulation of Problem

Tic-Tac-Toe is a game usually played on paper. This project aims to digitalize the game on a hardware level so that gaming becomes easier, more accessible and interesting. This project also intends to introduce the players to the world of digital logic design which is the basic of almost all hardware-based arcade games.

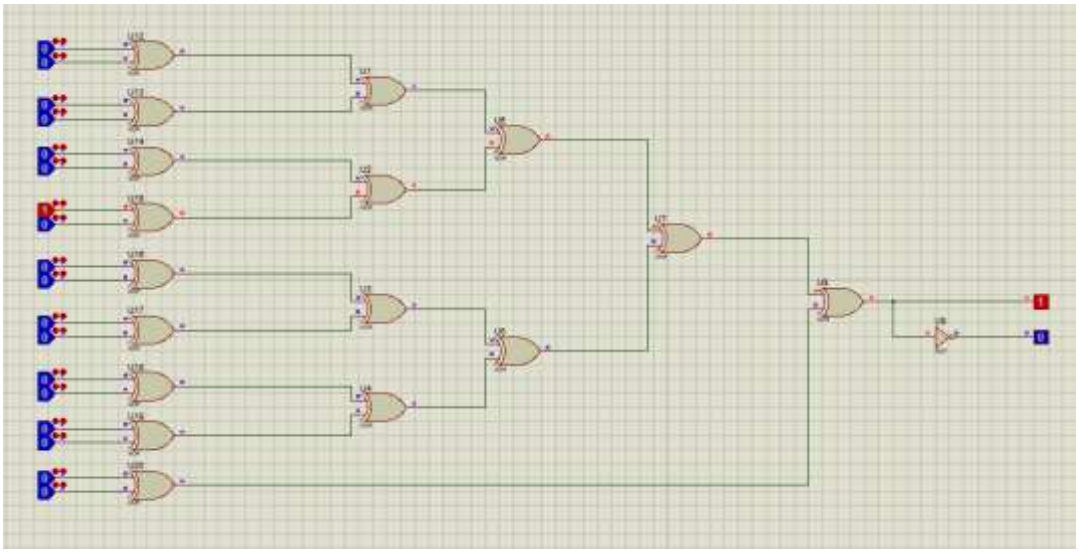
3.1.4 Analysis

When a pushbutton is pressed, it needed to be made sure that the same button cannot be stored again. Which means that the information needed to be stored by using flipflops. The flipflop combination needed to be used before every LED. Moreover, when all the buttons are pressed and winner is not found, the draw LED needed to be activated. Besides, when a winner is found, the game needed to be stopped so that pressing any other button does not change the output of the game.

3.2 Design Method

Identifying players:

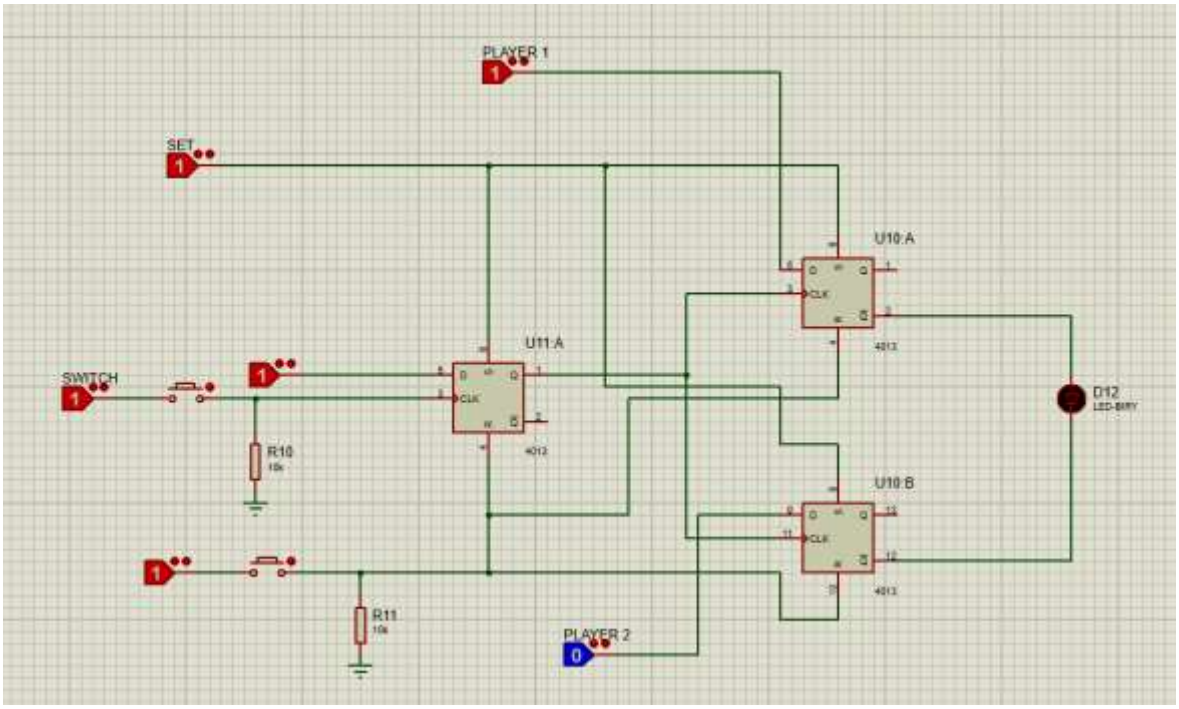
Each player is designated a certain color of the bicolor LEDs. The bicolor LED works in such a manner that when 1 and 0 is put on both ends of the common anode LED, the color is red and when 0 and 1 is put on both ends, the color is yellow. An XOR gate combination is used to identify the players. When even number of buttons are pressed, it recognizes player 2 (Yellow) and when odd number of buttons are pressed, it recognizes player 1 (Red).



A NOT gate is used so that the outputs are 1,0 or 0,1 indicating the two colors.

Storing player data:

A combination of 3 flipflops were used to store player data. The input to the first flipflop is always high and the pushbutton output is used as the clock for the first flipflop. When the pushbutton is pressed, the first flipflop is activated. The output of the first flipflop goes into the clock of the two other flipflops designated for the two players. When the first flipflop becomes high due to the press of the pushbutton, the information of the two players goes to the output of the LED. After that, when the pushbutton is pressed, the output of the two flipflops does not change and so the LED output does not change any further.



The flipflop combinations are used in front of each of the 9 bicolor LEDs.

Implementing Winning combinations:

8 different winning combinations are available in a game of Tic-Tac-Toe. A combination of AND and OR gates are used to identify the winning combination of each of the two players. When a particular player wins the game, the AND/OR combination for that player outputs HIGH and the combination for the other player outputs LOW. Since HIGH-LOW are found on both ends of the bicolor LED, the LED is turned on with color designated for player one. When LOW-HIGH is found, the bicolor LED is turned on with the other color.

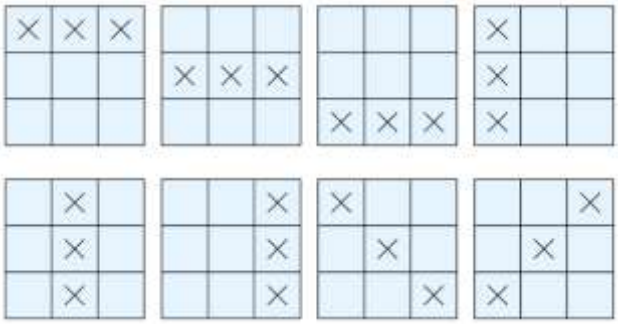
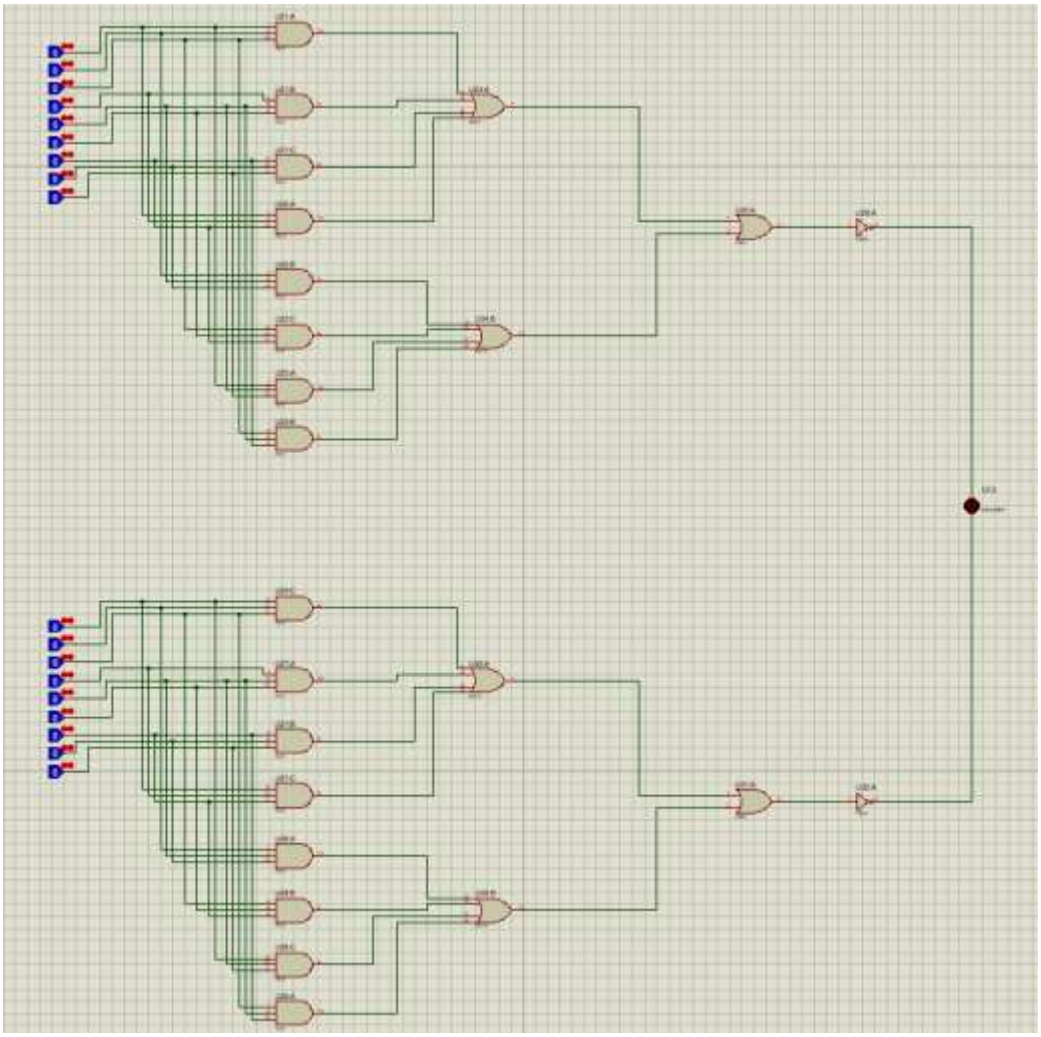
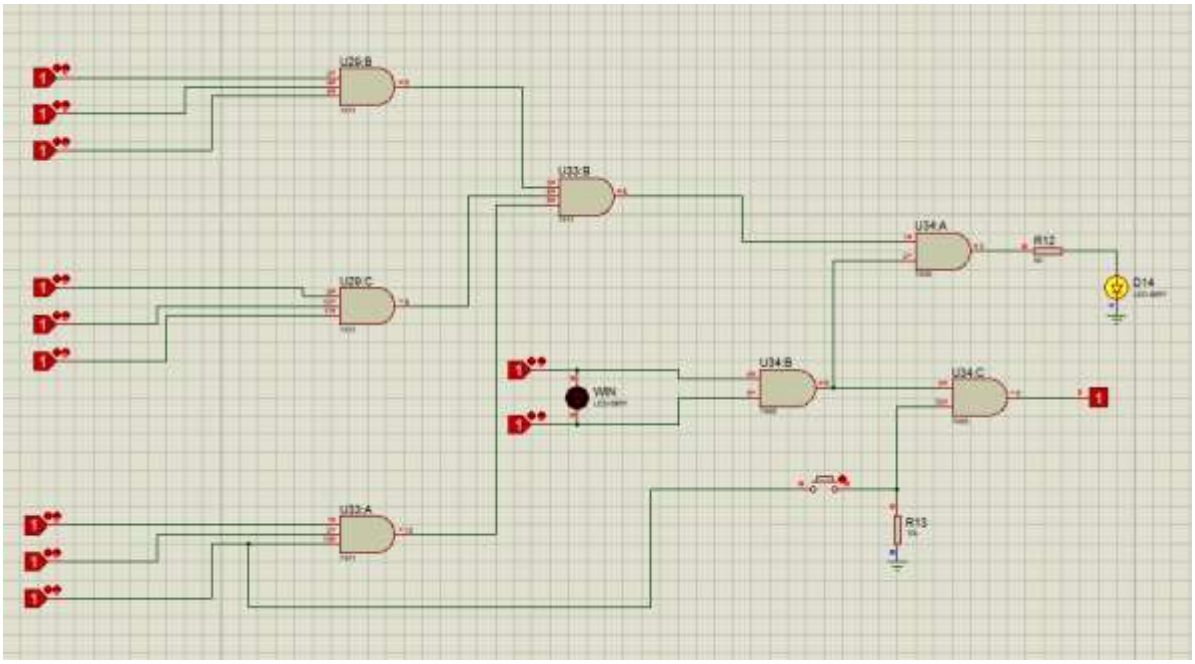


Figure: 8 winning combinations for Tic-Tac-Toe



Implementing Drawn Game:

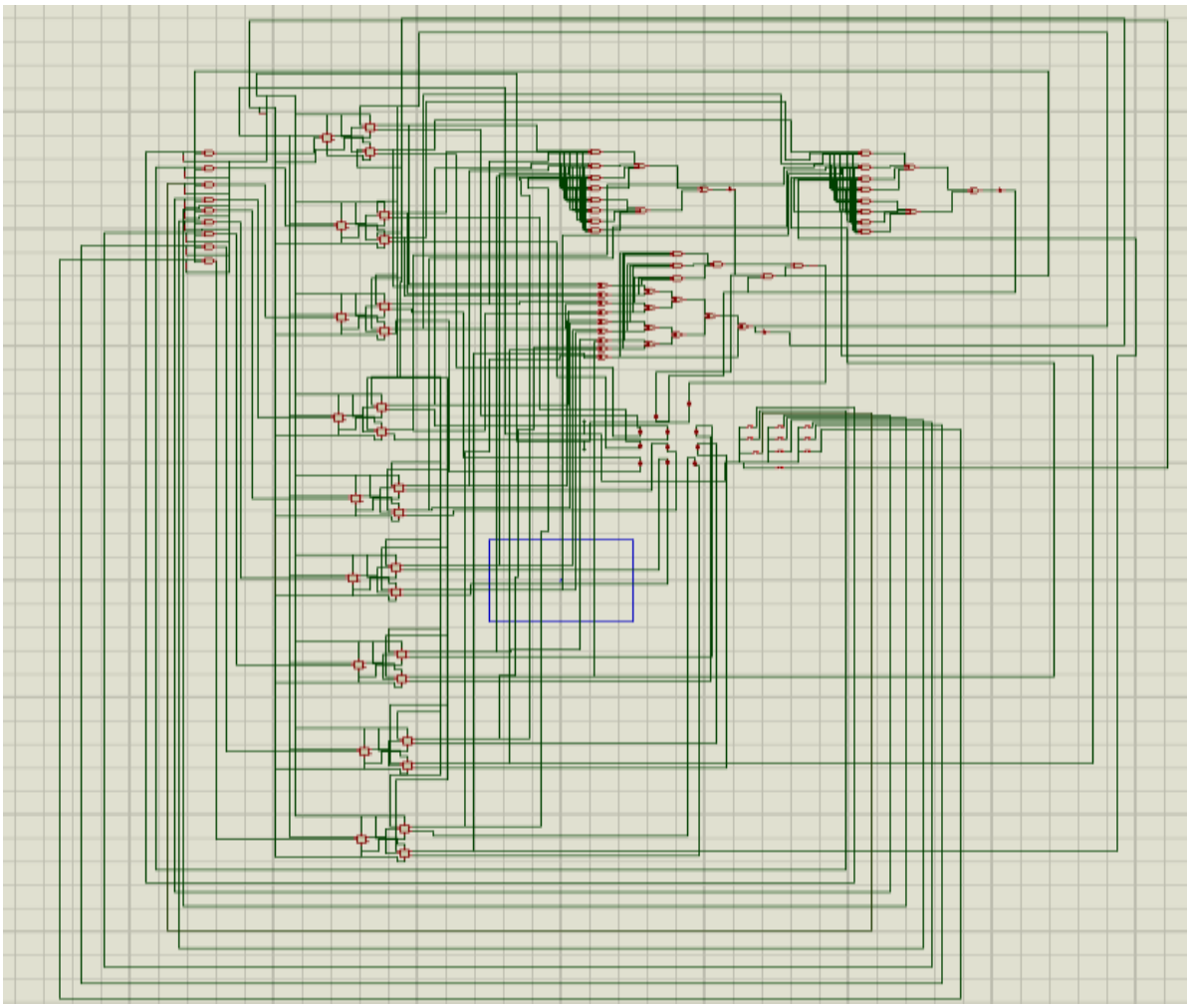
When all the LEDs are turned on and a winner is not found, the drawn LED is turned on. When all LEDs are turned on, the output of the AND gate connecting all LEDs is HIGH. Similarly, when Win LED is not turned off, the two ends of the Winning LED are HIGH (causing winning LED to remain OFF) and so the AND gate connecting the two ends is HIGH, causing the DRAW LED to turn on, which is unicolor.



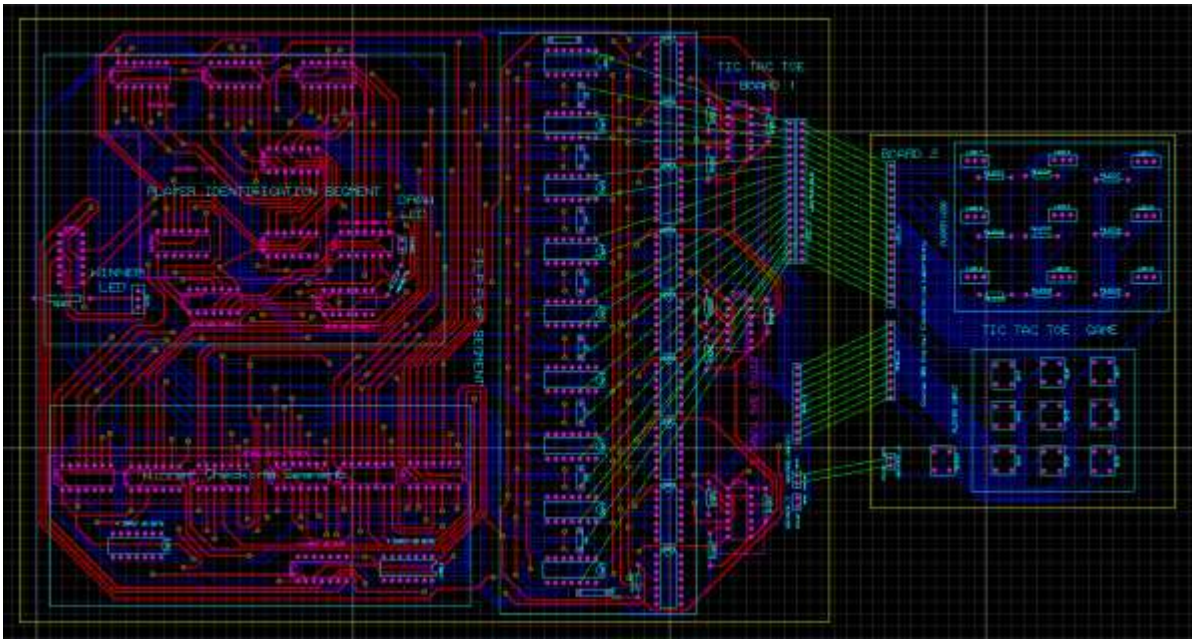
Preventing Additional switch pressing after win/draw:

After a match is won, the two ends of the winning LED are HIGH and LOW, causing the AND gate output to be zero. Another AND gate is used in the end where the two inputs are the output from the winning LED AND gate and pushbutton outputs. When the winning LED is turned on, the AND gate output in front of the winning LED is always LOW, causing the final AND gate to be LOW no matter what pushbuttons are pressed. This combination is used before every flipflop combination so that pressing the pushbuttons doesn't work anymore.

3.3 Simulation Model



3.4 PCB Design



4 Implementation

4.1 Description

We designed two different sets of PCBs to keep the design neat. The first larger PCB contains all the ICs. It contains segments like-

1. Player Identification Segment
2. Flip Flop Segment
3. Winning combination segment

The second PCB contains the pushbuttons, 9 LEDs for each pushbutton, winning LEDs and the DRAW LED. The two PCBs are connected using jumper wires.

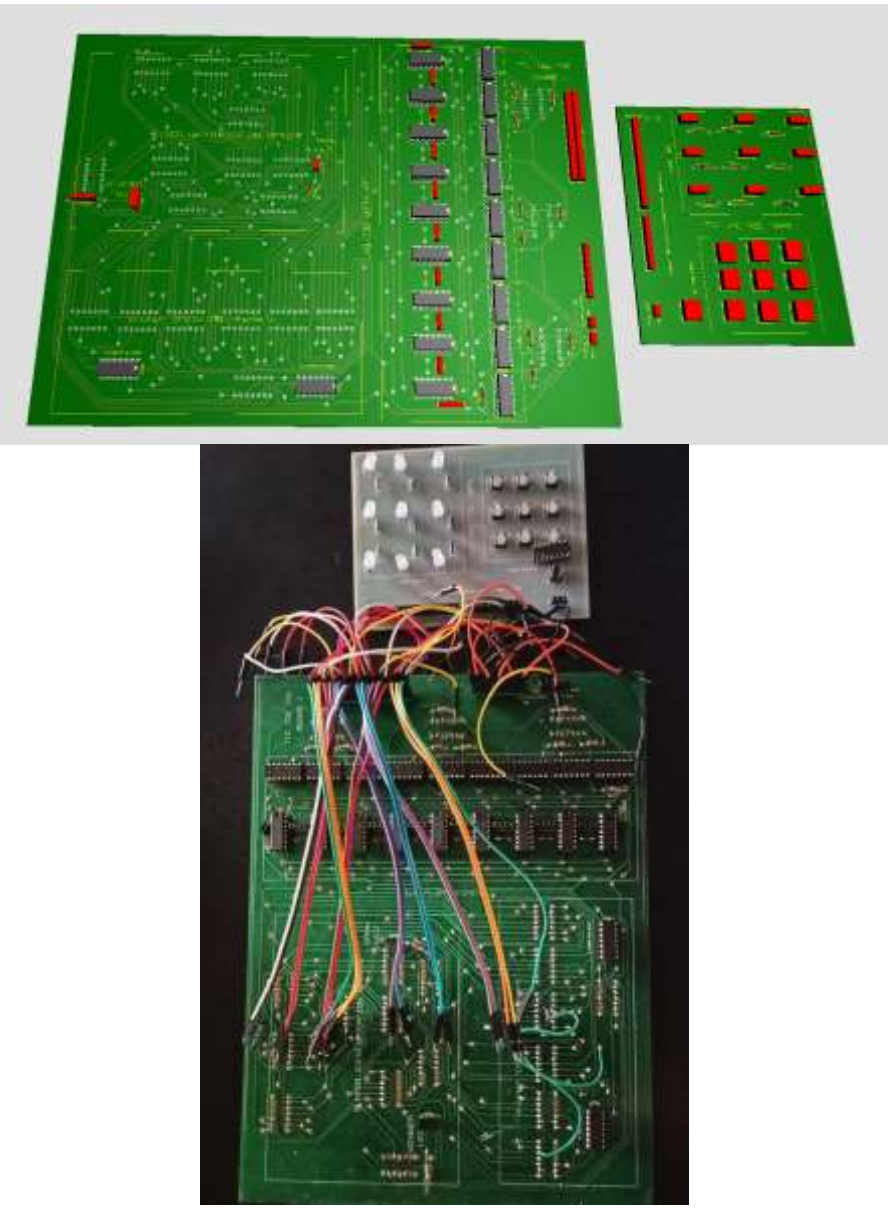


Figure: (Top) PCB Layout and (Bottom) Implementation of Design

4.2 Experiment and Data Collection

Each of the ICs were tested individually in the labs and truth table was verified for each of the ICs. The datasheet for each of the ICs were verified for voltage and current rating and matched resistors were used accordingly.

4.3 Data Analysis

Flip Flops and OR gates were of the CD series. 4 input OR gates of 74 Series are not available in the market easily. Rest of the ICs were used of the HC series because the voltage rating of the CD series matches with that of HC series. CD series can be given 3 levels of bias, 5,10 and 15V. We used a bias of 5V.

4.4 Results

Since the voltage and current rating of each of the ICs were evaluated beforehand, the output was found as expected. Each of the LEDs worked perfectly upon the press of the pushbuttons. The winning LED was turned on when a winning combination was found and the draw LED was turned on when the match was drawn. Upon the winning LED or draw LED being turned on, pressing any other pushbuttons didn't work. The game could be successfully restarted upon pressing reset button.

5 Design Analysis and Evaluation

5.1 Novelty

Instead of designing it on software, creating a hardware-based version of our traditional tic tac toe game allows people to interact with physical buttons to make their moves.

Our custom designed PCB is designed in a way that identifies the blocks which take input, the flip-flop block for saving input and preventing cheating, logic processing block for draws and wins, along with IC markers which identifies IC location. There is no scope for cheating i.e pressing a button twice or trying to force the game after a winner is decided. The Circuit consumes hardly any power and utilizes on a 5V supply with ICs consuming a few microampere currents.

A separate user interface for users to give input making game play very flexible and user friendly. The use of bicolored LED is a clever way to bypass the need for a display and make the game much more interactive and attractive to children.

5.2 Design Considerations

5.2.1 Considerations to public health and safety

- We've used headers to solder components into PCB to easily replace any damaged IC. This prevents us from discarding entire boards or injuring ourselves trying to figure out the problem. This makes it easier for us to dispose of dangerously hot ICs instantly.
- For the ease of removal of ICs and preventing any fires from spreading too quickly should we've used IC sockets. This prevents permanent damage to the board.
- Voltage level required is around 5V to prevent electric shock hazards. Each IC has a current requirement of around a few μA. This makes the board safe for use as possibility of spread of a fire is significantly reduced.
- Clear labelling that identifying different parts of the PCB is necessary to ultimately identify hazardous circuit elements and to remove them swiftly. This additionally informs users of the mechanics involved in the circuitry and where the device is sensitive to touch or where the users might have to be careful while touching.
- The user interface board is separated from the logical circuitry board. Therefore, possibility of injury from the larger sharper board is significantly reduced.
- Taking into consideration different health conditions such as epilepsy, we use LEDs with a moderate current-voltage rating to ensure that the blinking of LEDs do not cause nausea, headaches etc.

5.2.2 Considerations to environment

- The entire circuitry is a low power designs that requires only a 5V supply with each IC supplying around a few μA current. This design is energy efficient as less energy is wasted and the absence of heavy-duty battery which are hazardous to the environment.
- Longer life time is assured with the design as all regions of circuitry and ICs are properly identified and labelled across the PCBs with the ICs being fitted using IC sockets. This implies that we can identify any problem within the circuitry and easily replace said component without having to discard or damage the board in any way.
- The use of two different boards: one for user input and another for logical circuitry ensures that any damage to the logical circuitry board does not affect the user interface board or vice versa.

5.2.3 Considerations to cultural and societal needs

- The ultimate goal of this project is the improvement of human interactions and relationships by bringing people face to face to play this game instead of on virtual servers. Thereby improving the quality of relationships.
- For visual pleasure and personal aesthetic preferences, users can customize and use different BiColored LEDs to describe input and result.
- This has been made to make people more interested in DLD as it combines the fundamental ideas of digital logic design and the use of digital logic circuitry with the joy of making a game.

5.3Limitations of Tools

- We required 18 7474 D flipflops which we could not find so we had to use CD4013BE flip flop. We did not want to mix ICs of different series.

- We found multiple defective 7432HC ICs across different buyers. This made it very difficult for us to implement it in our circuit. Mistakes in batch IC manufacturing can limit performance unless tested.

- The circuitry is vast and there is only limited spacing while designing the PCB (manufacturer requirements) so we had to resort to two different boards.

- We had to use a lot of jumpers to connect from board to board. We did not have jumpers adequately sized at the same time.

- We are using a laboratory power supply to ensure a constant 5V power supply. We can use a separate power source using a voltage regulator. This is for safety only.

5.4 Impact Assessment

5.4.1 Assessment of Societal and Cultural Issues

- There is a literacy gap when it comes to digital logic design and digital logic circuitry. Our project combines the rigor and the primitive knowledge involved in DLD (use of flip flops, different elementary ICs etc.) and the logic involved in cascading different logic blocks and multiple ICs together with the fun of realizing a gaming interface that can be used to bond with others.
- The quality of human interactions has significantly dropped. People are more estranged now more than ever. While gaming brings people closer, most games are now on virtual platform. Our Tic Tac Toe game brings the virtual game on an interactive hardware interface so that two individuals can bond over playing this game thereby improving the quality of human relationships.

5.4.2 Assessment of Health and Safety Issues

- The biggest issue when it comes to electrical circuitry is the possible of sudden fires or electrical hazards. Our design is a low power design and thus, protecting the user from the possibility of high voltage/current shock or sudden fires. Burning ICs can be identified and removed just as fast because of proper labelling of the PCB.

5.4.3 Assessment of Legal Issues

- The project does not infringe on copyright materials, utilizing open-source resources available on the internet. Therefore, the distribution of the game does not have any legal challenge.

5.5 Sustainability and Environmental Impact Evaluation

- We use IC sockets. Therefore, if there are any damaged ICs, we can easily replace them without replacing the PCB board. Therefore, less metallic and electrical waste is produced. The design is sustainable as it has a longer life span.

- Two separate boards are used. Damaged to the logical circuitry does not affect input circuitry and vice versa. In the unfortunate event where we do have to replace the PCB, we might only have to replace a certain portion of the game and not the entirety of it.

- Low power consumption is the goal for any project. Our project uses a 5V supply and ICs which only consume around a couple of uA current making our project therefore environment friendly.

5.6 Ethical Issues

The project did not violate much ethical issues as each portion of the project were constructed by reviewing literature and open-source resources available online from different sources and merged together. Help was taken from video materials found on the internet. The PCB design, hardware implementation, IC selection and testing were all done manually. In short, the project did not violate any major ethical limitations.

6 Reflection on Individual and Team work

6.1 Individual Contribution of Each Member

- Md Hasib ur Rashid, 19059, was in charge of Proteus Simulations of the circuit.

- Tasmin Khan, 1906055, was responsible for designing the PCB.

- Bokhtiar Foysol Himon, 1906056, was in charge of literature review, purchasing parts and short testing the PCB along with supervising soldering.

- A K M Anindya Alam, 1906065, took over IC testing and debugging the circuit.

6.2 Mode of Team Work

The team worked together most of the time during the duration of this project. Those in charge of specific departments received assistance from one of the team members, those of who were available at the time. For example: Hasib Ur Rashid received assistance from Anindya Alam to debug problems in the Proteus circuit. Bokhtiar Foysol Himon received assistance from Tasmin Khan during soldering the PCB. The team was mostly present together during the final assembly and the last set of testing.

6.3 Diversity Statement of Team

The team worked in tandem together in order to distribute the pressure across the members so that no one had to bear an excess amount of pressure. Keeping in mind that the team had other course projects to attend to, they contributed to the team in different capacities based on availability of members. The team ensured an equitable environment constantly so that every single member enjoyed the work and was able to learn more about digital logic circuitry and the hardware implementation of it.

6.4 Log Book of Project Implementation

Date	**Milestone achieved**	**Individual Role**	**Team Role**	**Comments**
Week 3-4	Literature Review	ID 1906056	1906059 helped in finding resources online	
Week 5-6	Proteus Simulation	ID 1906059	1906065 helped in proteus simulation blocks	
Week 7-9	PCB Design	ID 1906055		
Week 10	PCB Soldering	ID 1906056	1906055 guided the process	
Week 11-12	IC testing	ID 1906065	All team members worked together on IC testing	
Week 12-13	Hardware implementation and debugging	Unified effort of all team members		

7 Communication

7.1 Executive Summary

The project “Tic Tac Toe” is an interactive, board-based game that utilizes the knowledge of digital logic design and digital logic circuitry to implement the popular tic tac toe game. More often than not the game is played on a virtual interface where interactions between two players is limited. It is important for us to improve the quality of human relationships

and so, we've designed this interactive and easy to understand game for everyone to play and have fun.

We also hope to inspire people to learn more about Digital Logic Design and Circuitry so that they too are able to implement similar projects. Our project uses some of the fundamental ideas of Digital Logic Design and use some basic ICs, logic gates (AND, OR, NOT, XOR) and sequential circuits such as flip flops, and some logical deduction to implement this project.

7.2 User Manual

1. There are two boards connected to each other by a set of jumpers. The smaller board is the I/O interface while the larger board is the core digital logic circuitry of the project.

2. Connect the power source to the smaller board to the terminals marked as "power source". The positive, negative and ground terminals are specified on the board.

3. To reset the board, press the "Reset" button.

4. Start playing the game. The player going first is identified by "Red" and the player going second is identified by "yellow". Each Button position is identified by the LED corresponding to the specific position

5. When a player wins (all three LED colors matching either linearly or diagonally), the game automatically stops. Further pushing any button won't yield any result.

6. If a button is already pressed and the corresponding LED is lit, users won't be able to cheat by trying to change color of an already lit LED as the LEDs will take only one input unless and until the system is "reset".

7. If player 1 wins, the winning LED on the larger board becomes red. If player 2 wins, the winning LED on the larger board becomes yellow.

8. If there is a draw, the draw LED lights up. For a draw to happen, all push buttons must be pressed and all LEDs must light up. Even if it is obvious that player 1 or 2 wins, all buttons have to be pressed for a draw to happen.

8 Project Management and Cost Analysis

8.1 Bill of Materials

Components	Per Unit Price (BDT)	Units
74HC86N	25	6
74HC08N	25	4
74HC32N	25	1
74HC04N	25	1
74HC11N	25	8
CD4072BE	60	2
CD4013B3	30	18
14 PIN DIP IC SOCKETS	5	45
220 OHM RESISTANCE	1.5	2
Common Cathode LED	6	10
Single colored LED	5	1
Jumper	100	-
PCB	2000	-
Soldering	3200	-
Total (BDT)	6753	

9 Future Work

- The project is planned to be scaled and taken to an arcade level where children are able to play games on it and can be mass produce and sold on a commercial basis.

- The game is planned to be packaged to make it safer and more durable to stress and blows to avoid accidents, damage and more suitable for children under the age of 10.

- To make it even more interactive and allow for better customization, we hope to replace the blinking LEDs by an actual display with a 3x3 grid to show the users' input. This makes the game more attractive to buyers and makes it commercially more profitable.

10 References

1. Making a Tic Tac Toe using digital logic design by Rashedul Haq. (YouTube)

2. Tic Tac Toe Game (Sean Kirschke, Douglus Loper, Daniel Struck, Andrew Galczyk, Oakland University, Rochester MI)

3. Chapter 5: Fundamentals of Digital Logic with Verilog Design by Brown