DD Design Assignment

Automating Chess Board

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Question

Design an automated chessboard where the user selects the chess piece and inputs the final position. Based on user input design a system that moves the chess pieces. Assume that your chess board is only automated for the queen and rook only. Assume that these pieces are automated by servo motors that move one box at a time in any direction.

Introduction

The Chess board is mapped as a 2 dimensional graph with bottom left corner as origin and the top right corner as (7,7). The current location of each piece is already stored in circuit , so to start the simulation the circuit must be initialized by

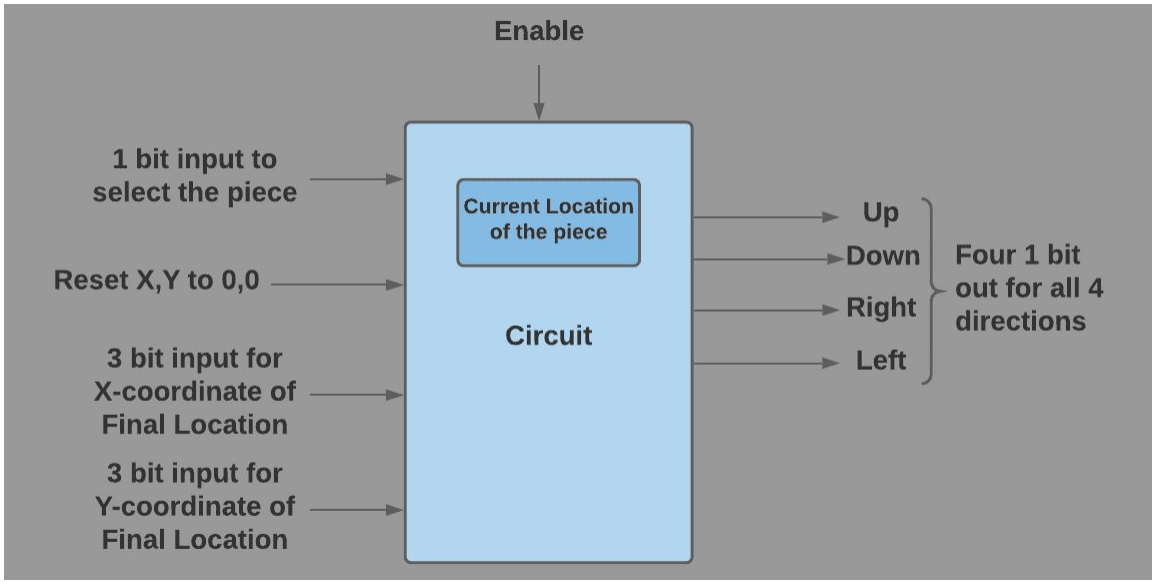
- setting the input values equal to the JK Flip-Flops for both X and Y coordinates of each piece for initializing the piece to a specific location.
- Use the Reset Button to initialize the piece at (0,0)

Currently we are using the same circuit for both the pieces so the current location of the piece is lost if we change the piece from Rook to queen , So while implementing on hardware we could reuse the circuit and automate both rook and queen individually and not lose the current location of the piece.

Design Assumptions

- The board contains only one piece on the board.
- In case of an invalid move the piece would not move.
- After giving the input the players would wait till the circuit reaches a stable state, i.e. the piece reaches the final location. The player does not change the input in the middle of the move.

Top Level Diagram



Inputs -

- Input to **select the piece** to be moved
    - To move **queen** give the input 0
    - To move **rook** give the input 1
- **X-coordinate** input
    - 3 bit input of the x-coordinate of final location in binary form.
- **Y-coordinate** input
    - 3 bit input of the y-coordinate of final location in binary form
- Circuit **Enable**
    - Circuit works when enable is 1
- A physical button used as **Reset**
    - When reset is 1, the location of the piece would be initialized to 0,0

Output -

- Four 1 bit outputs which would be used as input for actuator, which could convert it to timing diagrams for inputs of servo motors. The states are coded as follows
    - When Up is 1 ,the piece moves up ,else does not change in that direction.
    - When Down is 1 ,the piece moves Down ,else does not change in that direction.
    - When Left is 1 ,the piece moves Left ,else does not change in that direction.
    - When Right is 1 ,the piece moves Right ,else does not change in that direction.

- The value store in the JK Flip Flop or the Register can also be logged to check the movement and the current location of the piece.

State Table

LSB output of Priority encoder = v
MSB output of Priority encoder = u
Xs = Stored value of X coordinate
Xi = Input of X coordinate
Ys = Stored value of Y coordinate
Yi = Input of Y coordinate

For Rook-

Piece = 1
For uv= 00 , Xs > Xi,
For uv= 01 , Xs= Xi,
For uv= 10 , Xs<Xi,
For uv= 11 , Ys != Yi

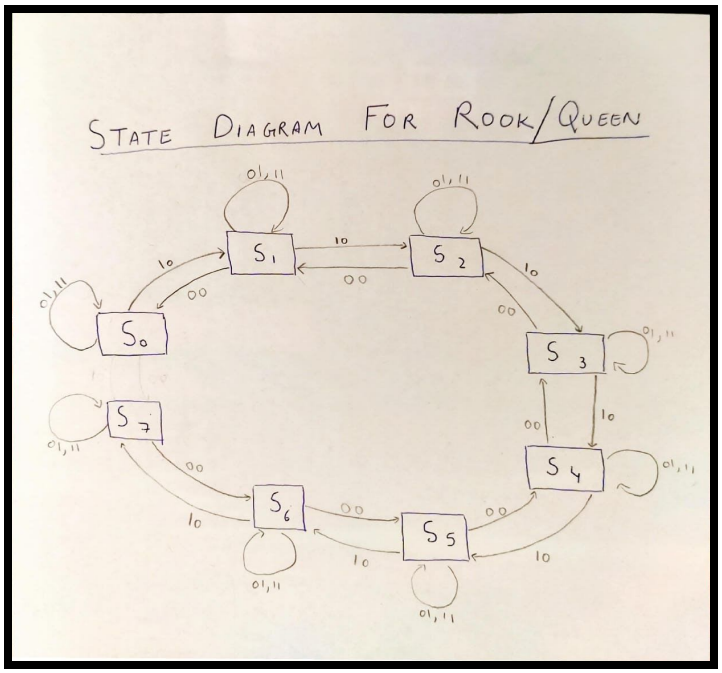
For Queen-

Piece = 0
For uv= 00 , Xs > Xi,
For uv= 01 , Xs= Xi,
For uv= 10 , Xs<Xi,
For uv= 11 , Ys != Yi and Xs != Xi and |Xs-Xi| != |Ys- Y1|

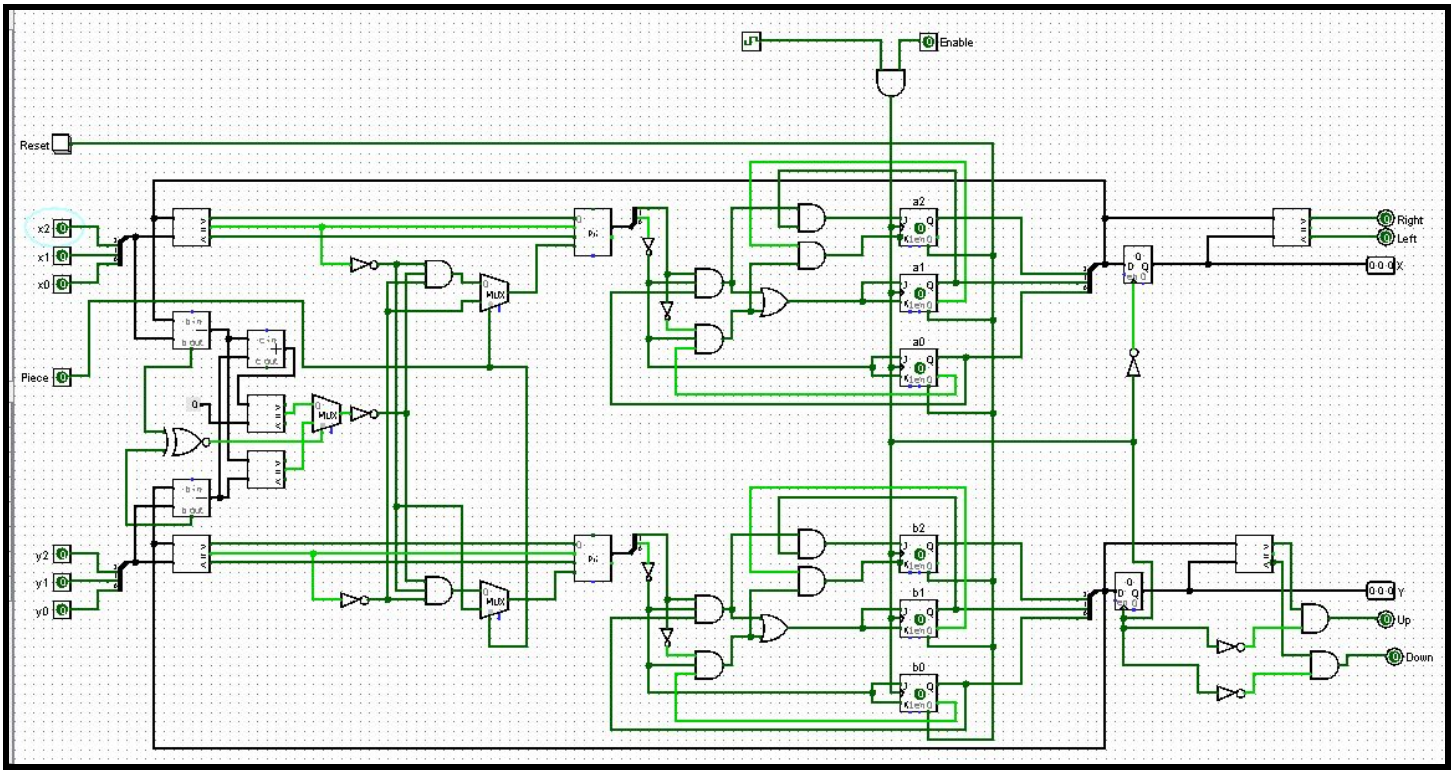
X coordinate				
Present State	**Next State**			
	uv=00	uv=01	uv=10	uv=11
S0	x	S0	S1	S0
S1	S0	S1	S2	S1
S2	S1	S2	S3	S2
S3	S2	S3	S4	S3
S4	S3	S4	S5	S4
S5	S4	S5	S6	S5
S6	S5	S6	S7	S6
S7	S6	S7	x	S7

Similar State Table of Y coordinate can be obtained by replacing Xs with Ys , Ys with Xs , Xi with Yi and Yi with Xi.

State Diagram



Circuit Diagram

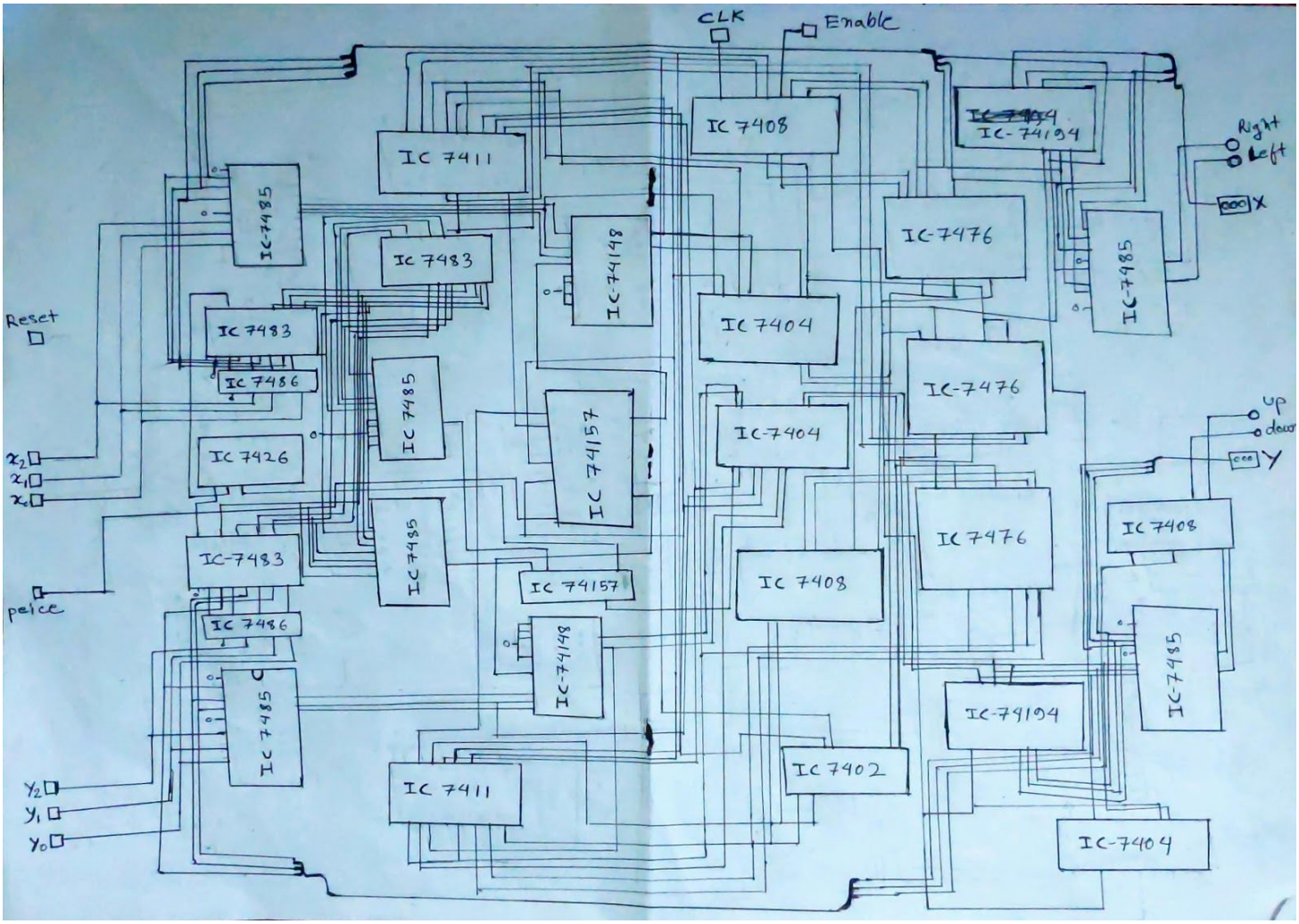


Bill of Materials:

Total 30 ICs of 12 varieties were used for this project:

- IC DM74LS85 4-bit Magnitude Comparators (x6)
- IC 74LS83A 4-bit binary Full Adder (x3)
- IC DM7486 Quad 2-input Exclusive-OR Gate(x2)
- IC DM74LS266 Quad 2-input Exclusive NOR gate
- IC DM74LS11 Triple 3-input AND gate(x2)
- IC SN74LS148 8 Line to 3 Line Priority Encoder(x2)
- IC DM74157 Quad 2-Line to 1-Line Data Selector/Multiplexer (x2)
- IC DM7404 Hex Inverting Gates(x3)
- IC DM7408 Quad 2-input AND gates(x3)
- IC DM7402 Quad 2-input NOR gates
- IC 74LS194 4-bit Bidirectional Universal Shift register(x2)
- IC DM7476(x3) Dual Master-Slave JK Flip-Flops

Pinout Diagram



Sample input/output Combination

Sample Output for Queen

The following Logging Table shows the move of Queen from (3,4) to (0,7). It also shows how servo motors would carry out this move (first left then up for 3 times).

Piece = 0 (Queen), x2 x1 x0 are inputs of X coordinate and y2 y1 y0 are inputs of Y coordinate , X and Y are the Binary representation of the Current location of queen starting from (3,4) to (0,7)

Piece	x2	x1	x0	y2	y1	y0	X	Y	Left	Right	Down	Up
0	0	0	0	1	1	1	011	100	1	0	0	0
0	0	0	0	1	1	1	010	100	0	0	0	1
0	0	0	0	1	1	1	010	101	1	0	0	0
0	0	0	0	1	1	1	001	101	0	0	0	1
0	0	0	0	1	1	1	001	110	1	0	0	0
0	0	0	0	1	1	1	000	110	0	0	0	1
0	0	0	0	1	1	1	000	111	0	0	0	0

Sample Output for Rook

The following Logging Table shows the move of Rook from (2,4) to (6,4). It also shows how servo motors would carry out this move (right 4 times).

Piece = 1 (Rook) , x2 x1 x0 are inputs of X coordinate and y2 y1 y0 are inputs of Y coordinate, X and Y are the Binary representation of the Current location of rook starting from (2,4) to (6,4)

Piece	x2	x1	x0	y2	y1	y0	X	Y	Left	Right	Down	Up
1	1	1	0	1	0	0	010	100	0	1	0	0
1	1	1	0	1	0	0	011	100	0	0	0	0
1	1	1	0	1	0	0	011	100	0	1	0	0
1	1	1	0	1	0	0	100	100	0	0	0	0
1	1	1	0	1	0	0	100	100	0	1	0	0
1	1	1	0	1	0	0	101	100	0	0	0	0
1	1	1	0	1	0	0	101	100	0	1	0	0
1	1	1	0	1	0	0	110	100	0	0	0	0

Additional Functionality

- The above shown circuit is a hybrid circuit which can be used for both rook and queen , which helps in creating a modularity between design and the same circuit could be used to create other pieces of chess board.
- In case the piece is changed after moving to a location , say (4,6) , the next piece would start from the current location as the previous piece ,i.e. (4,6). The location of the piece can also be initialized to (0,0) by using the reset button. This reset to to (0,0) can also be changed to any other location by simply changing the connections to JK FlipFlop and for each piece it could be different locations on the chess board.

Further Development

- The inputs for the coordinates can be converted to Decimal inputs from binary to improve user-experience , by using an encoder.
- Checking the validity of the move can be improved , checking if the path is empty or not can be implemented.
- The circuit can be expanded to include all the pieces and the pieces can be coded as follows

    4 bits representation with MSB representing the color(black or white) of the piece

    - Pawn 0001
    - Knight 0010
    - Rook 0011
    - Bishop 0100
    - Queen 0101
    - King 0110