Department of Computer Science
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UNIVERSITI TEKNOLOGI MALAYSIA

SUBJECT NAME:	DIGITAL LOGIC
SUBJECT CODE:	SCSR1013 / SECR1013
SEMESTER:	Sem 1 – 2025 2026
LAB TITLE:	**Lab 2: Combinational Digital Circuit Design Simulation Using Deeds Simulator**
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A. Objectives

i) To expose student with producing digital logic circuit, generating truth table and Timing Diagram with Deeds Simulator

ii) To expose student with a complete cycle process of a combinatorial circuit design and simulate with Deeds Simulator

B. Material

Install Deeds Software for Windows to your computer / laptop

C. Introduction

Deeds Simulator

The Digital Circuit Simulator ***d-DcS*** appears to the user as a graphical schematic editor, with a library of simplified logic components, specialized toward pedagogical needs and not describing specific commercial products.

As described before, the schematic editor allows building a simple digital networks composed of gates, flip-flops, pre-defined combinational and sequential circuits and custom-defined components (defined as Finite state machine).

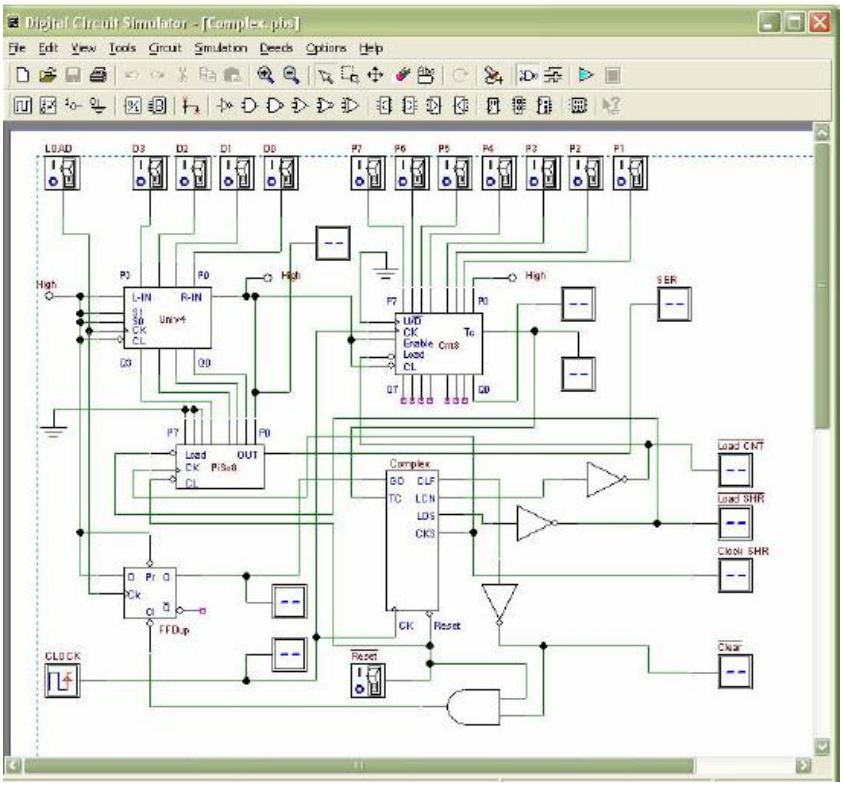


Fig. 1 Circuit Editor of Digital Circuit Simulator (d-DcS)

Simulation can be interactive or in timing-mode. In the first mode, the student can *"animate"* the digital system in the editor, controlling its inputs and observing the results. This is the simplest mode to examine a digital network, and this way of operation can be useful for the beginners. In the timing mode, the behavior of the circuit can be analyzed by a timing diagram window, in which the user can define graphically an input signal sequence and observe the simulation results.

Digital Circuit Simulator (d-DcS): A Simple Example

In following screen shots (Fig. 2a, 2b, and 2c), student can see the circuit during the drawing and then simulated by animation by following these simple steps:

a) student picks-up components from the bin on the Component Tool Bar.

b) connects them using Wires.

c) student activates the animation.

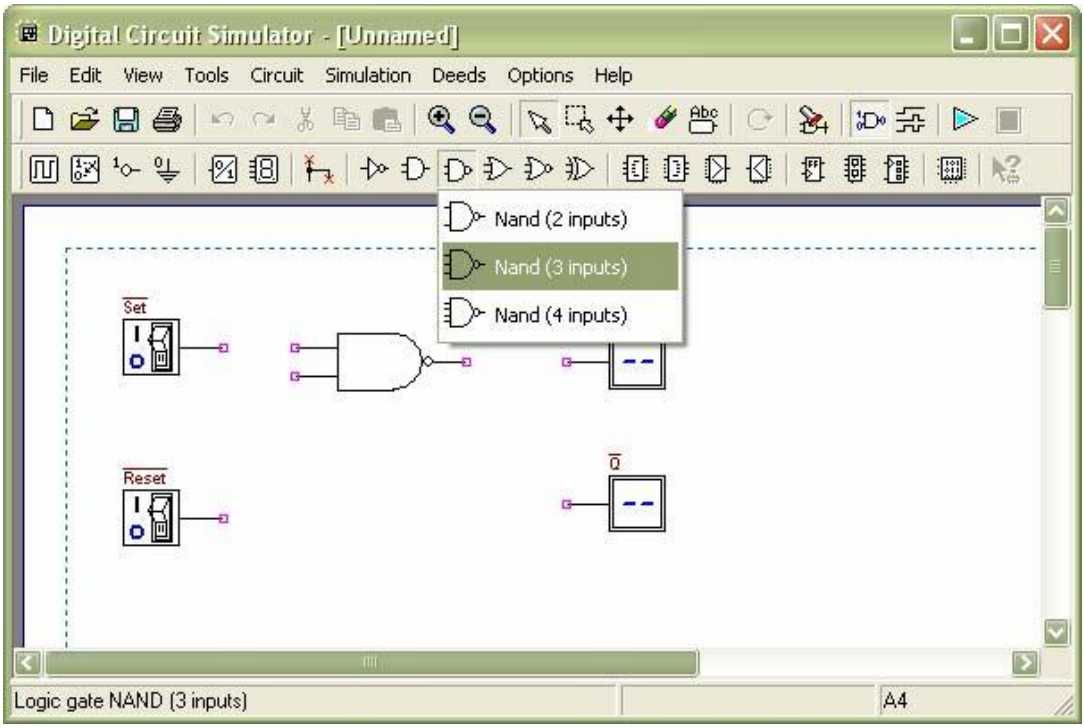


Fig. 2a Drawing Phase of the Digital Circuit Editor: Insertion of Components

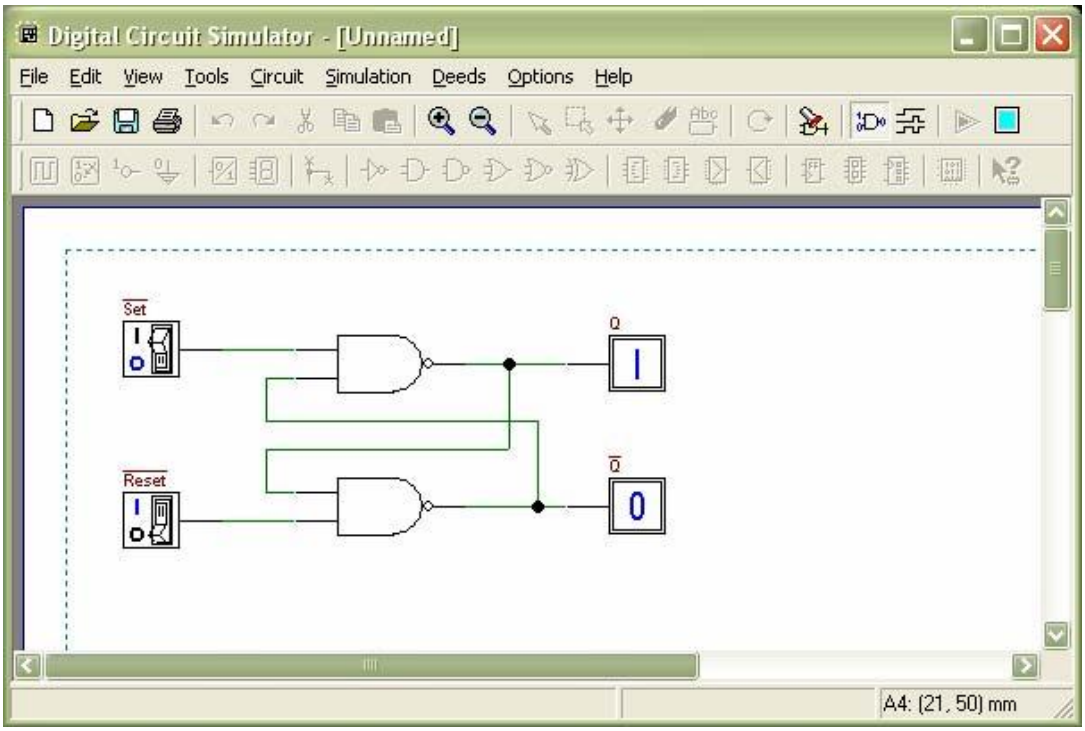


Fig. 2b Next Phase of the Work: Connection of Components using Wires

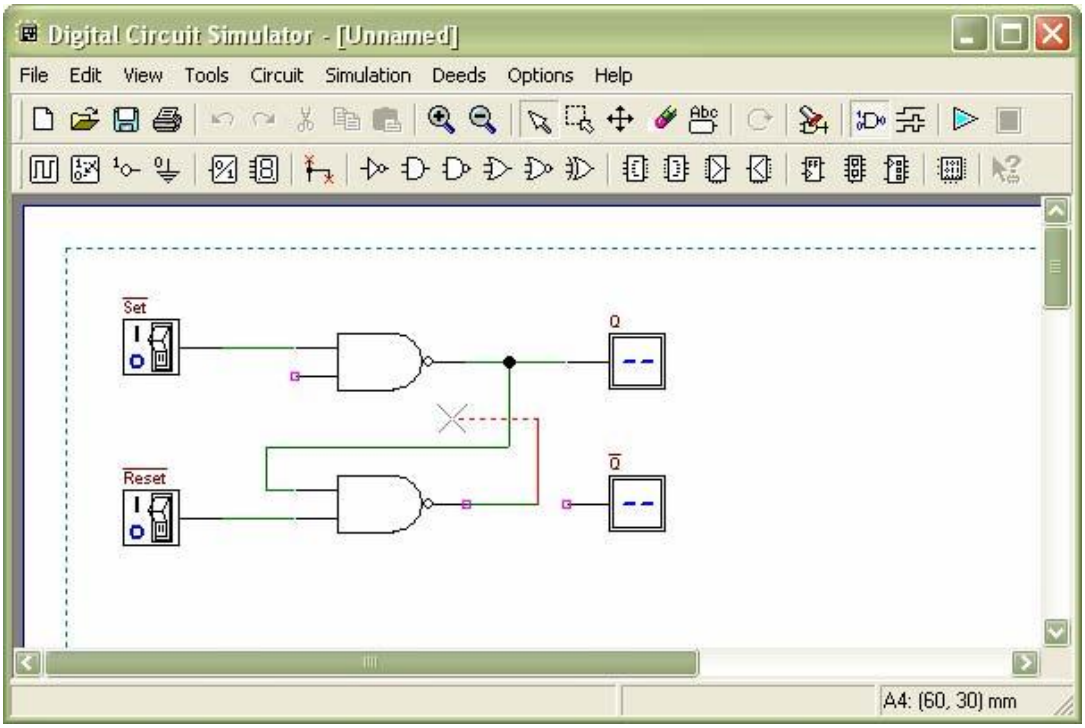


Fig. 2c Animation: User Switches Inputs and the Circuit Shows Changes on Outputs

To exit the 'animation' mode, it is necessary to click on the square 'stop' button.

Instead, if the timing simulation is to be performed, student should click on the Timing Simulation button. This will show the Timing Diagram simulation window (Fig. 3).

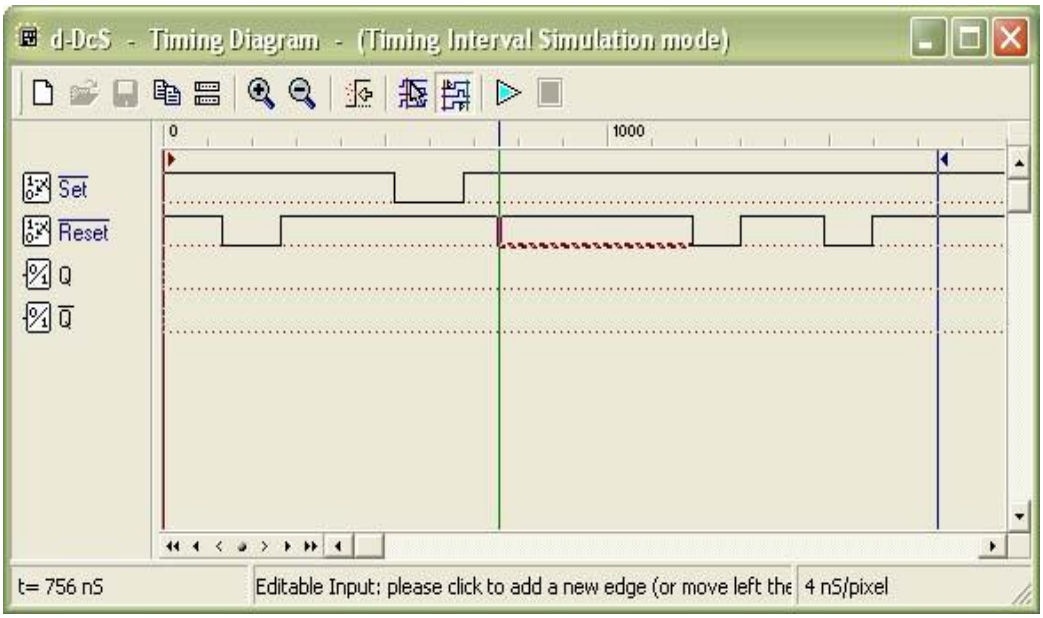


Fig. 3 Timing Diagram Simulation Window

In this window, first student should define the timing of the input signals, drawing them on the diagram with the mouse. A vertical line cursor permits to define the ‘end time’ of the simulation. When student clicks on the triangular ‘play’ button on the toolbar, the simulation is executed, and its results are displayed in the same window (Fig. 4).

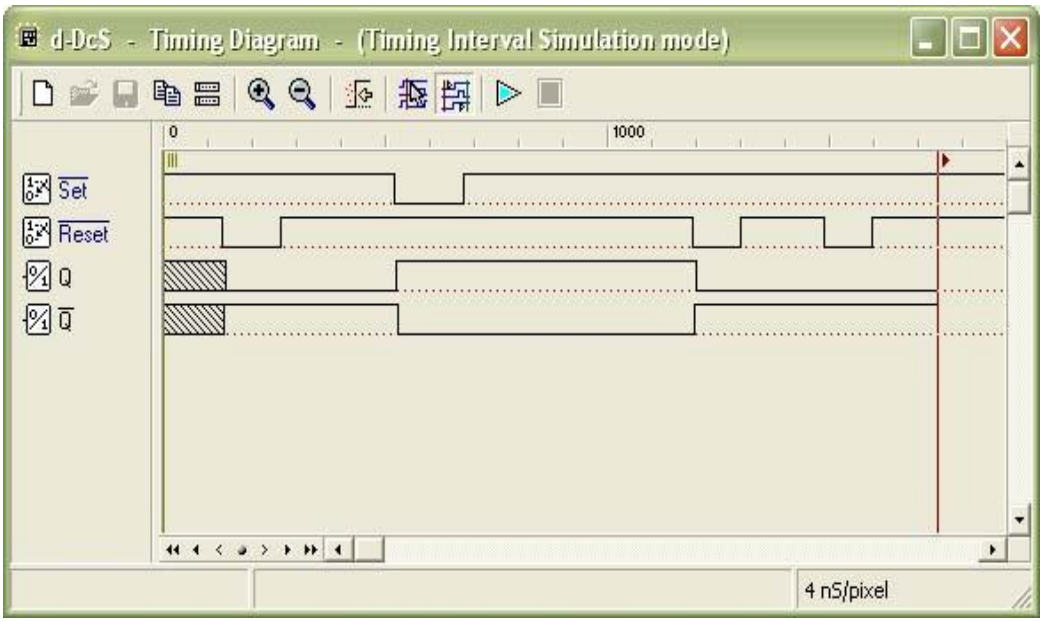


Fig. 4 Timing Simulation Results, Displayed in Timing Diagram Window

Student can verify the correct behavior of the network under test, comparing simulation results with reasoning and theory concepts.

D. Experiment

Part 1:

Refer to circuit in **Figure 1** below:

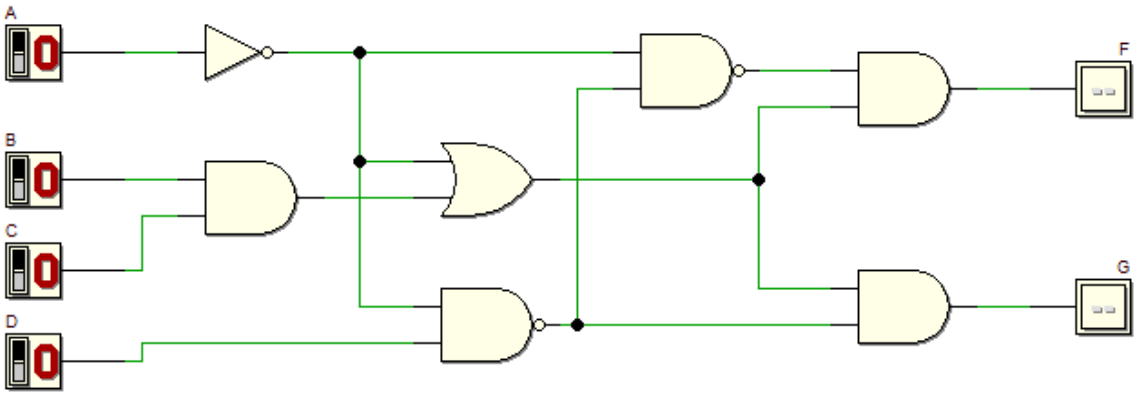


Figure 1

a) Refer to the above circuit. Derive Boolean expression for output F and G.

$$F = (\bar{A} + (B \cdot C)) \cdot \overline{(\bar{A} \cdot \overline{(\bar{A} \cdot D)})}$$

$$G = (\bar{A} + (B \cdot C)) \cdot \overline{(\bar{A} \cdot D)}$$

b) Simplify the equation output F using laws, rules and De Morgan Theorem, and write the equation in Sum of Product (SOP).

$$\begin{aligned} F &= (\bar{A} + (B \cdot C)) \cdot \overline{(\bar{A} \cdot \overline{(\bar{A} \cdot D)})} \\ &= (\bar{A} + (B \cdot C)) \cdot (\bar{\bar{A}} + \overline{(\bar{A} \cdot D)}) \\ &= (\bar{A} + (B \cdot C)) \cdot (A + (\bar{A} \cdot D)) \\ &= (\bar{A} + (B \cdot C)) \cdot (A + D) \\ &= \bar{A}A + \bar{A}D + ABC + BCD \\ &= 0 + \bar{A}D + ABC + BCD \\ &= \bar{A}D + ABC + BCD \end{aligned}$$

c) Simplify equation output G using laws, rules and De Morgan Theorem, and write the equation in Product of Sum (POS).

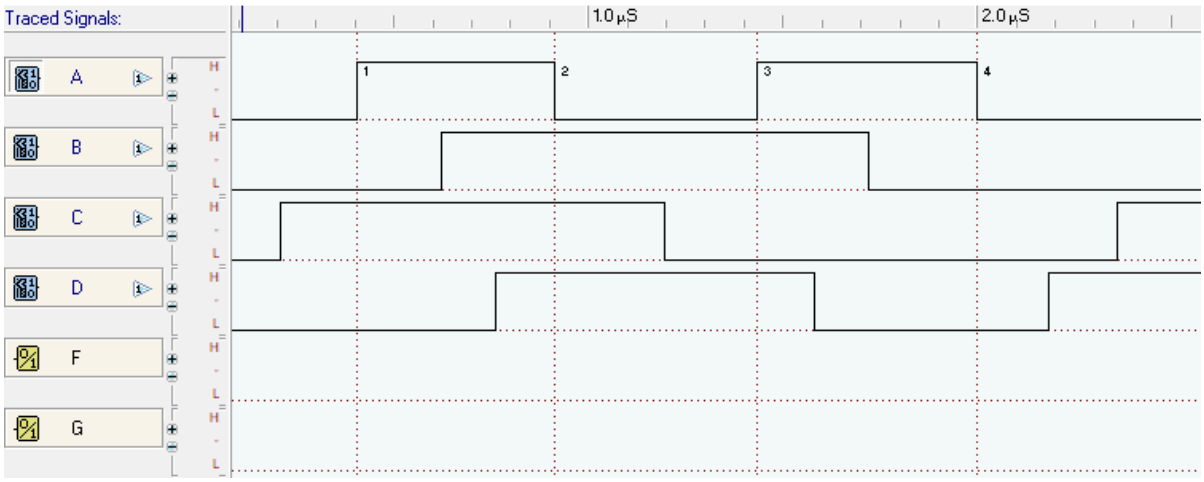
$$G = (\bar{A} + (B \cdot C)) \cdot \overline{(\bar{A} \cdot D)}$$
$$= (\bar{A} + (B \cdot C)) \cdot (\bar{\bar{A}} + \bar{D})$$
$$= (\bar{A} + (B \cdot C)) \cdot (A + \bar{D})$$
$$= \bar{A}A + \bar{A}\bar{D} + ABC + BC\bar{D}$$
$$= 0 + \bar{A}\bar{D} + ABC + BC\bar{D}$$
$$= \bar{A}\bar{D} + BC(A + \bar{D})$$
$$= (\bar{A}\bar{D} + BC)(\bar{A}\bar{D} + A + \bar{D})$$
$$= (\bar{A}\bar{D} + BC)(\bar{D}(\bar{A} + 1) + A)$$
$$= (\bar{A}\bar{D} + BC)(\bar{D} + A)$$
$$= (\bar{A} + B)(\bar{A} + C)(B + \bar{D}) + (C + \bar{D})(A + \bar{D})$$

c) Simulate the circuit and construct the truth table and complete the following.

Truth table for output circuit F and G shown in Figure 1

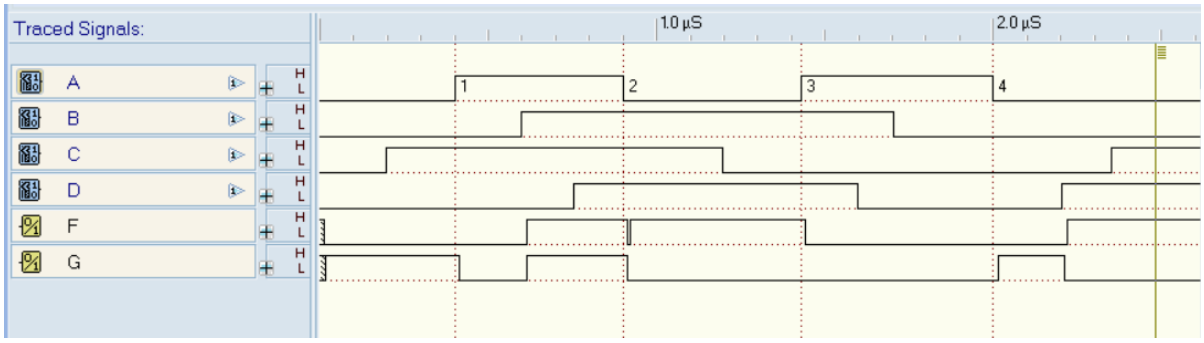
Input				Output	
A	B	C	D	F	G
0	0	0	0	0	1
0	0	0	1	1	0
0	0	1	0	0	1
0	0	1	1	1	0
0	1	0	0	0	1
0	1	0	1	1	0
0	1	1	0	0	1
0	1	1	1	1	0
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	0
1	0	1	1	0	0
1	1	0	0	0	0
1	1	0	1	0	0
1	1	1	0	1	1
1	1	1	1	1	1

d) Using Deeds, draw circuit as shown in previous Figure 1. Simulate and complete the waveform output F and G by referring the following diagram:



Answer

Copy and paste your timing diagram in Deeds below:



e) Write Boolean equation for output F using Sigma notation.

F = ∑ ABCD (1, 3, 5, 7, 14, 15)

f) Write Boolean equation for output G using Pi notation.

G = ∏ABCD (1, 3, 5, 7, 8, 9, 10, 11, 12, 13)

Part 2:

Combinational circuit design process and simulate with Deeds Simulator

Design Process

i) Determine Parameter Input / Output and their relations
ii) Construct Truth Table
iii) Using K-Map, get the SOP optimized form of all Boolean equation outputs
iv) Draw the circuit and use duality symbol; convert AND-OR circuit to NAND gates ONLY.
v) Simulate the design using Deeds Simulator. Check the results according to Truth Table and Timing Diagram Operation.

Problem Description

Using universal gate **NAND gates** only, design a logic circuit that controls an LRT coach door *OPEN* operation at 3 LRT Stations: *Pandan (S1), Pudu (S2)* and *Maluri (S3)*.

Consider the following **inputs**:

- *LRT coach moving status (S)*
  - *S = bit 1 indicates the coach has stopped.*
  - *S = bit 0 indicates the coach is moving.*

- *Sensor location at Station S1, S2, and S3*
  - *HIGH indicates the LRT coach has arrived at the particular station. For instance, S1 = 1 indicates LRT coach has arrived at station S1, and sensor S2=S3=0.*
  - *It is IMPOSSIBLE for the LRT coach to arrive at more than one station at one time.*

The circuit **outputs** are the *OPEN* and *ALARM* signal

- *OPEN = bit 1 indicates the coach door will be opened*
- *ALARM =bit 1 indicates the alarm is activated*

The following are the **conditions** for *OPEN* and *ALARM* outputs at Station *S1*, *S2*, and *S3*

- *The door will be opened ONLY IF the coach stopped at any ONE of the stations.*
- *The alarm will be activated:*
  - *If the coach arrives at any station and it does not stop.* ***or***
  - *If the coach stopped but NOT at stations S1, S2 or S3.*

Experimental steps

i) Complete the Truth Table in Table 1 below for the LRT operations. Use variables *S, S1, S2,* and *S3* as INPUTS and *OPEN* and *ALARM* as OUTPUTS.

Table 1

INPUT				**OUTPUT**	
S	**S1**	**S2**	**S3**	**OPEN**	**ALARM**
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	X	X
0	1	0	0	0	1
0	1	0	1	X	X
0	1	1	0	X	X
0	1	1	1	X	X
1	0	0	0	0	1
1	0	0	1	1	0
1	0	1	0	1	0
1	0	1	1	X	X
1	1	0	0	1	0
1	1	0	1	X	X
1	1	1	0	X	X
1	1	1	1	X	X

ii) Use K-Map to get optimized SOP Boolean equations for the *OPEN* and *ALARM* circuits.

OPEN

SS1/S2S3	00	01	11	10
00			X	
01		X	X	X
11	1	X	X	X
10		1	X	1

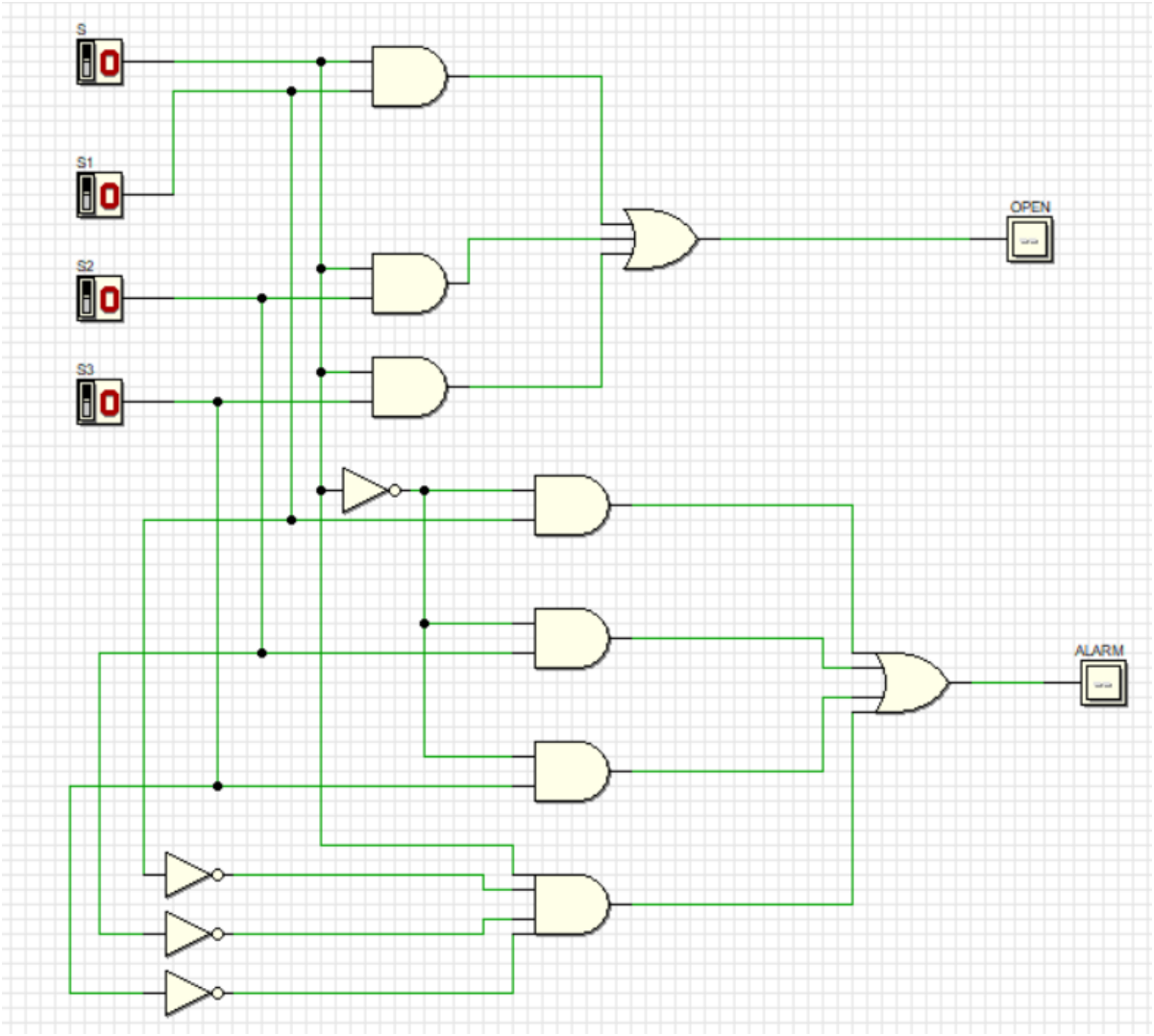
OPEN = SS1 + SS2 + SS3

ALARM

SS1/S2S3	00	01	11	10
00		1	X	1
01	1	X	X	X
11		X	X	X
10	1		X	

ALARM = S'S1 + S'S2 + S'S3 + SS1'S2'S3'

iii) From equations in (ii), draw your final *OPEN* and *ALARM* circuits using Deeds Simulator. Paste your circuit diagram below:



iv) Simulate the circuit design in (iii) and construct Truth Table in Table 2.

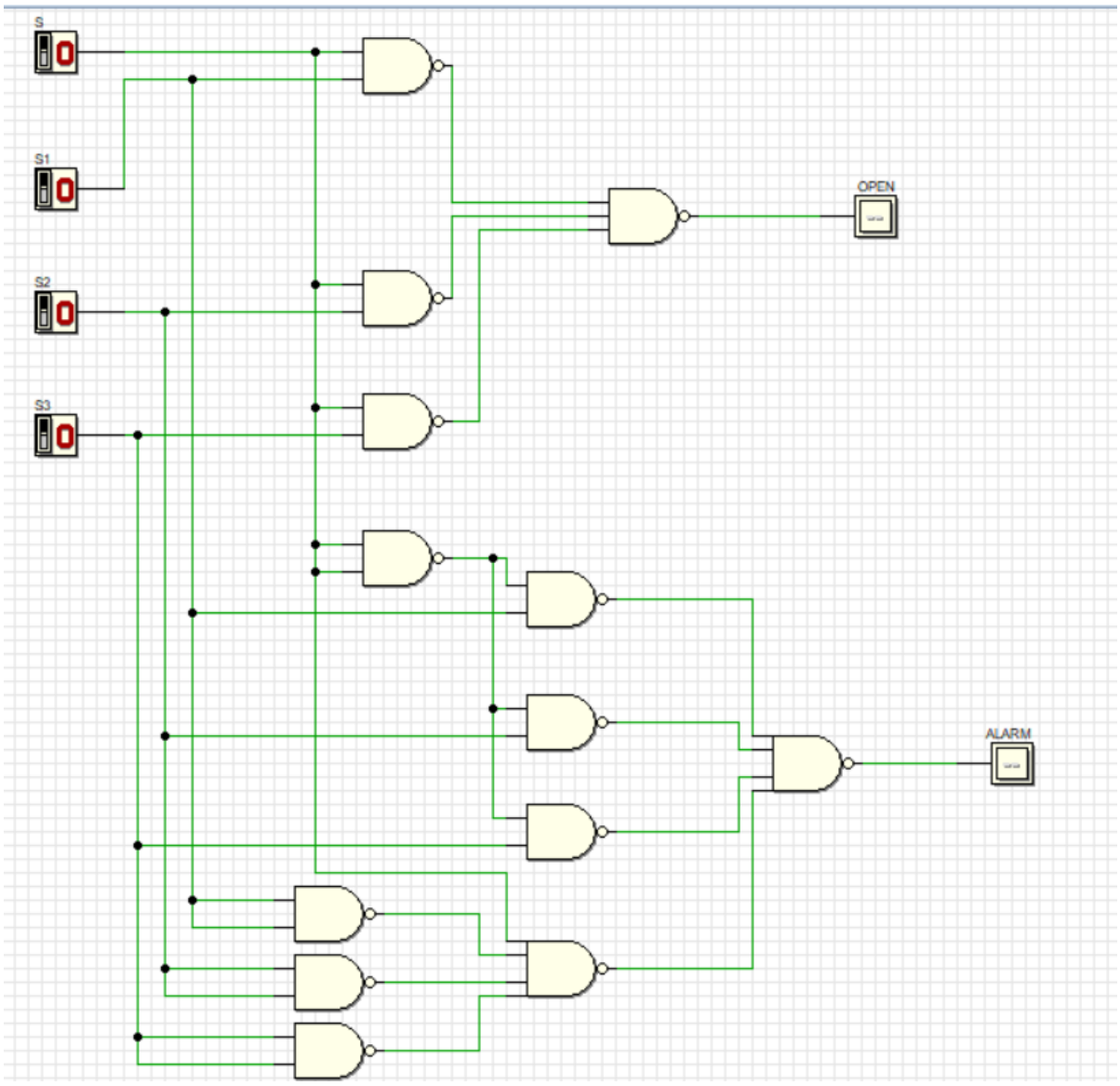
Table 2

INPUT				OUTPUT	
S	**S1**	**S2**	**S3**	**OPEN**	**ALARM**
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	0	1
0	1	0	1	0	1
0	1	1	0	0	1
0	1	1	1	0	1
1	0	0	0	0	1
1	0	0	1	1	0
1	0	1	0	1	0
1	0	1	1	1	0
1	1	0	0	1	0
1	1	0	1	1	0
1	1	1	0	1	0
1	1	1	1	1	0

Compare the answer of Table 2 and Table 1. What is your conclusion?

Table 1 contains don't care conditions meanwhile table contains fixed assigned value because the truth table after K-Map simplification may change. It is because don't care can be assigned either 0 or 1 allowing larger groupings and obtain a simpler Boolean expression. The simulated circuit for table 2 successfully implements the Boolean equation that has been obtained from table 1 through K-Map.

v) Use dual symbols to convert, AND-OR circuit to NAND gates only. Draw the final circuit using Deeds Simulator. Paste your circuit diagram below:



vi) Simulate the final NAND gates design in (v) and construct Truth Table in Table 3.

Table 3

INPUT				OUTPUT	
S	**S1**	**S2**	**S3**	**OPEN**	**ALARM**
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	0	1
0	1	0	1	0	1
0	1	1	0	0	1
0	1	1	1	0	1
1	0	0	0	0	1
1	0	0	1	1	0
1	0	1	0	1	0
1	0	1	1	1	0
1	1	0	0	1	0
1	1	0	1	1	0
1	1	1	0	1	0
1	1	1	1	1	0

Compare the answers of Table 2 and Table 3. What is your conclusion?

Truth table 2 is equivalent to truth table 3 even though output truth table 2 was stimulated using a basic logic circuit and truth table 3 was stimulated using NAND logic circuit. It produced the same output as NAND gate, which is a universal gate which can be converted and perform the function basic logic gate. Therefore, the NAND logic circuit and its simulation match the basic logic circuit.

Fully Completed ☐ Partially Completed ☐ Checked by: _____