Student Name: Yupu Wang
Student ID:20012100012
HW ID: H00365030
Programme:BEng in Telecommunications Engineering
University: Xidian University & Heriot-Watt University
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Lab 1 – Introduction to Logisim and Implementation of simple Logic circuits

Part 1: Introduction

In Year 1, you have learnt that custom digital logic designs can be implemented in a programmable logic device. This year, you are going to learn how to implement such designs using a design and simulation tool called *Logisim*.

Logisim is a free open-source software package, it is written in java and is platform-independent. You can download it for free on your own computers to work on, available at http://www.cburch.com/logisim/.

In this first lab, you are going to familiarize yourself with the Logisim workspace and implement simple functions with basic logic gates.

Part 2: Familiarizing yourself with the Logisim workspace

Go ahead and open Logisim on your computer. You will be greeted with the main workspace of Logisim. This window will look something like Figure 1.

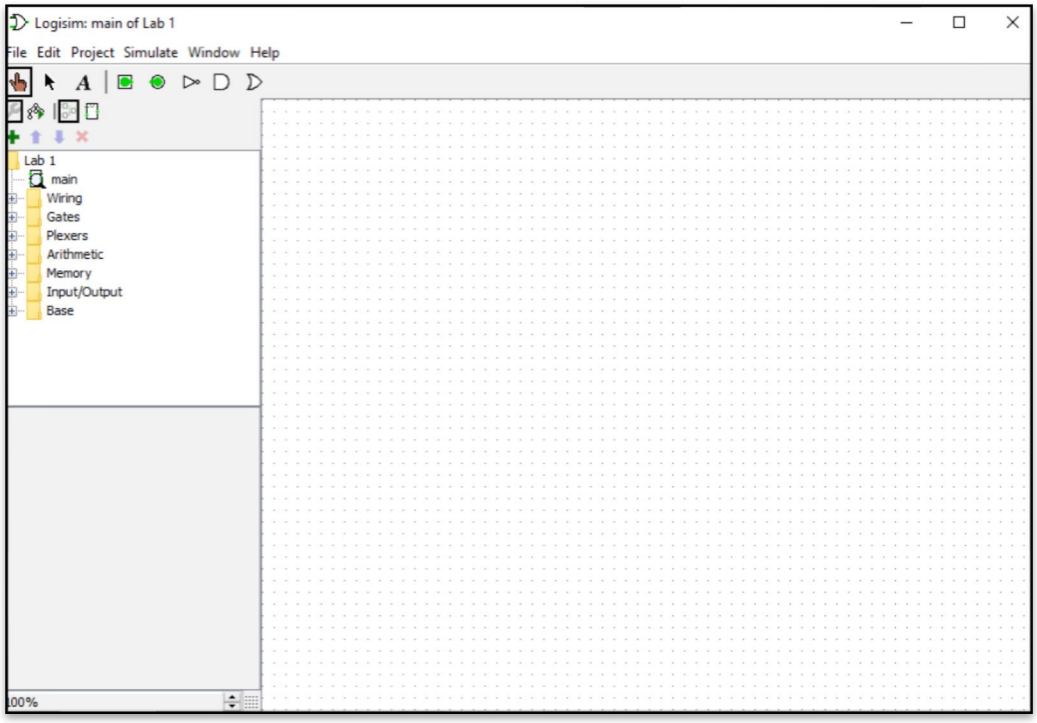
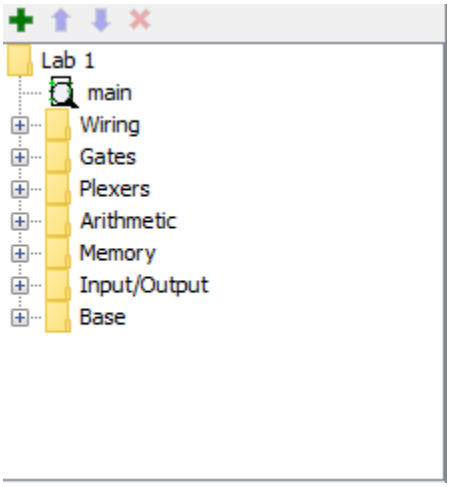


Figure 1: Logisim Main Workspace

The main workspace consists of an object browser on the left, property window on the bottom left, a grid workspace, a tool bar above it and a menu bar above that. Let us learn about each of these items individually.

1. Object browser:



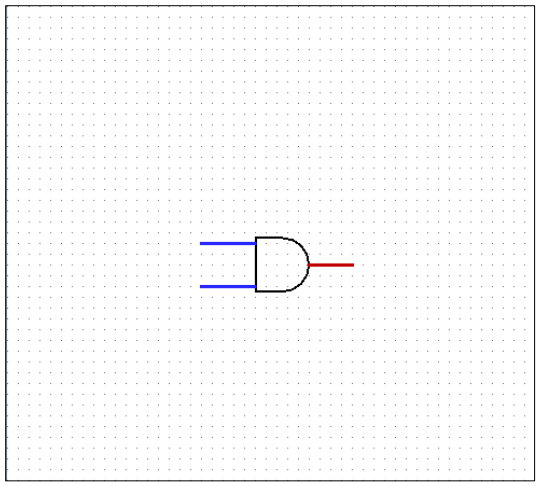
The object browser lets you find, and place various parts required to create your circuits. This includes wiring from wires, pins, power, ground, splitters, etc. It also includes all kinds of logic gates, combinational circuitry, multiplexers, etc. You can simply drag a component from the object browser directly onto the main window to place an object into your workspace.

2. Property window:

Selection: AND Gate	
Facing	East
Data Bits	1
Gate Size	Medium
Number Of Inputs	5
Output Value	0/1
Label	
Label Font	SansSerif Plain 12
Negate 1 (Top)	No
Negate 2	No
Negate 3	No
Negate 4	No
Negate 5 (Bottom)	No

The property window in the bottom left section of Logisim will show you various properties of the component you have currently selected, this lets you change various parameters for different logic components. For example, you can change the number of inputs on an AND gate, you can also change the direction it faces and even give it a label. Different components will have different parameters, if you are unsure how to modify a component to suit your circuit, check this section first as it might have what you are looking for.

3. Grid workspace:



The main workspace section is where you place and design your circuit for testing. You can also see the results of your simulations here and modify various wiring as needed.

4. Logisim tool bar:

The Logisim toolbar consists of various buttons which allow you to change how you interact with the main workspace, it also consists of some shortcuts for frequently used components.

 The probe button allows you to change values of the components in the circuit.

 The select button allows you to select different components to move or edit in the circuit.

 The text button allows you to add text (a label) to a component on the circuit or in the background of the circuit.

 The input pin button allows you to add an input pin to the circuit to act as a source

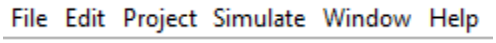
 The output pin button allows you to add an output pin to the circuit to act as a destination.

 The NOT gate button allows you to place a NOT gate into the circuit.

 The AND gate button allows you to place an AND gate into the circuit.

 The OR gate button allows you to place an OR gate into the circuit.

5. Menu bar:



The menu bar consists of different sections that allow you to do a range of functions from saving a circuit to adjusting simulation options within the circuit.

Part 3: Creating your first Logisim circuit

Now that you are more familiar with the workspace of Logisim, lets play around a bit and implement some simple circuits and test their functionality. Let us start with the simplest logic gate, the NOT gate. Before starting, ensure you are on the selection mode ( ).

Step 1: Click on the NOT gate button ( ) and place a NOT gate into your workspace.

Step 2: Click on the input pin button ( ) and place it a few spaces to the left of the input side of the NOT gate.

Step 3: Click on the output pin button ( ) and place it a few spaces to the right of the output side of the NOT gate.

Step 4: Click and drag from the input node of the input pin to the input node of the NOT gate. (you should see a small circle appear when you hover over the input node)

Step 5: Click and drag from the output node of the output pin to the output node of the NOT gate.

If you have followed these steps correctly, you should see that the output pin will now have a result displayed. You can switch the value of the input pin between 0 and 1 by using the probe button ( ). Fill in the table below with the results you have observed, is this correct?

Table 1: NOT gate truth table

Input Pin	Output Pin
0	1
1	0
Expected?	Yes

What is the Boolean equation for the NOT gate circuit assuming the input pin is ‘a’ and output pin is ‘q’?

Answer: $q = a'$ (Bonus: label the input and output pins ‘a’ and ‘q’ respectively in Logisim)

Part 4: AND gates and OR gates

Now we are going to look at AND gates and OR gates. You can create a new circuit by going to File -> New on the menu bar. You can also use the same workspace as the NOT gate if you wish. Let us start with the AND gate. Before starting, ensure you are on the selection mode ( ).

Step 1: Click on the AND gate button ( ) and place an AND gate into your workspace.

You may notice that the default AND gate comes with five inputs. Let us change that to two inputs for the purposes of this lab.

Step 2: Click on the AND gate. On the property window, change the parameter for "Number of Inputs" to 2. (Number Of Inputs 2)

Step 3: Click on the input pin button ( ) and place it a few spaces to the left of the first input node of the AND gate. Repeat for the second input node. You should have two input pins.

Step 4: Click on the output pin button ( ) and place it a few spaces to the right of the output side of the AND gate.

Step 5: Click and drag from the input node of the first input pin to the first input node of the AND gate. Repeat for the second input pin. (you should see a small circle appear when you hover over the input node)

Step 6: Click and drag from the output node of the output pin to the output node of the AND gate.

Like the previous experiment with the NOT gate, use the probe button ( ) to flip between the input pins and record the observations into the truth table below.

Table 2: AND gate truth table

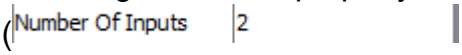
Input Pin 1	Input Pin 2	Output Pin
0	0	0
0	1	0
1	0	0
1	1	1
Expected?	Yes	

What is the Boolean equation for the AND gate circuit assuming the input pins are 'a' and 'b' and output pin is 'q'?

Answer: $q = a \cdot b$ (Bonus: label the input and output pins ‘a’, ‘b’ and ‘q’ respectively in Logisim)

Now, let us do a similar experiment on the OR gate. Before starting, ensure you are on the selection mode ().

Step 1: Click on the OR gate button () and place an OR gate into your workspace.

Step 2: Click on the OR gate. On the property window, change the parameter for “Number Of Inputs” to 2. (

)

Step 3: Click on the input pin button () and place it a few spaces to the left of the first input node of the OR gate. Repeat for the second input node. You should have two input pins.

Step 4: Click on the output pin button () and place it a few spaces to the right of the output side of the OR gate.

Step 5: Click and drag from the input node of the first input pin to the first input node of the OR gate. Repeat for the second input pin. (you should see a small circle appear when you hover over the input node)

Step 6: Click and drag from the output node of the output pin to the output node of the OR gate.

Like the previous experiment with the AND gate, use the probe button () to flip between the input pins and record the observations into the truth table below.

Table 3: OR gate truth table

Input Pin 1	Input Pin 2	Output Pin
0	0	0
0	1	1
1	0	1
1	1	1
Expected?	Yes	

What is the Boolean equation for the OR gate circuit assuming the input pins are ‘a’ and ‘b’ and output pin is ‘q’?

Answer: $q = a + b$ (Bonus: label the input and output pins ‘a’, ‘b’ and ‘q’ respectively in Logisim)

Part 5: Combining gates

Now that you have been able to successfully implement and simulate the NOT, AND and OR gate, it is time to perform some exercises and create other logic gates, XOR, NAND and NOR gates. For the following gates, implement and simulate the results using Logisim and record it in a truth table like you have done for Part 3 and 4.

1. 2 input XOR gate with inputs 'a', 'b' and output 'q' (use only AND, OR and NOT gates to implement):

Input Pin 1	Input Pin 2	Output Pin
0	0	0
0	1	1
1	0	1
1	1	0
Expected?	Yes	

What is the Boolean equation for the 2 input XOR gate circuit?

Answer: $q = a'b + ab'$

2. 3 input NAND gate with inputs 'a', 'b', 'c' and output 'q' (use only AND, OR and NOT gates to implement):

Input Pin 1	Input Pin 2	Input Pin 3	Output Pin
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0
Expected?	Yes		

What is the Boolean equation for the 3 input NAND gate circuit?

Answer: $q = a' + b' + c'$

Part 6: Boolean Logic and Karnaugh Map Implementation

Let us try to design a combinational logic circuit. The circuit shown in Table 6 is a 4 – input majority function (output is "1" when more than one input is "1")

Table 6: 4 – input majority function

A	B	C	D	F
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

F(A, B, C, D) = $A'B'CD + A'BC'D + A'BCD' + A'BCD + AB'C'D + AB'CD' + AB'CD + ABC'D' + ABC'D + ABCD' + ABCD$

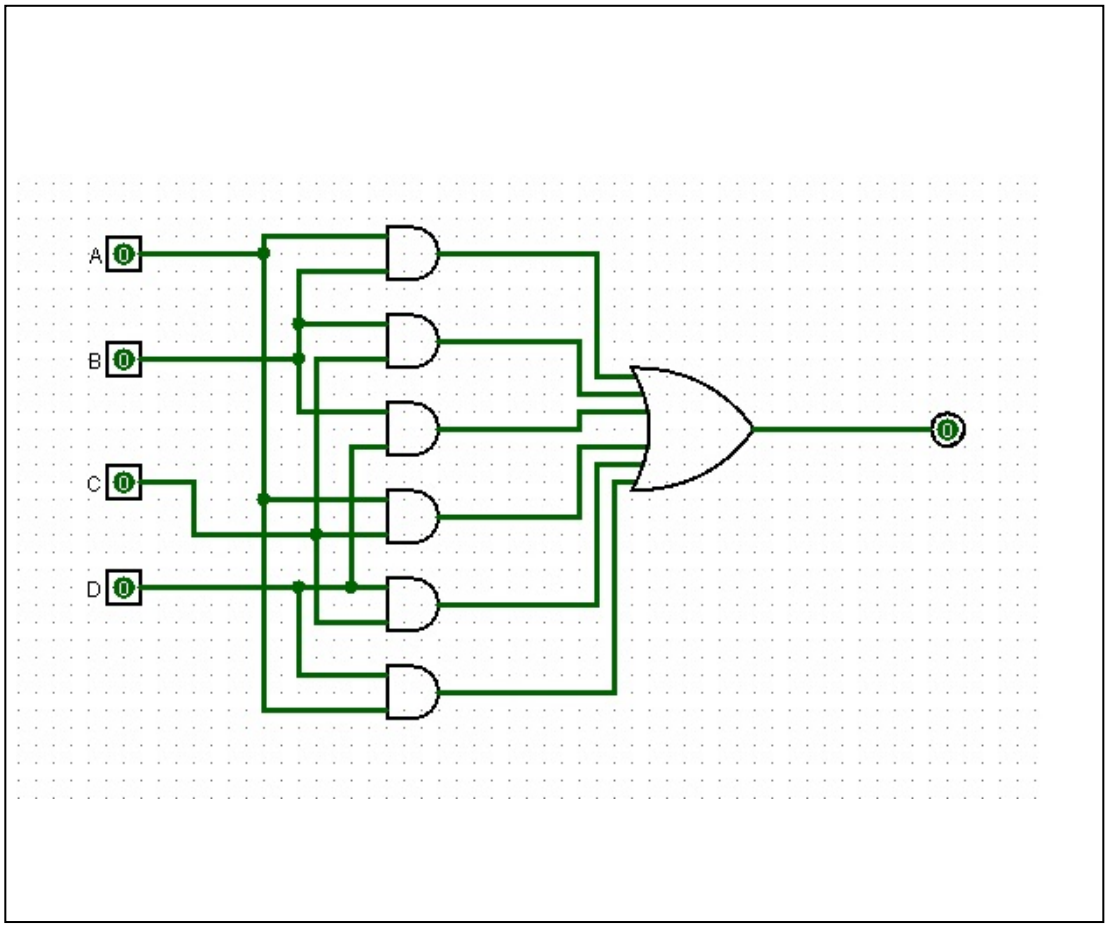
To obtain the simplified logic expression for the 4 – input majority function, you need to use a Karnaugh map. Show your working on the empty Karnaugh map provided below and obtain the logic expression.

ab \ cd	00	01	11	10
00	0	0	1	0
01	0	1	1	1
11	1	1	1	1
10	0	1	1	1

F(A, B, C, D) = $AB + BC + AC + AD + BD + CD$

Implement the obtained logic expression in Logisim and use the knowledge you have learnt so far to verify the truth table results.

Attach the screenshot of 4- input majority function Logisim circuit.



Part 7: Conclusion

In this lab, you should have familiarized yourself with the basics of Logisim. You should now be able to drag and drop components onto the Logisim workspace. You should understand when to use the Probe button ( ) and when to use the Select button ( ). You should understand how to implement basic input and output pins and use various simple logic gates to obtain results.