ERS 220

Practical report 3:

Ping pong game

Group 35

Ausiku M.S.	[redacted]
Botha F.	29042951
Omar M. W.	[redacted]
Taghizadeh S.	[redacted]

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UNIVERSITY OF PRETORIA

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These guidelines must be read and followed by all students. It is expected that a copy of these guidelines be signed by each student and attached to the first practical report. Failure to do so will result in a zero for your practical and report.

1. Please remember this is a DEMO session i.e. your practical must be completed before the assigned time. Do NOT arrive at the session expecting three hours to work on your practical.
2. Every group member MUST have a lab book. Sharing is not permitted i.e. every group must have the respective number of completed lab books. Pro rata of the total for the practical will be deducted for every lab book not present.
3. If you are late for your demo session, as allocated, you will receive zero for the practical. This is not negotiable. If one of your group members fails to arrive they will receive zero, unless for medical reasons or prior arrangements have been made with the lecturer.
4. If your practical does not function correctly during the session you may be allowed a re-demo. This will occur during the next week's practical and will only be given if your group can demonstrate that work was completed on the practical prior to the session and all of your lab books are complete.
5. Your practical report (1 per group) must be handed to your demonstrator at the completion of your demonstration. It must have a cover page, stating your group number clearly, table of contents, plagiarism statement signed by ALL group members, group members who do not sign will receive zero for the report and failure to include a statement will result in the group receiving zero, a signed copy of these guidelines and all the headings listed in the study guide. Failure to hand in a report during the session will result in a zero for the report.
6. When you arrive at the practical session write your chosen bench number under your group number. As you have chosen the bench you will be expected to be at the bench given. Demonstrators will not wonder around the labs trying to find you. If you have not demonstrated your practical during your allocated time you will receive zero. This is not negotiable. If you fail to indicate your bench number your practical will not be marked and you will receive zero.
7. Arrive at least 15-20 minutes before your allocated time to ensure your practical's functionality.
8. Students have not been assigned to benches. As such if you choose a non-functioning bench, change benches. Non-functioning benches will NOT be accepted as an excuse for non-functioning practicals.
9. Each group must complete their own practical. If it is determined that more than one group has demonstrated the same circuit the groups that colluded will receive zero and NOT given the option to re-demo.
10. Students must buy their own components. As such not having correct components is NOT a valid reason to not complete a practical.

Declaration:
I have read and understood these guidelines and will follow them during all practical sessions.

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Summary

In this practical we explore the principles of sequential circuits by designing a ping pong game. We explore to implementations using shift registers. One using the asynchronous reset of the shift register chip is illustrating the pitfalls of mixing synchronous and asynchronous systems; the second using the parallel load function of the chip to avoid the asynchronous reset.

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Introduction

Problem Statement

Combinational logic is very useful for many problems, but unfortunately it is limited to the inputs that are currently available and the outputs occur in real time. Often we need systems to respond differently based on events that occurred earlier, or to have some sort of delay before outputting results. Such systems are said to have memory and are known as sequential systems. A good example of a sequential system is the television remote that knows what the next station is because it has memory to know which station it is on an the logic functions to tell it what the next station is.

Problem Formulation

The nature of sequential circuits will be explored by designing a ping pong game.

Background

There exist two types of branches in logic circuits, which are combinational and sequential logic circuits. A circuit whose outputs depends only on its current inputs is referred to as, a combinational logic circuit A circuit whose outputs not only depend on inputs but also on the past sequence of inputs is called a sequential circuit (J. F Wakerly, 2006).

In this practical, our objective was to design a sequential circuit which simulates a game known as “Ping-Pong”. This game employed a row of LEDs which switch on in succession to represent the motion of the ‘ball’. As per design specifications stipulated in the practical manual, the design of the circuit which is going to simulate this ‘Ping-Pong’ game must be realized in hardware (breadboard circuit design) as well as software realization (coded in VHDL). To design this circuit, background knowledge on Karnaugh Maps, shift registers, VHDL, FPGA and memory chips was assumed of us as students. (Reddy 2011)

Design and Implementation

Approach

In this Practical a classical state machine was designed to create a ping pong game. The first approach uses a state machine to control the modes of a bidirectional shift register following a Meanly structure. As some problems where encountered with the asynchronous reset of the bidirectional shift register the definition of the problem and the state definitions where refined to follow a Moore structure and a different approach to controlling the shift register.
These two designs will be referred to as the reset and load method du to the method used to control the shift register.

Detailed Design and Implementation

The word problem for the ping pong game is as follows:

“The game will start with the LED's flashing in sequence indication the movement of a ping-pong ball in two dimensions. The ball will start at the right with RLAMP and move left to LLAMP. The purpose of the game is to bounce the ball back by pressing the LPB button when the ball has reached the LLAMP. Holding the button will hold the ball at LLAMP till it is released/bounced back by releasing LPB. The ball will then move from LLAMP to RLAMP and must be bounced back by using button RPB. The ball is missed by pressing the LPB button when the LLAMP is not lit and will result in the ball starting from RLAMP (automatic serve). Similarly, the ball is missed when RPB is pressed when RLAMP is not lit.” (Reddy 2011)

The first step was to define states based on this word problem. This depended directly on the implementation one had in mind. In our case a bidirectional shift registers. A state table would then be drawn up using the word problem. This state table is then used to attain the simplified excitation equations for the state memory in the form of a D flip-flops. Further output functions for the purpose of controlling the shift register and keeping score are then synthesised based on the state definition.

Results and Discussion of Results

Reset method

The functions of the 74HC194 bidirectional shift register are defined as follows:

FUNCTION TABLE

OPERATING MODES	INPUTS							OUTPUTS			
	CP	$\overline{MR}$	S_1	S_0	D_{SR}	D_{SL}	D_n	Q_0	Q_1	Q_2	Q_3
reset (clear)	X	L	X	X	X	X	X	L	L	L	L
hold ("do nothing")	X	H	l	l	X	X	X	q_0	q_1	q_2	q_3
shift left	↑ ↑	H H	h h	l l	X X	l h	X X	q_1 q_1	q_2 q_2	q_3 q_3	L H
shift right	↑ ↑	H H	l l	h h	l h	X X	X X	L H	q_0 q_0	q_1 q_1	q_2 q_2
parallel load	↑	H	h	h	X	X	d_n	d_0	d_1	d_2	d_3

Figure 1 Functions of 74HC194 Bidirectional shift register

The state definitions where based on values required by the S1 and s0 inputs of the shift register used to control its functions. The state table and definitions are shown below.

State table

State table (L_B R_B L_LAMP R_LAMP)

S	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
HOLD_R	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	HOLD_R	HOLD_R	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	HOLD_R	HOLD_R
SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	HOLD_R	SHIFT_R	HOLD_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	HOLD_R	SHIFT_R	HOLD_R
SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	HOLD_L	HOLD_L	SHIFT_L	SHIFT_L	HOLD_L	HOLD_L
HOLD_L	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L

State codes

S	
HOLD_R	00
SHIFT_R	01
SHIFT_L	10
HOLD_L	11

State table (L_B R_B L_LAMP R_LAMP)-1

S	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
00	10	10	10	10	00	00	00	00	10	10	10	10	00	00	00	00
01	01	01	01	01	01	00	01	00	01	01	01	01	01	00	01	00
10	10	10	10	10	10	10	10	10	10	10	11	11	10	10	11	11
11	01	01	01	01	01	01	01	01	11	11	11	11	11	11	11	11

Figure 2 State table reset method

The following Karnaugh maps where draw up from the state table to obtain the simplified excitation equations.

Excitation Karnaugh maps for S1

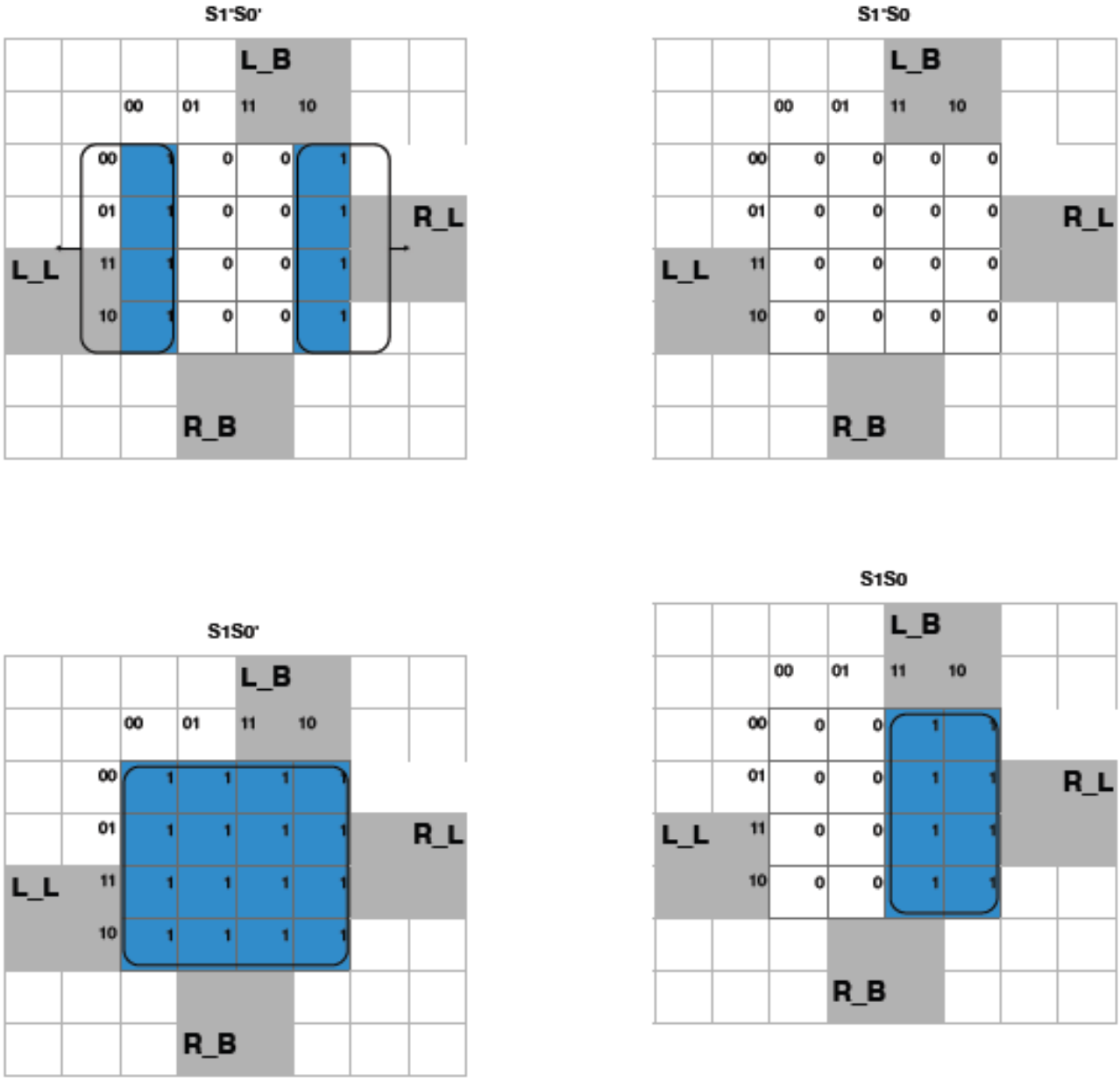


Figure 3 Excitation Karnaugh maps for S1 reset method

The excitation equation for S1 is:

S1next = S1.S0 + S0'.R_B' + S1.L_B

Excitation Karnaugh maps for S0

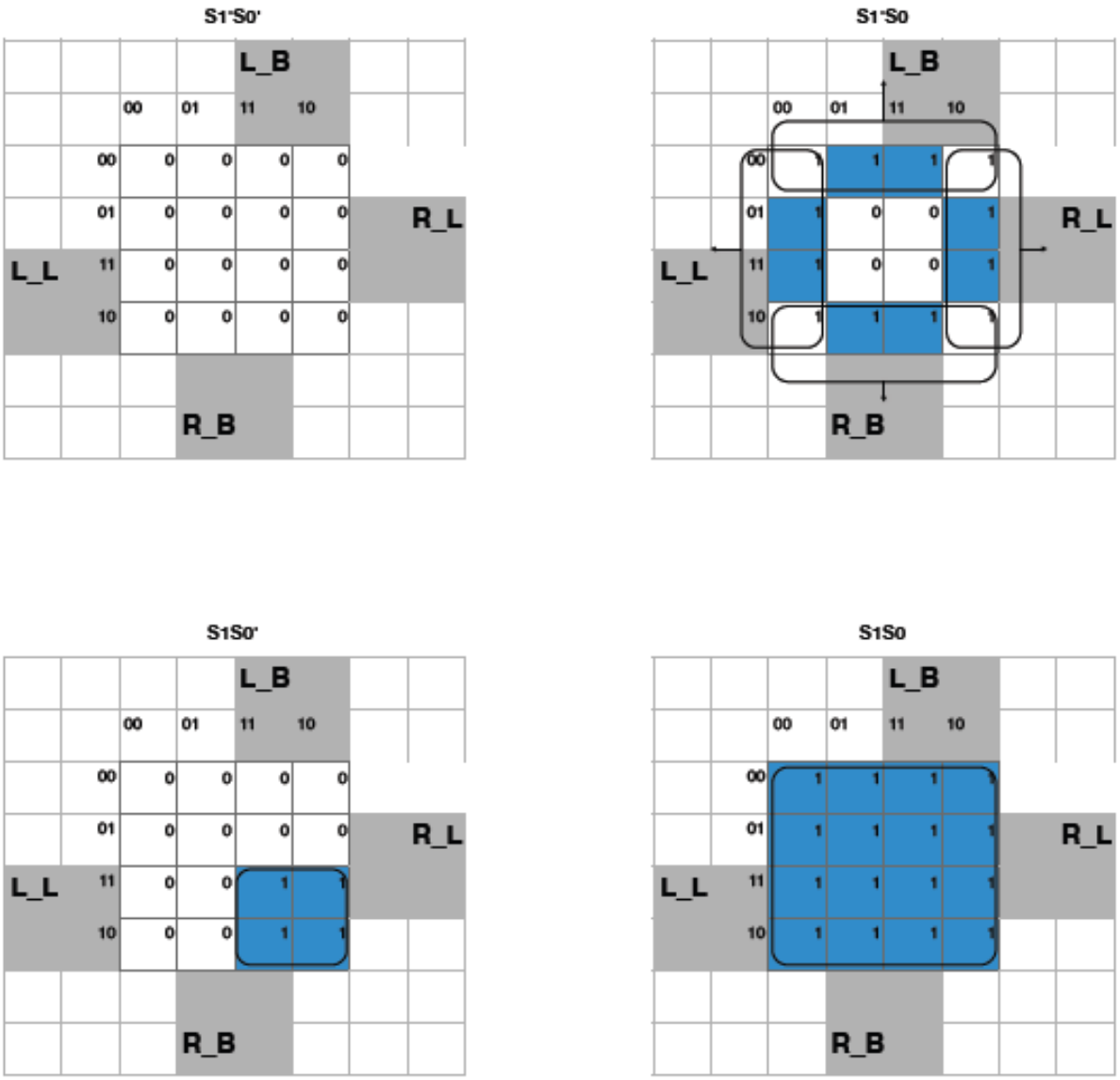


Figure 4 Excitation Karnaugh maps for S0 reset method

The excitation equation for S0 is:

S0next = S1.L_B.L_L + S1.S0 + S0.R_L' + S0.R_L'

Circuit diagram

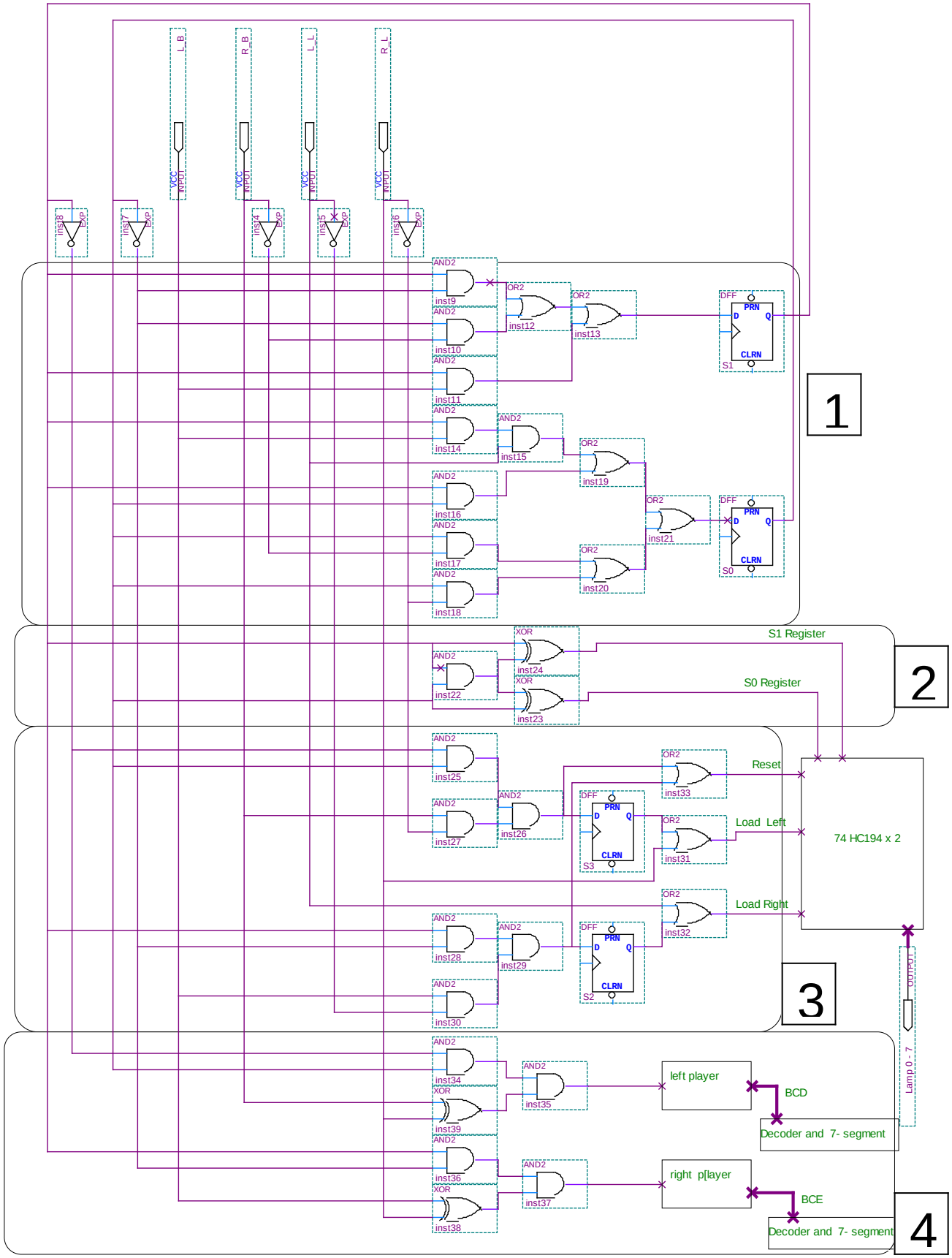


Figure 5 Circuit reset method

The circuit above was designed using the excitation equations and the functional table of the shift registers. The first section of the circuit diagram (marked as 1) represents the excitation equations and the state memory. The second section translates the state codes to the function codes for the shift registers So that in both the HOLD_R and HOLD_L states the shift registers would go into hold mode. When the player presses the button to early the state machine must remain in the current state (SHIFT_R or SHIFT_L) but must return to the start. This was done using the reset function of the shift registers and D-flip-flop to load the serial load pins after the reset, as shown in 3 on the diagram. The equations for the reset are:

Reset and load left = S1'.S0.R_B.R_L'

Reset and load right = S1.S0'.L_B.R_L'

The third section also shows the circuitry for when the last lamp lights and the button is not pressed. The last lamps on both sides are connected to the serial load pins on the opposite side using an OR-gate. The fourth section shows the circuitry for keeping score. The conditions for a player to score are defined by the following equations:

Left player = S1'.S0.R_B.R_L' + S1'.S0.R_B'.R_L
= S1'.S0.(R_B (+) R_L)

Right player = S1'.S0.R_B.R_L' + S1'.S0.R_B'.R_L
= S1'.S0.(R_B (+) R_L)

Note: This circuit failed to function correctly because the asynchronous reset took longer than a clock cycle to complete. This prompted us to redesign the circuit using the lad method shown next.

Load

To simplify the circuit design the state transition in the state table where modified such that instead of the reset function being used when the button is pressed to early , the state machine would return to the hold state on the opposite side. This is a slight deviation from the word problem as it enables the player to hold the light on at the restart if he reacts quickly to the other players mistake.

State Table

State table (L_B R_B L_LAMP R_LAMP)

S	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
HOLD_R	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	HOLD_R	HOLD_R	SHIFT_L	SHIFT_L	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	HOLD_R	HOLD_R
SHIFT_R	SHIFT_R	HOLD_L	SHIFT_R	HOLD_L	HOLD_L	HOLD_R	HOLD_L	HOLD_R	SHIFT_R	HOLD_L	SHIFT_R	HOLD_L	HOLD_L	HOLD_R	HOLD_L	HOLD_R
SHIFT_L	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	SHIFT_L	SHIFT_L	HOLD_R	HOLD_R	HOLD_R	HOLD_R	HOLD_L	HOLD_L	HOLD_R	HOLD_R	HOLD_L	HOLD_L
HOLD_L	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	SHIFT_R	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L	HOLD_L

State codes

S	
HOLD_R	00
SHIFT_R	01
SHIFT_L	10
HOLD_L	11

State table (L_B R_B L_LAMP R_LAMP)-1

S	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
00	10	10	10	10	00	00	00	00	10	10	10	10	00	00	00	00
01	01	11	01	11	11	00	11	00	01	11	01	11	11	00	11	00
10	10	10	00	00	10	10	00	00	00	00	11	11	00	00	11	11
11	01	01	01	01	01	01	01	01	11	11	11	11	11	11	11	11

Figure 6 State table load method

The following Karnaugh maps where draw up from the state table to obtain the simplified excitation equations.

Excitation Karnaugh maps for S1

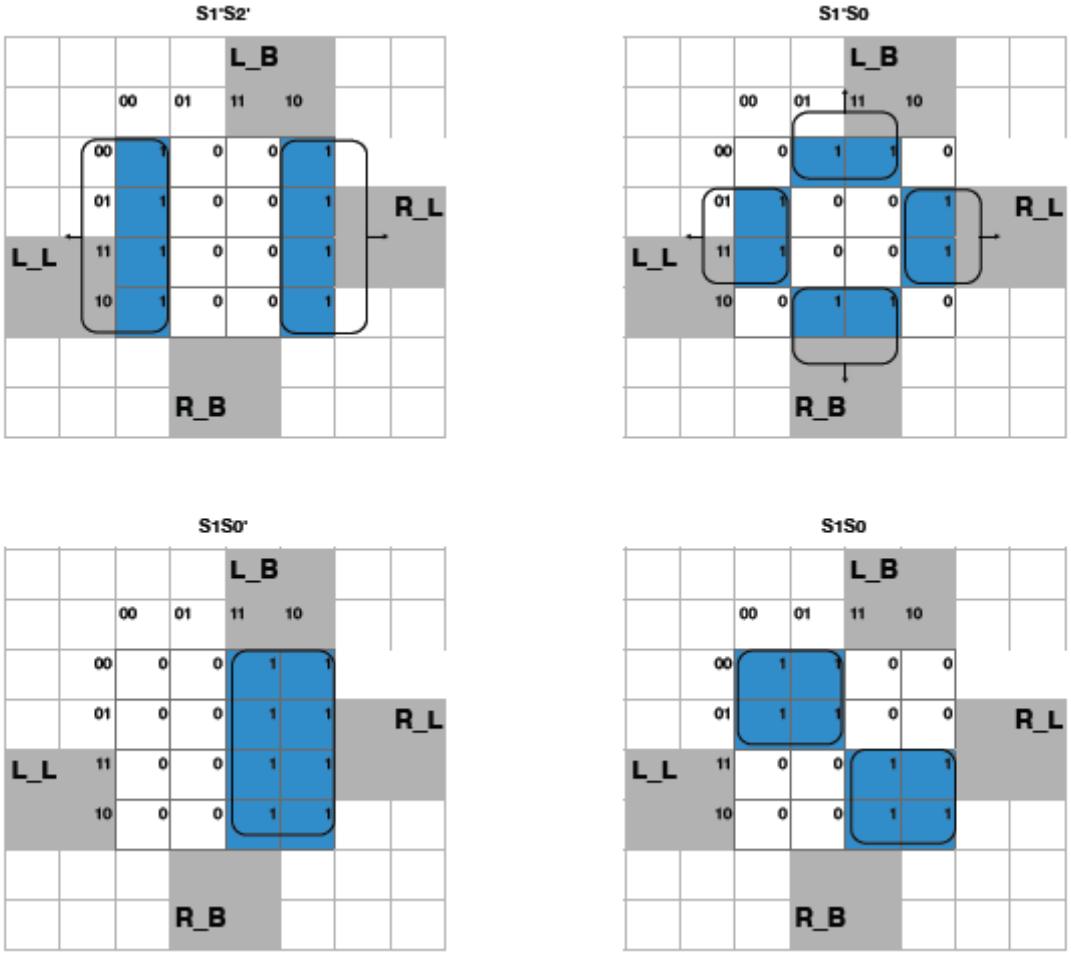


Figure 7 Excitation Karnaugh maps for S1 load method

The excitation equation for S1 is:

S1next = S'S0.R_L'.R_B + S1'.S2'.R_B + S1'.R_L.R_B' + S1.S0'.L_B + S1.L_B.L_L

Excitation Karnaugh maps for S0

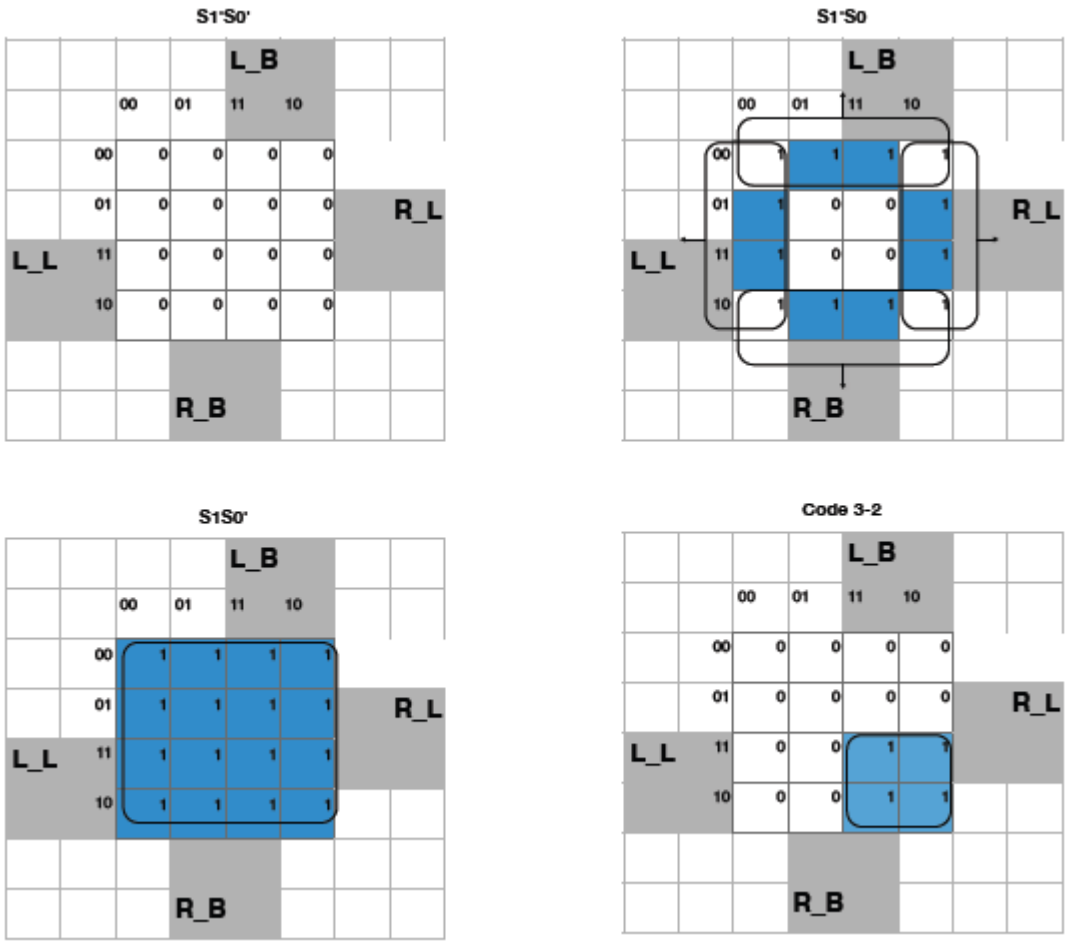


Figure 8 Excitation Karnaugh maps for S0 load method

The excitation equation for S0 is:

S0next = S1.L_B.L_L + S1.S0 + R_L' + R_B'

Circuit diagram

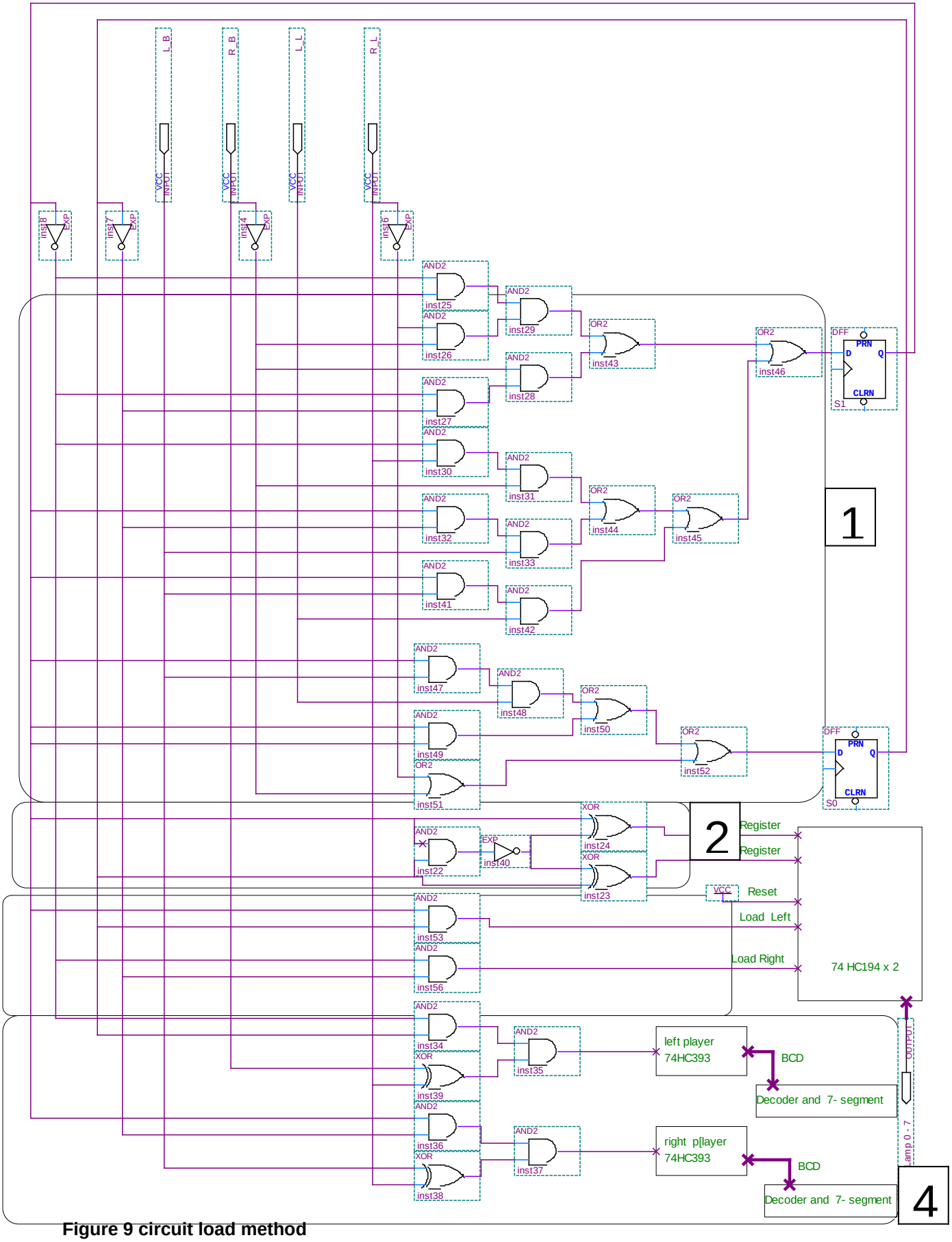


Figure 9 circuit load method

3

The circuit above was designed using the excitation equations and the functional table of the shift registers. The first section of the circuit diagram (marked as 1) represents the excitation equations and the state memory. The second section translates the state codes to the function codes for the shift registers So that in both the HOLD_R and HOLD_L states the shift registers would go into load mode. When the player presses the button to early the state machine will go in to the parallel load mode. The and gates in part 3 determine in what mode the state machine is and loads the value at either left or right. The fourth section shows the circuitry for keeping score. The conditions for a player to score are defined by the following equations:

Left player = S1'.S0.R_B.R_L' + S1'.S0.R_B'.R_L
= S1'.S0.(R_B (+) R_L)

Right player = S1'.S0.R_B.R_L' + S1'.S0.R_B'.R_L
= S1'.S0.(R_B (+) R_L)

Conclusion

State machines enable us to implement simple sequential control systems to implement circuits that can take past event into account. It is important to take care that inputs do not take longer than a clock cycle to change from lo to high or vice versa as this causes metastable behavior and unpredictable results. A function such as an asynchronous reset can't be used in conjunction with sequential circuitry.

References

1. Reddy, S. 2011. *Study Manual, Digital Systems.* University of Pretoria
2. Wakerley, J.F. 2006. *Digital Design, Principles and practices* Pearson, Pretence Hall