21.09.20 12:42

CSCI 150
Introduction to Digital and Computer System Design
Lecture 2: Combinational Logical Circuits I

Jetic Gū

2020 Fall Semester (S3)

Overview

- Focus: Boolean Algebra
- Architecture: Combinatory Logical Circuits
- Textbook v4: Ch2 2.1 2.2; v5: Ch2 2.1 2.2
- Core Ideas:
    1. Logical Gates
    2. Introduction to LogicWorks

Logic Gates

And, Or, Not Gates, LogicWorks

Summary

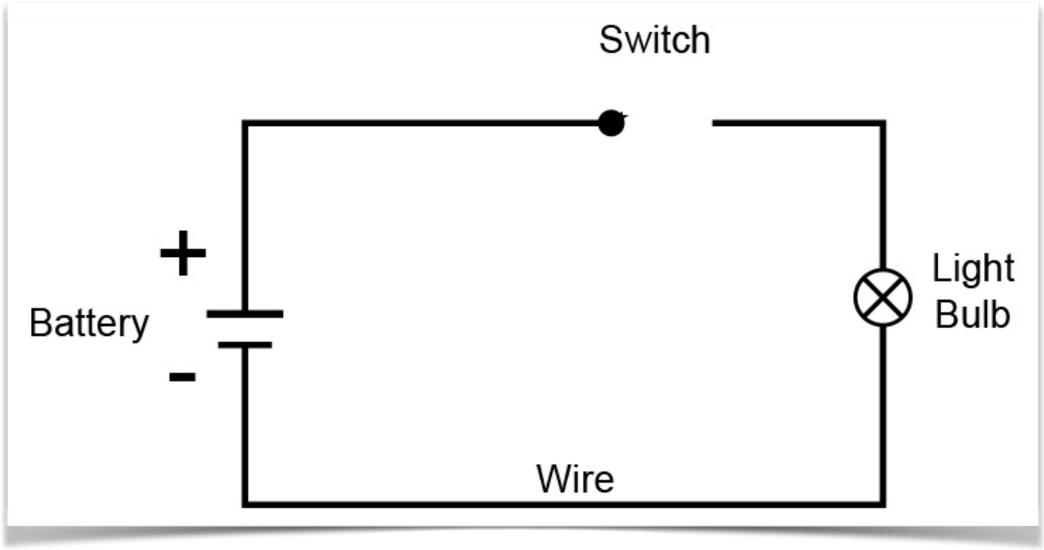
What is a Logic Gate?

- A basic circuit unit implemented using transistors and interconnections
  - We when analysing a digital circuit, are not concerned with the internals of a gate, but only it’s external properties
  - Performs a single logical operation
    operate on one or more binary input signals to produce an output signal

Concept

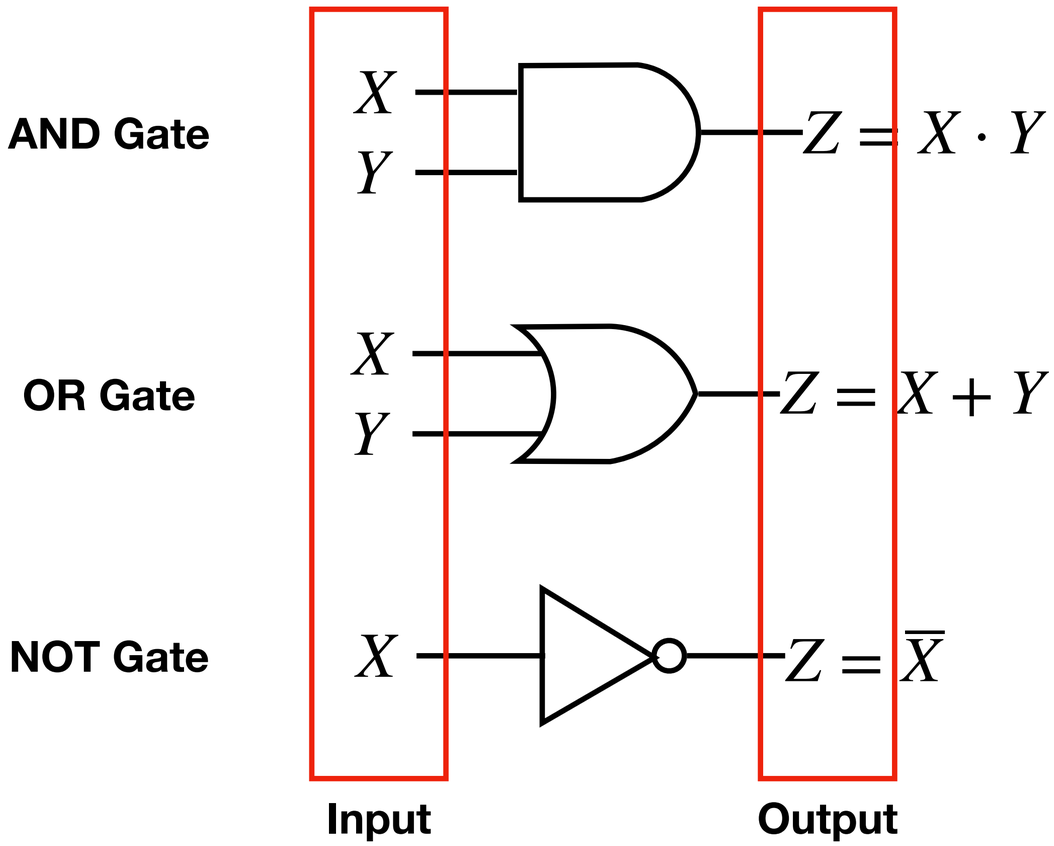
What is a Logic Gate?

- Similar to in electric circuit design, we are not concerned with the design of the lightbulb or battery, but we know what it does.
- A logic gate is like that, we know it's external logic properties, that's enough.



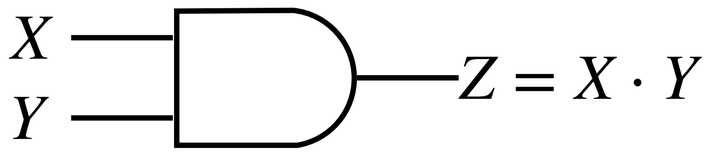
Concept

First 3 Gates



Concept

AND Operator and Boolean Algebra / Binary Logic

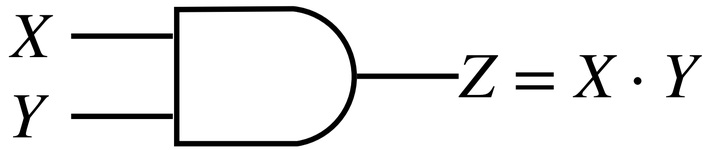


- Boolean Algebra
  - Each variable can only have one of two values:
    - TRUE/ON/1
    - False/OFF/0
- AND: Z is equal to X AND Y
  - Operator: $\cdot$ (`\cdot`)

Concept

P1
Logic Gates

AND Operator and Boolean Algebra



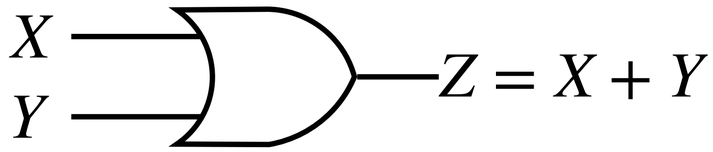
AND Truth Table

X	Y	$Z = X \cdot Y$
0	0	0
0	1	0
1	0	0
1	1	1

- AND: Z is equal to X AND Y
  - Operator: $\cdot$ (`\cdot`)
- Truth Table
  - Left: all combinations of input values
  - Right: corresponding output values

Concept

OR Operator



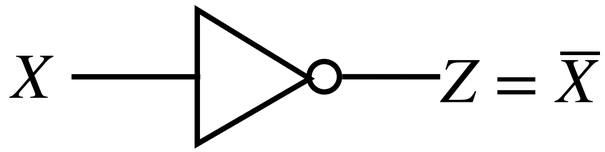
OR Truth Table

X	Y	$Z = X + Y$
0	0	0
0	1	1
1	0	1
1	1	1

- OR: Z is equal to X or Y
- Operator: $+$

Concept

NOT Operator



OR Truth Table

X	$Z = \overline{X}$
0	1
1	0

- NOT: Z is equal to NOT X
  - Operator: $\overline{X}$ (`\overline{X}`)
  - Also called: *Complement* operation; *Inverter* gate

Concept

Logic Gate and Boolean Algebra

- Logic Gates
  - AND Gate, OR Gate, NOT Gate
  - Actual physical components
- Boolean Algebra Operators
  - AND ($\cdot$), OR ($+$), NOT ($\overline{X}$)
  - Mathematical Representations

THEY HAVE DIFFERENCES!

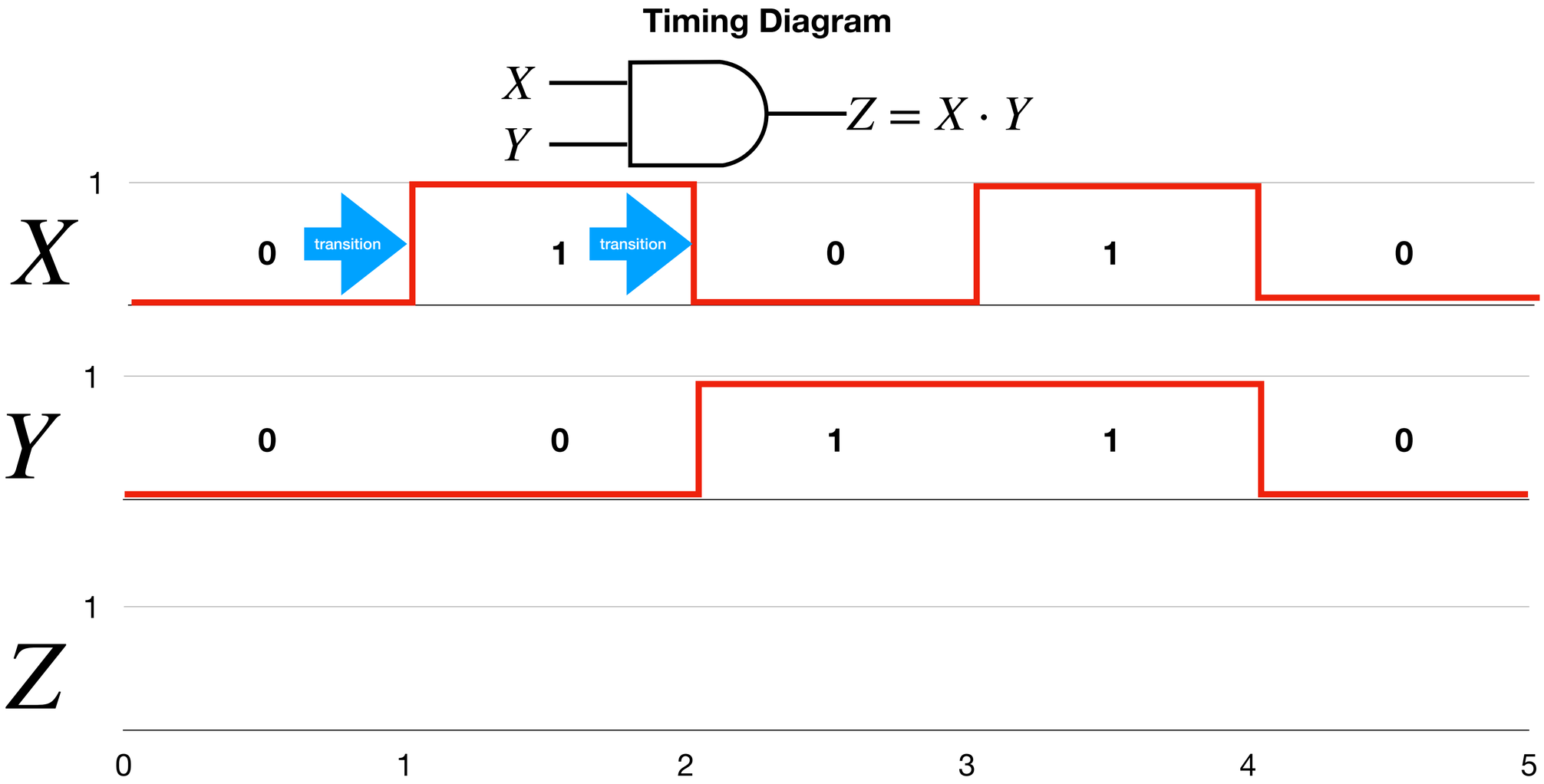
Concept

Digital Logical Gates

- In math, everything happens simultaneously
  - An equation like $250 + 760 = 1010$ doesn't change with time/location
- In digital circuits, we have **electrons as 'messengers'.** They travel at about 2,200 kilometres per second
  - Logic gates are tiny circuits, which means they still have internal components: even slower
  - This means: there will be tiny delays called **Gate Delay**

P1
Logic Gates

Digital Logical Gates

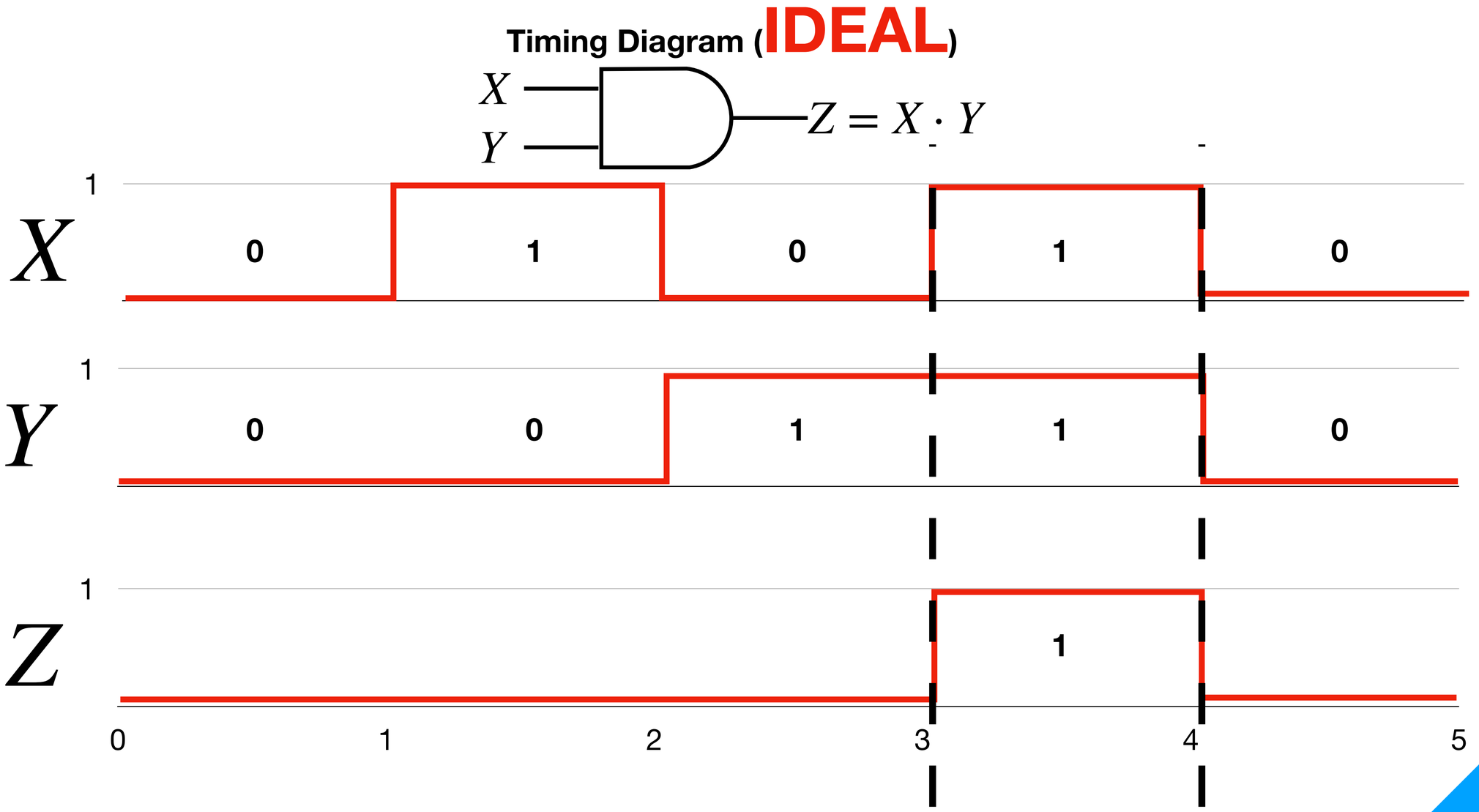


Technical

P1
Logic Gates

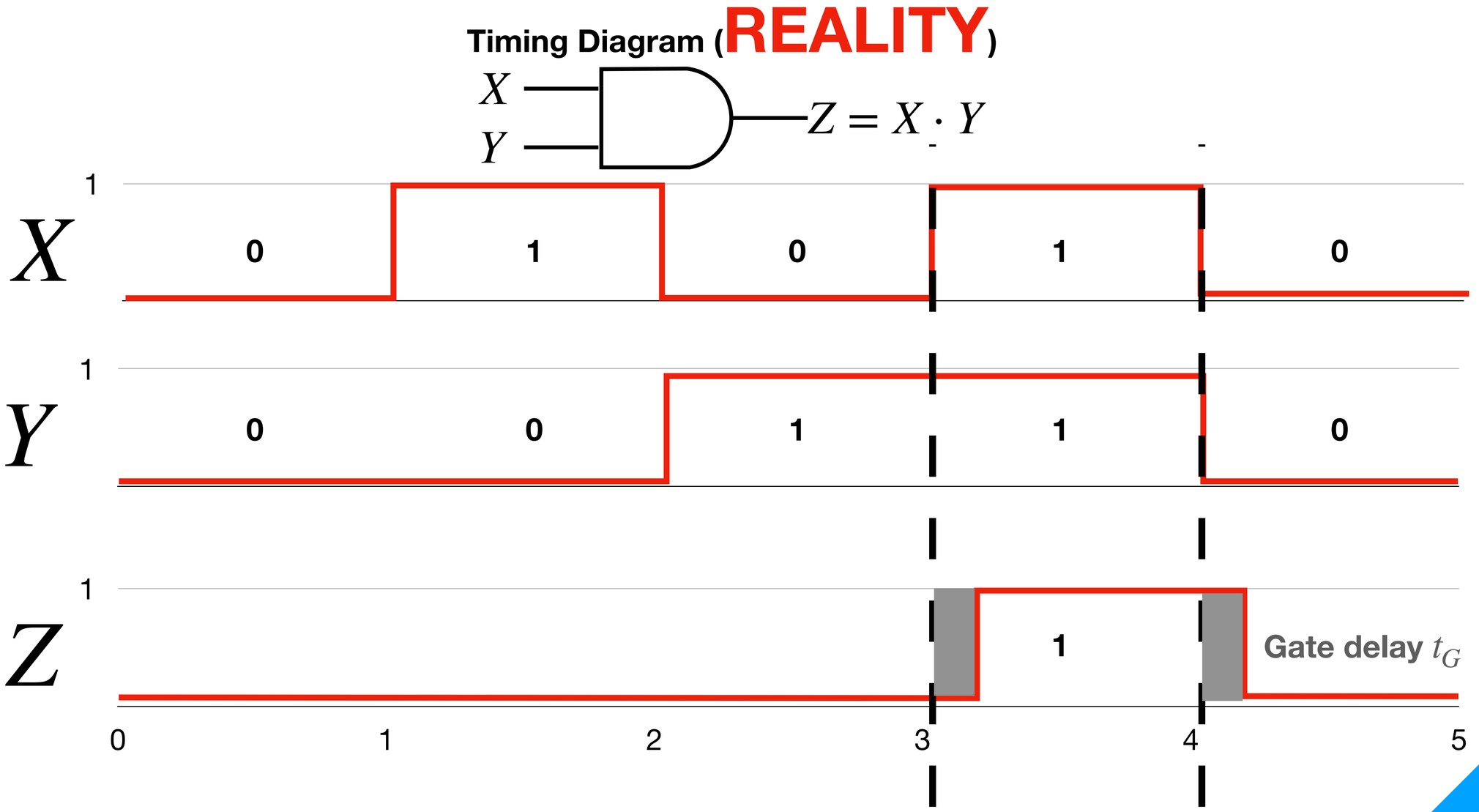
Digital Logical Gates

Timing Diagram (IDEAL)



Technical

Digital Logical Gates



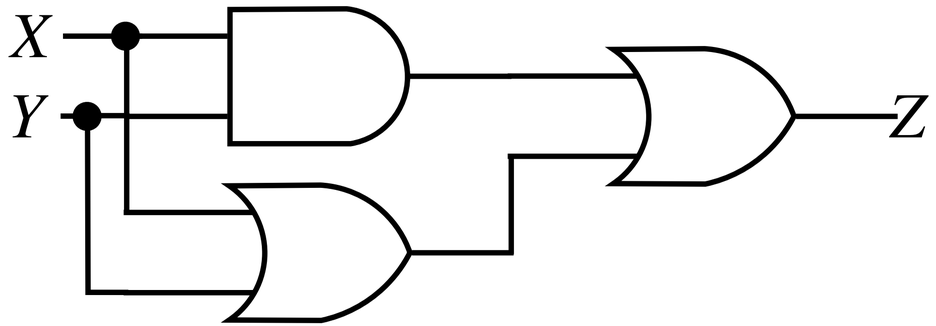
Gate Delay

- Gate delay are small, but not ignorable in practice
  - for simulation, you can ignore it for now
- Gate delay differs for different types and implementations of Gates

Simulation 1

Truth Table

X	Y	$Z = (X \cdot Y) + (X + Y)$
0	0	
0	1	
1	0	
1	1	

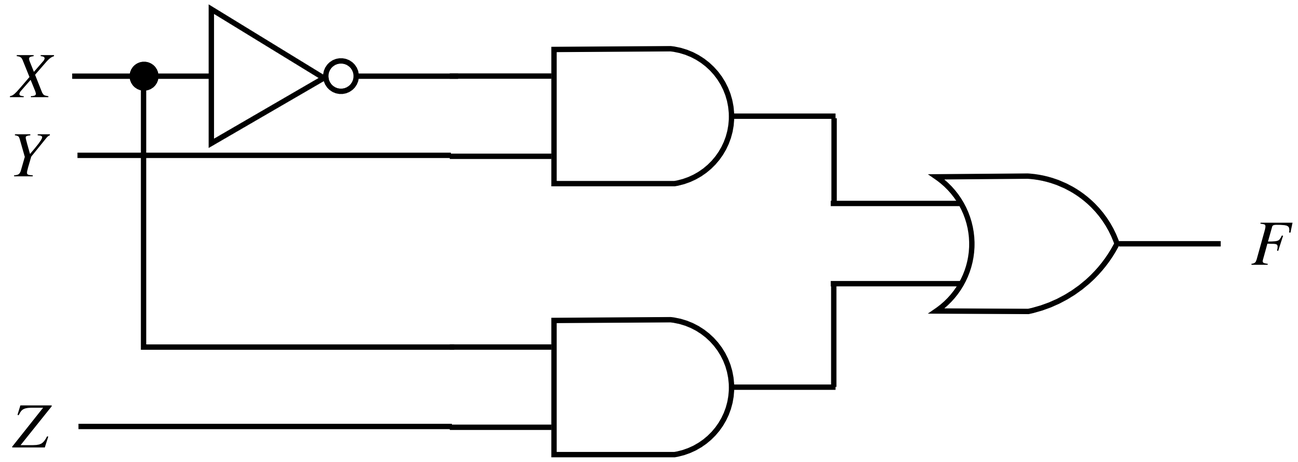


Example

Simulation 2

Truth Table

X	Y	Z	$F = (\overline{X}Y) + (XZ)$
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

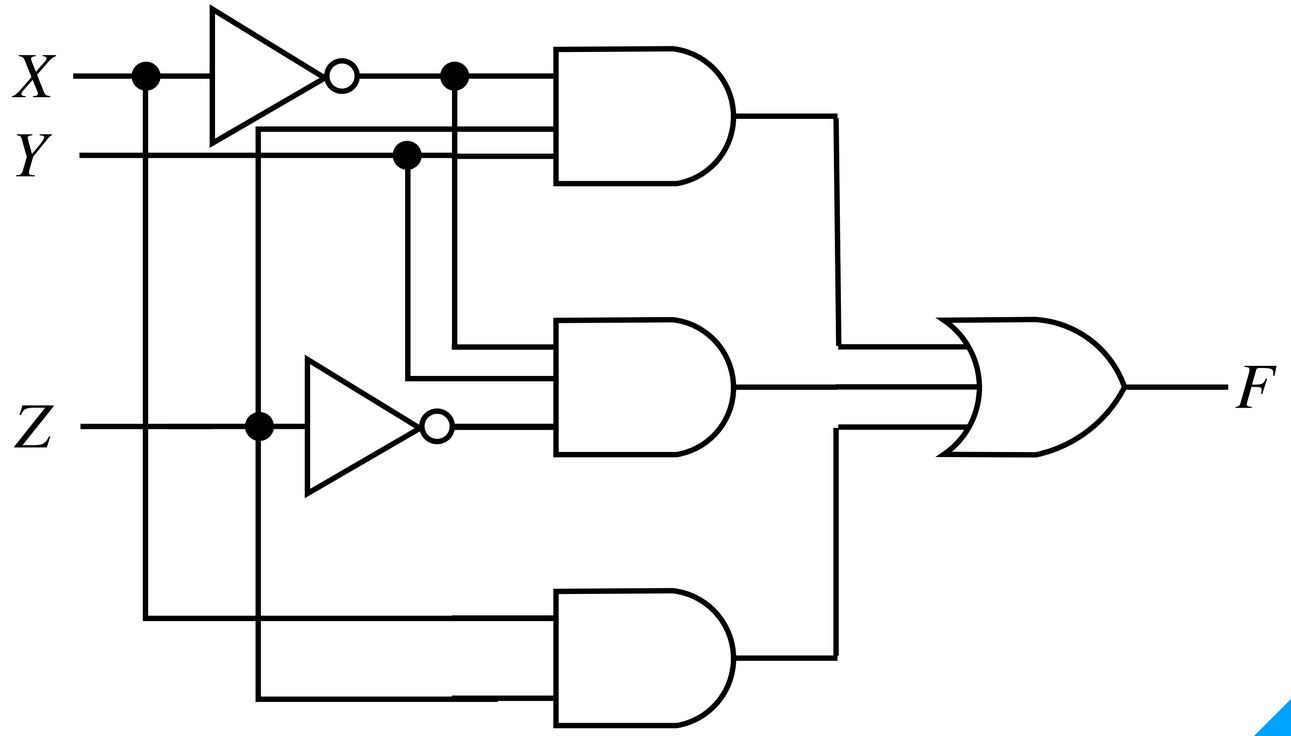


Example

Simulation 3

Truth Table

X	Y	Z	$F = \bar{X}YZ + \bar{X}Y\bar{Z} + XZ$
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	



Example

Summary

- AND, OR, NOT Operators
- Logic Gates
- Timing diagram
- Truth Table
- Gate Delay

Review

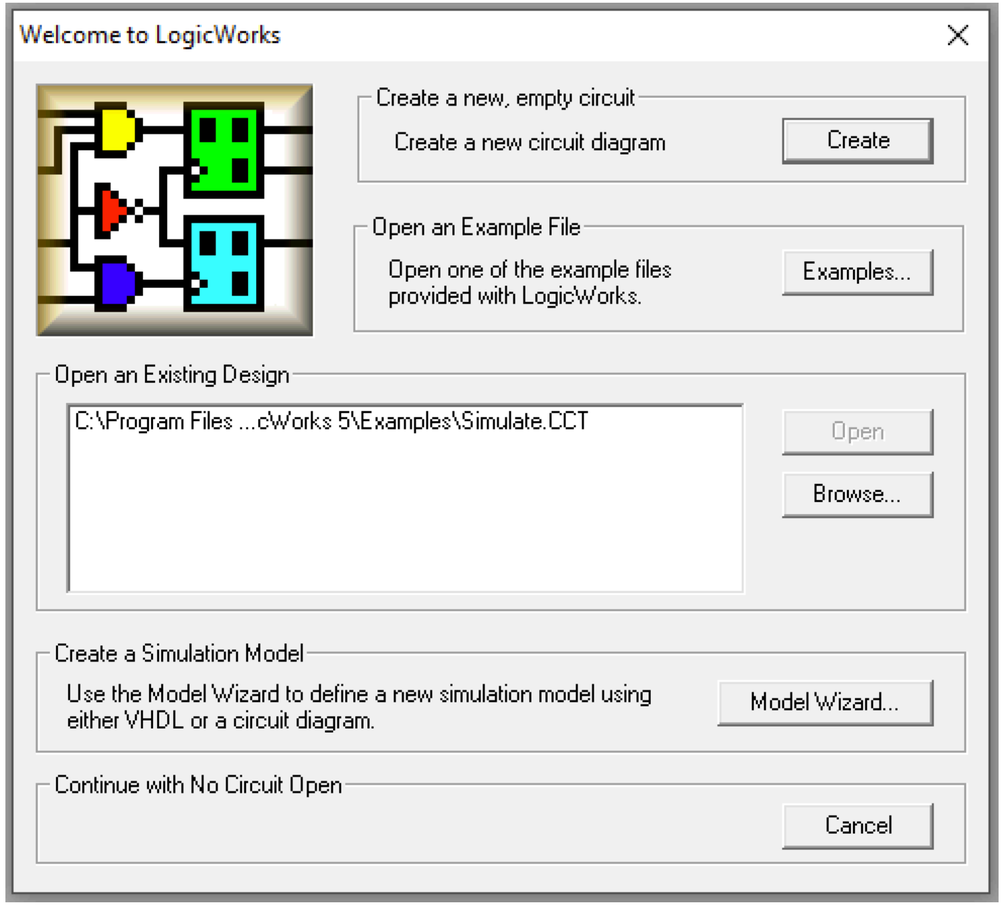
P2
Tutorial

LogicWorks

Fire up your computer please!

Summary

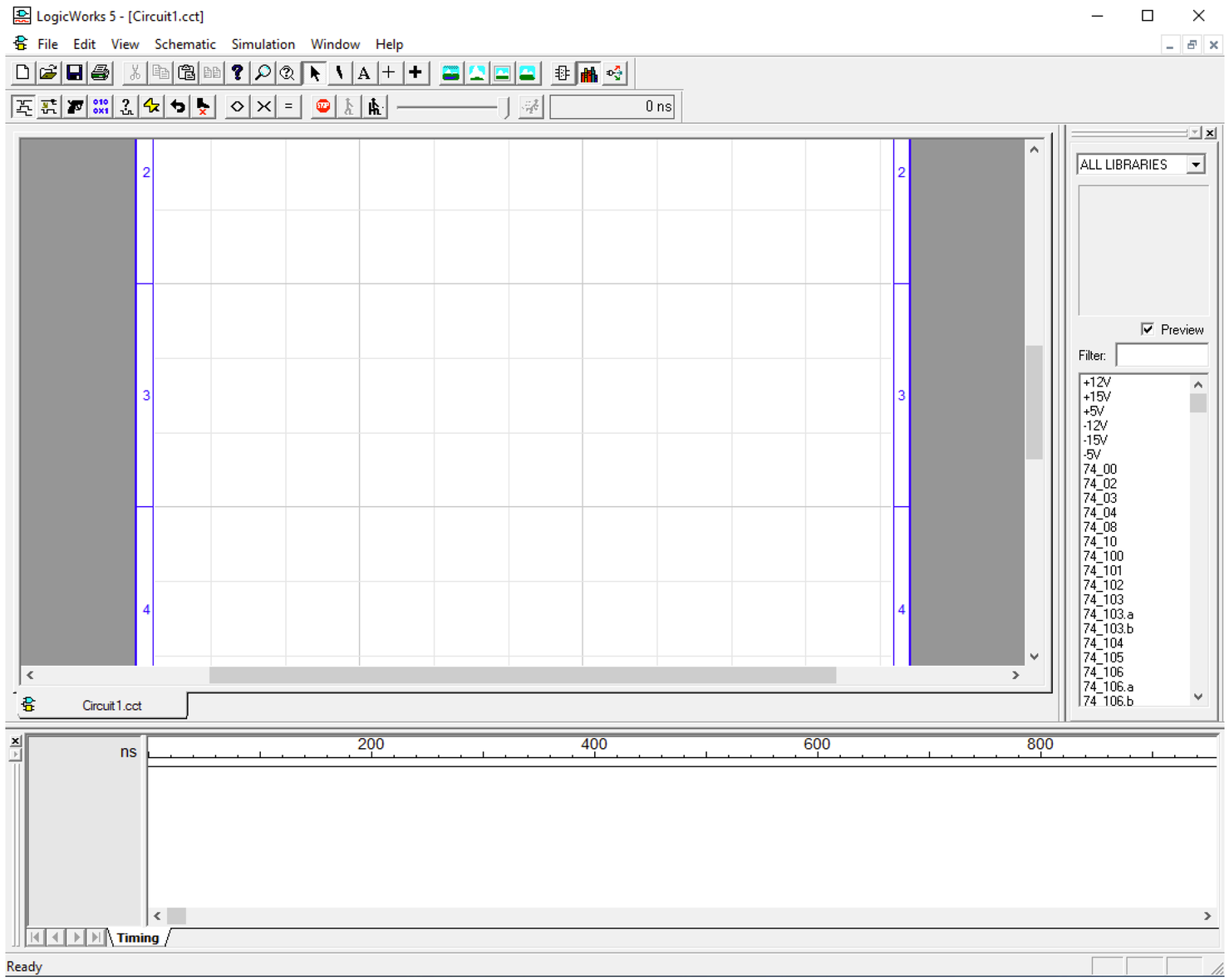
P2
Tutorial



1. Open LogicWorks, **Create** new circuit diagram

Demo

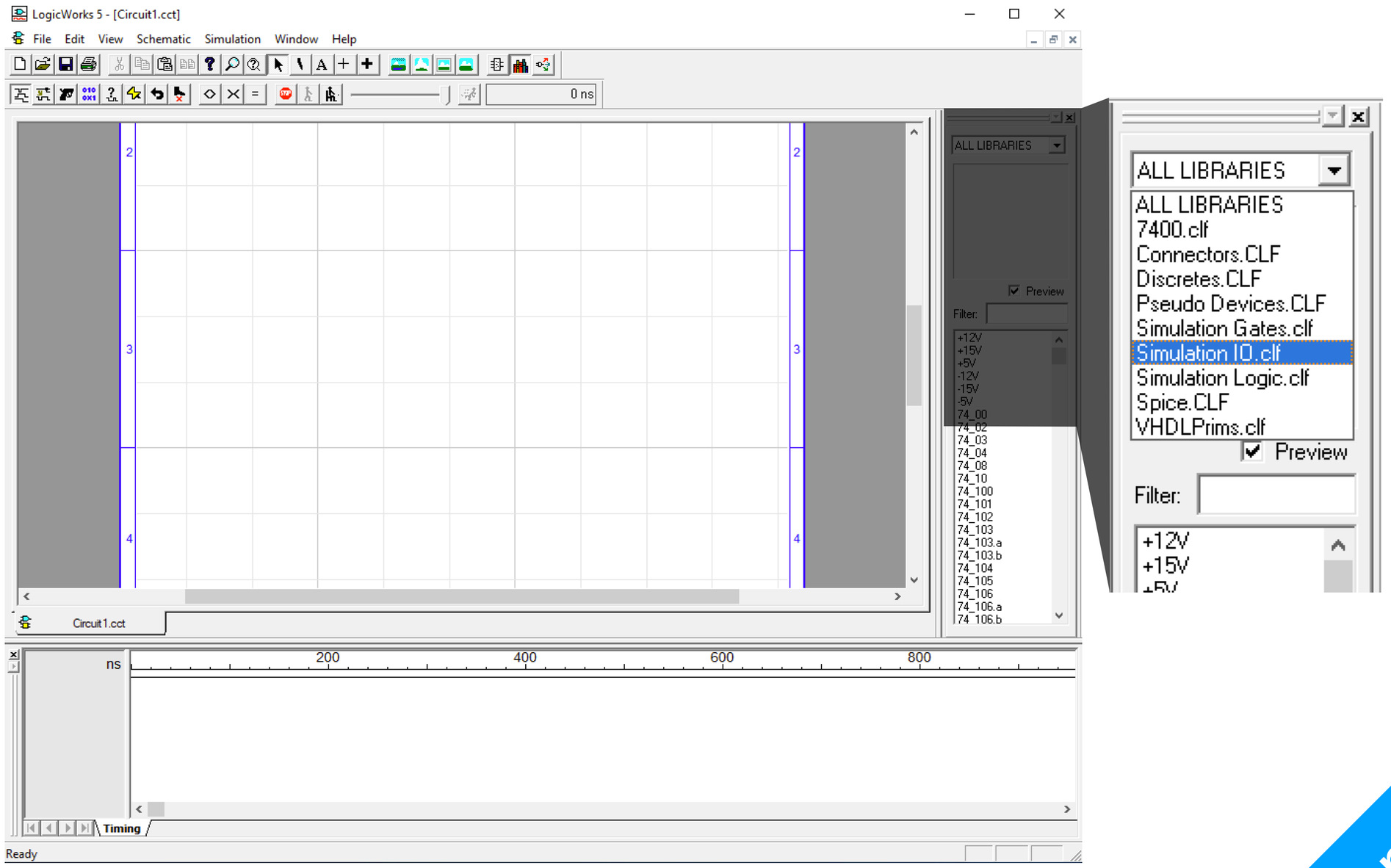
P2
Tutorial



1. This is the main interface

Technical

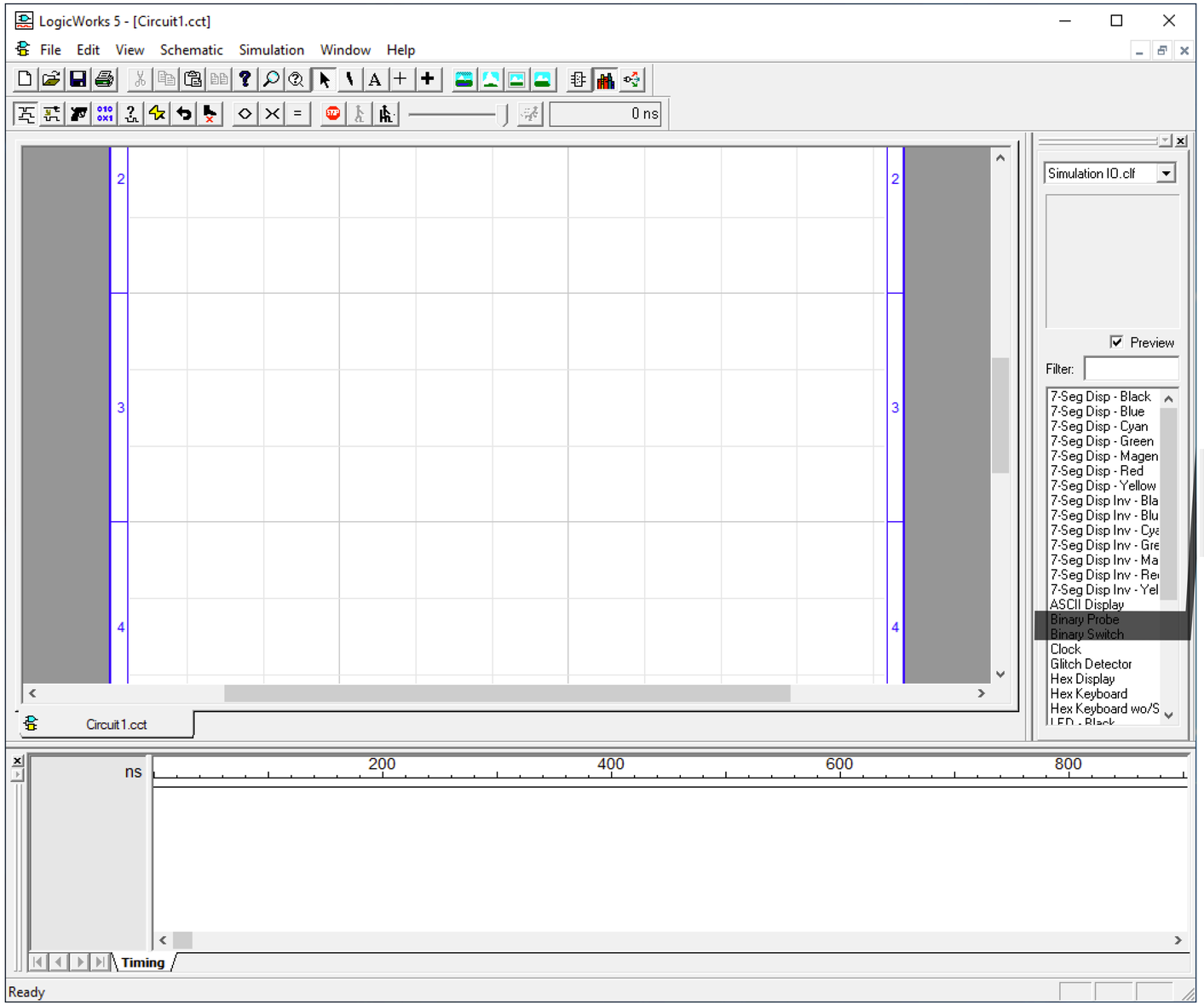
P2
Tutorial

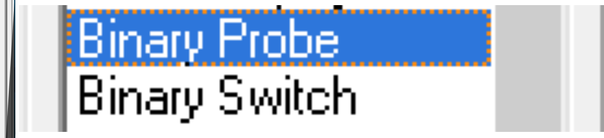


1. Select **Simulation IO** from the **Parts Palette**

Technical

P2
Tutorial

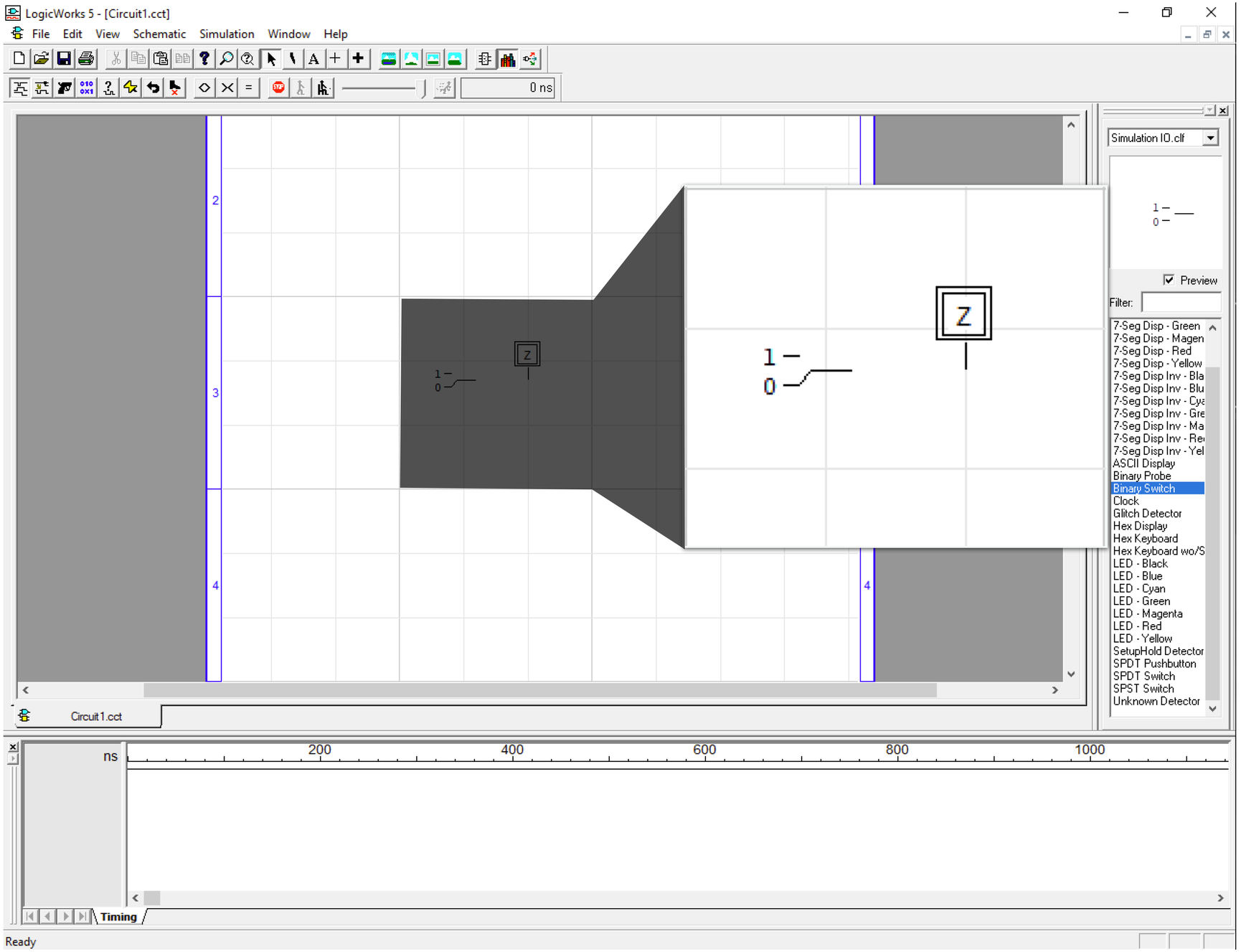




1. Pay Attention to **Binary Probe** and **Binary Switch**

Technical

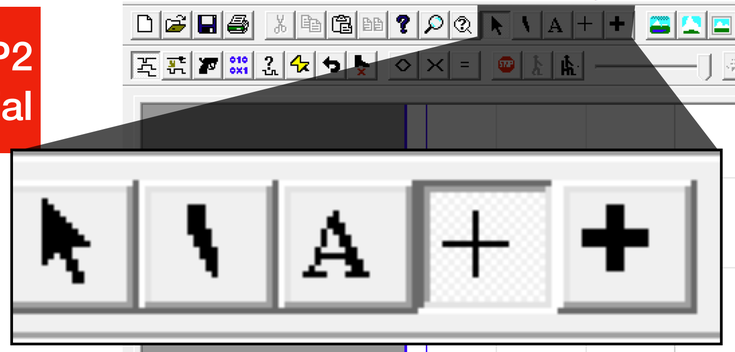
P2
Tutorial



1. Double click and place one of each on the main board

Technical

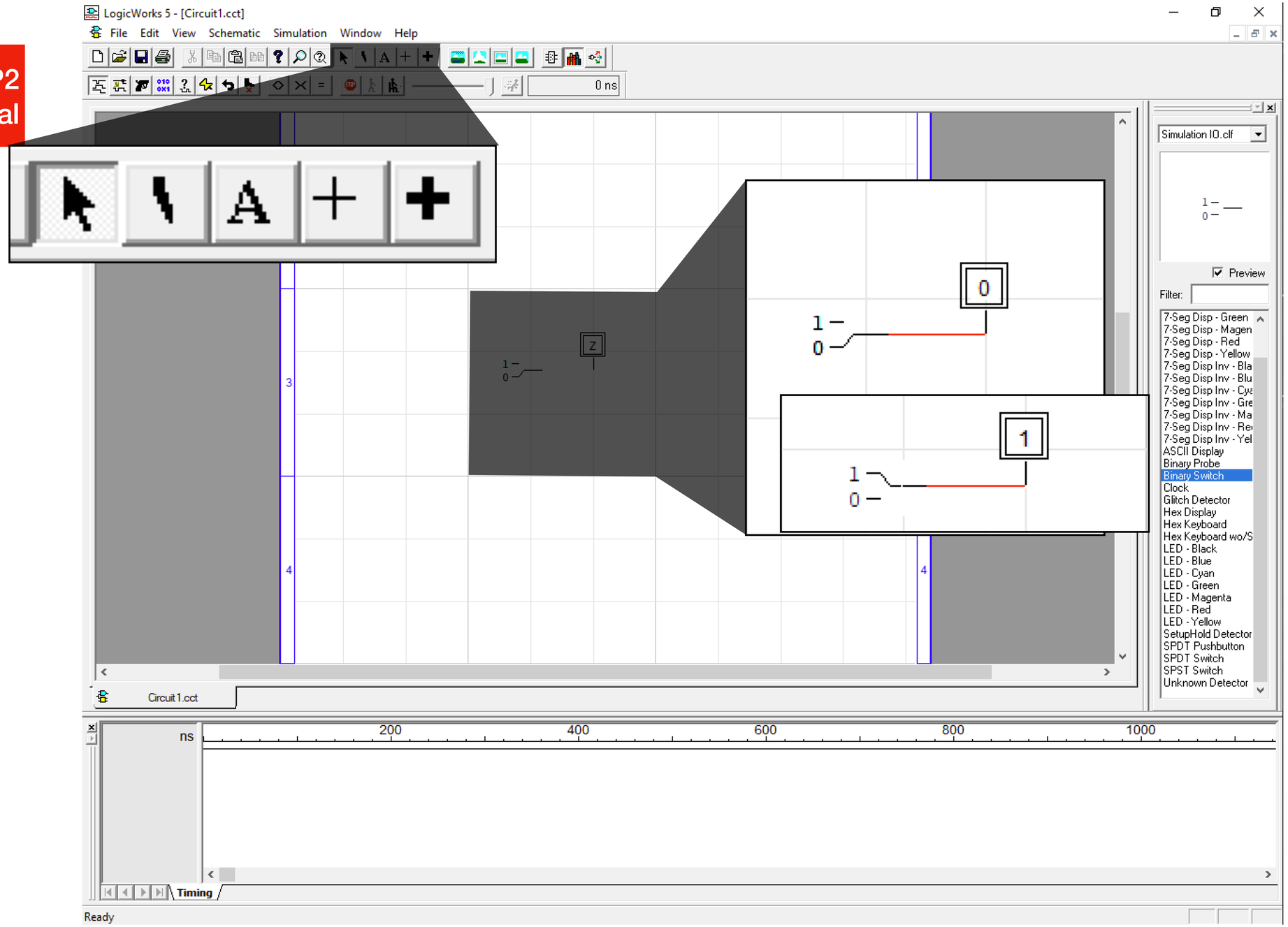
P2
Tutorial



1. Use the 'Draw Signal' tool to connect the two parts

Technical

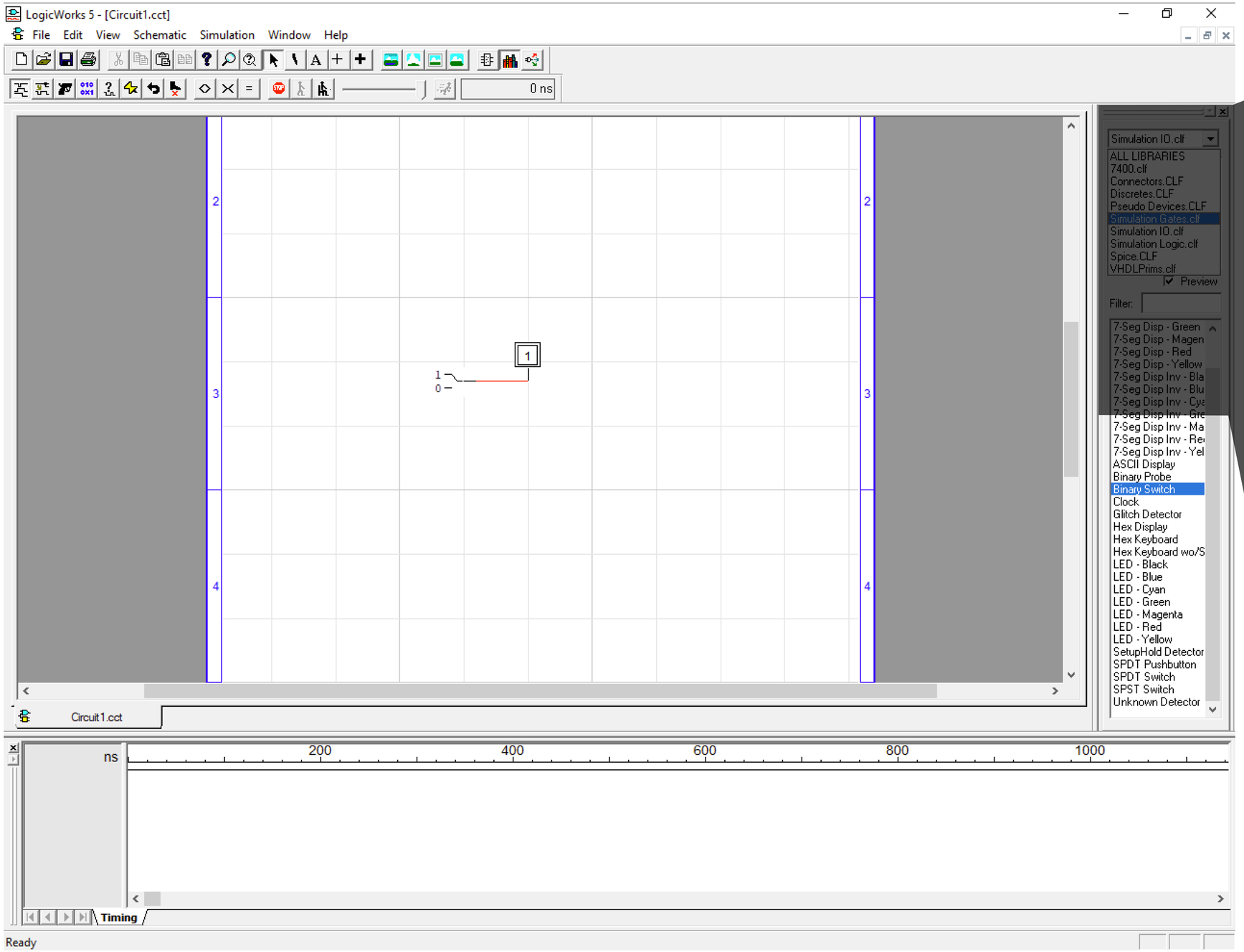
P2
Tutorial



1. Switch back to the **Cursor** mode, now click on the switch and you can change the signal value

Technical

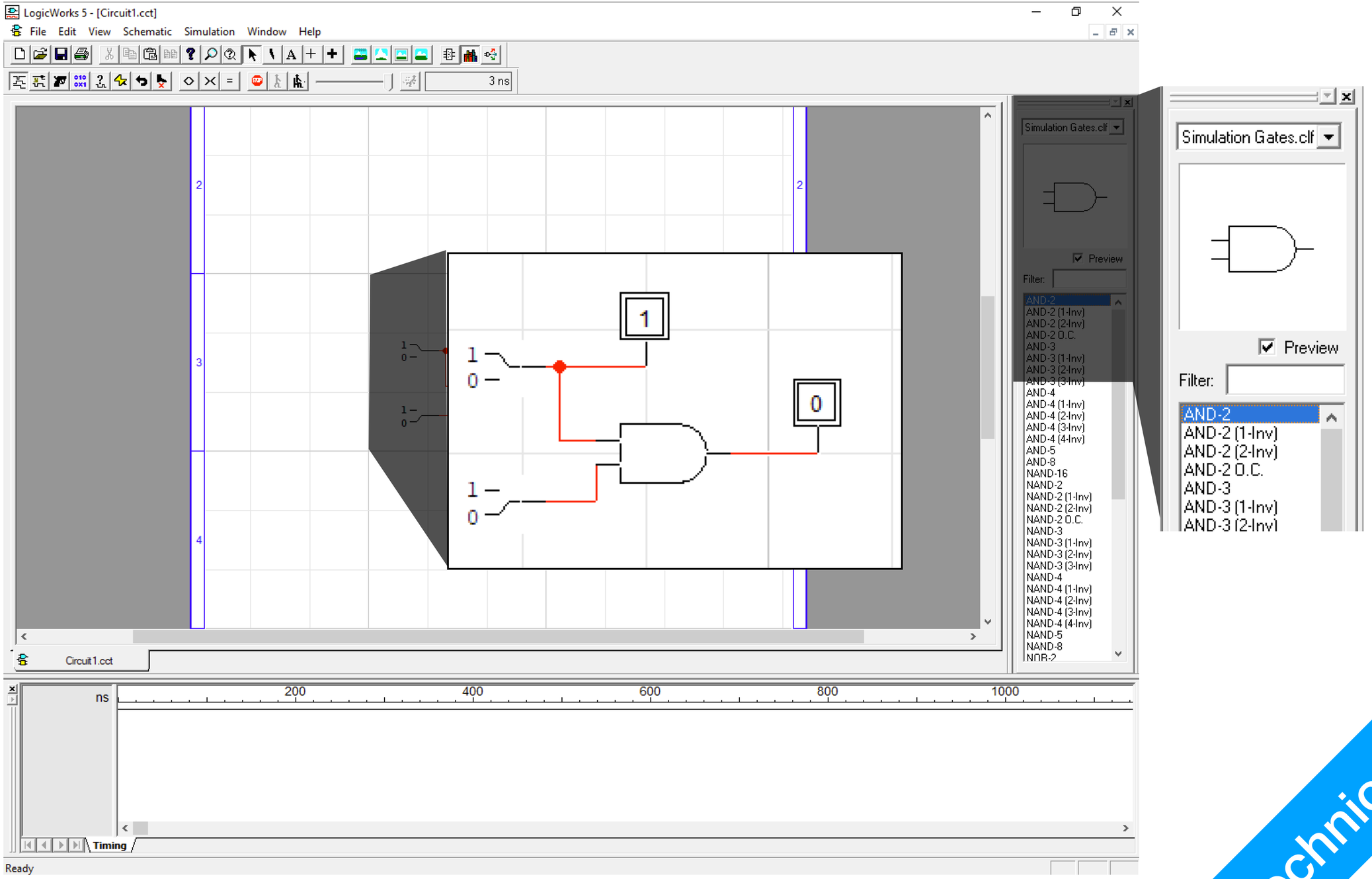
P2
Tutorial



1. Select **Simulation Gates**

Technical

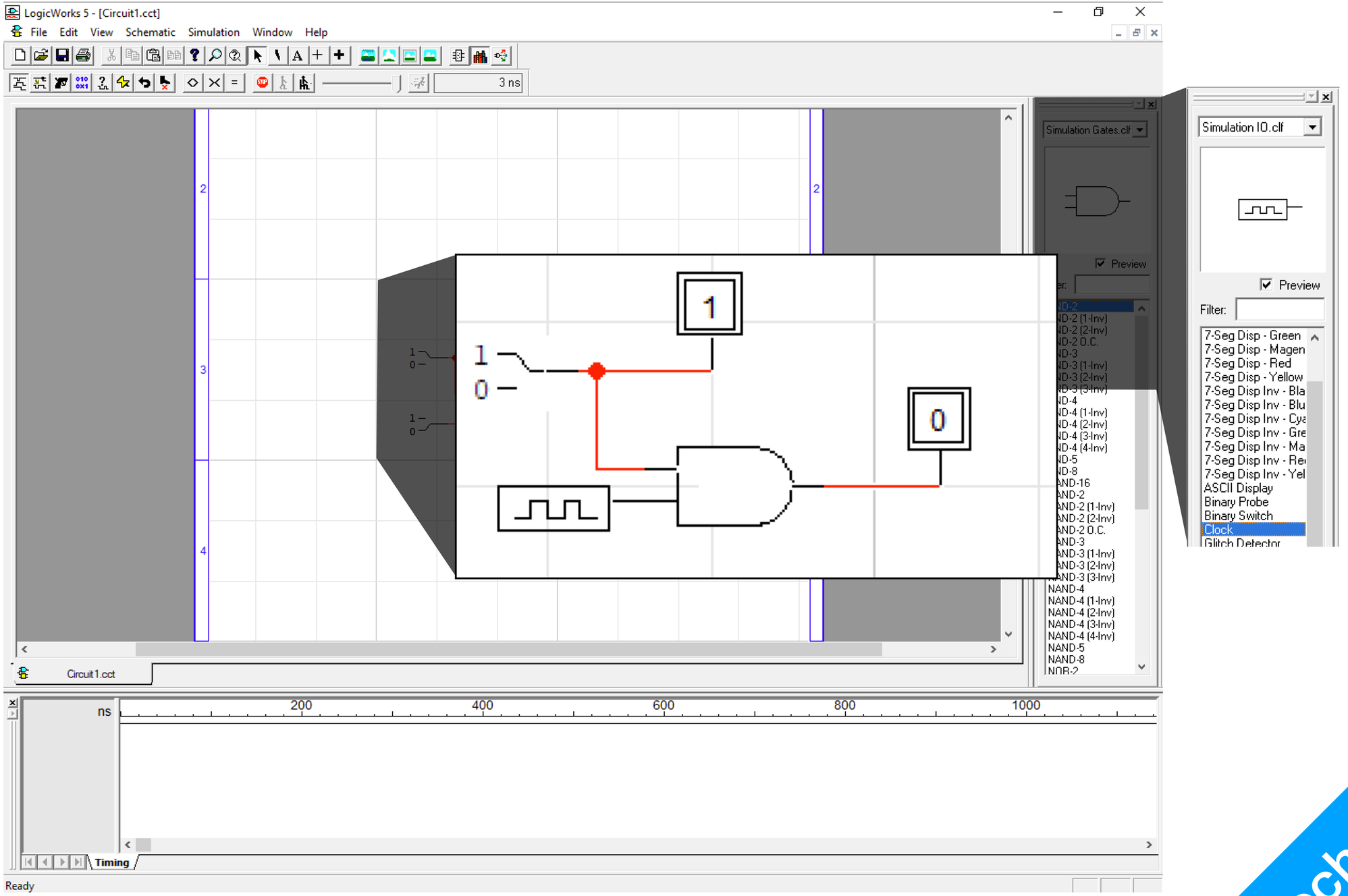
P2
Tutorial



1. Select **AND-2**, then complete the above diagram

Technical

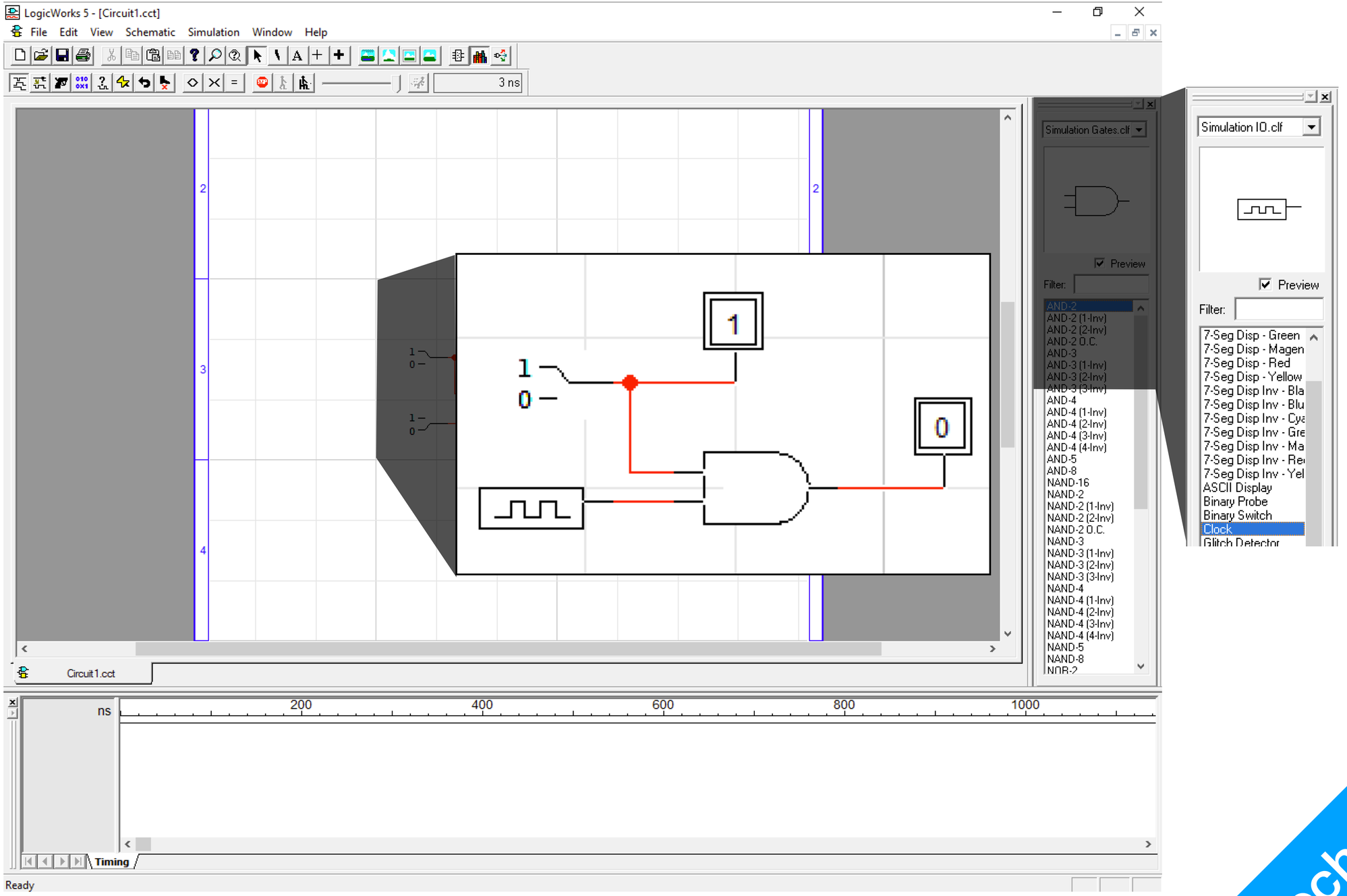
P2
Tutorial



1. Select **Clock** from **Simulation IO**, then replace the lower **Binary Switch** with it. A **Clock** is a device that generates a **1** at a certain frequency

Technical

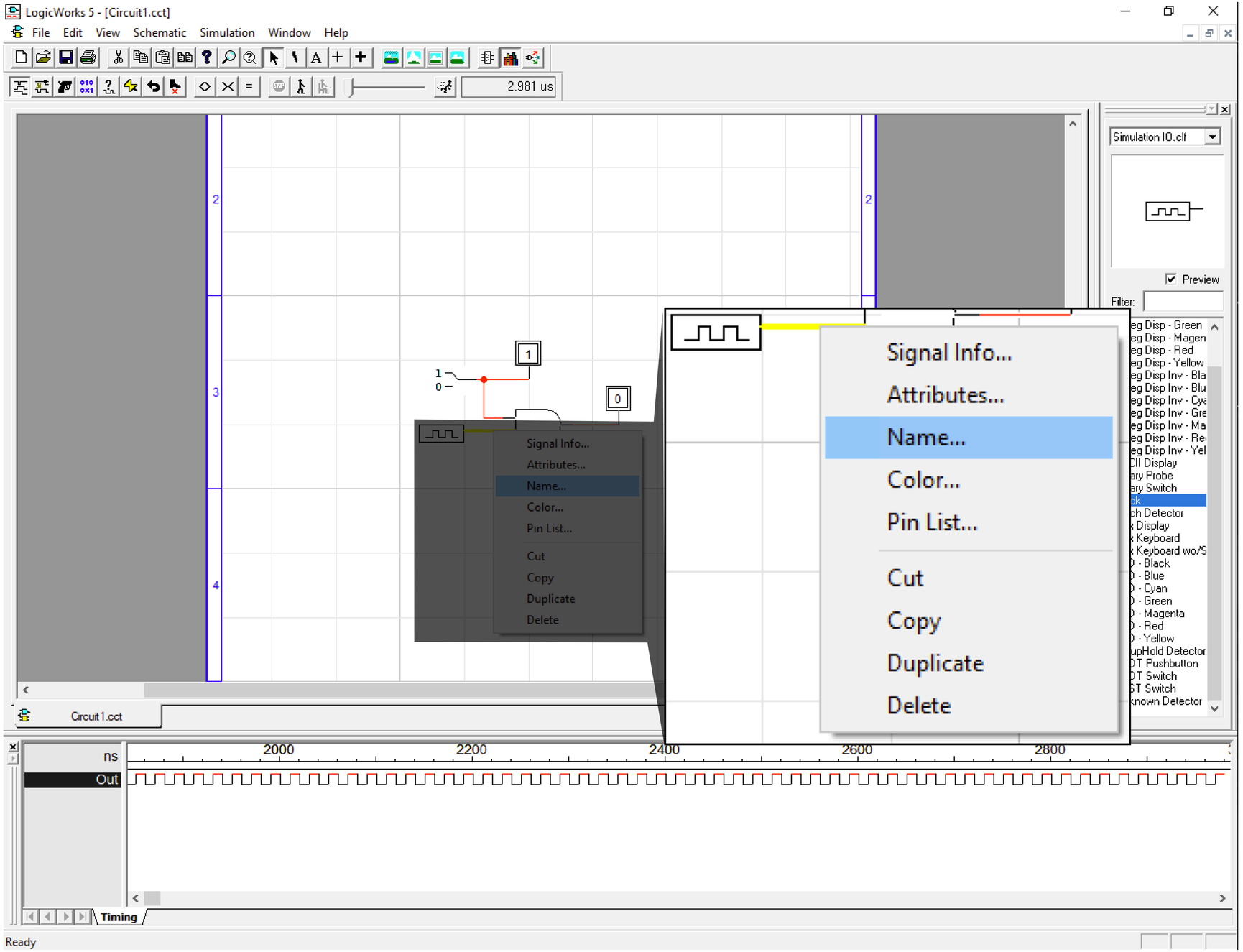
P2
Tutorial



1. Select **Clock** from **Simulation IO**, then replace the lower **Binary Switch** with it

Technical

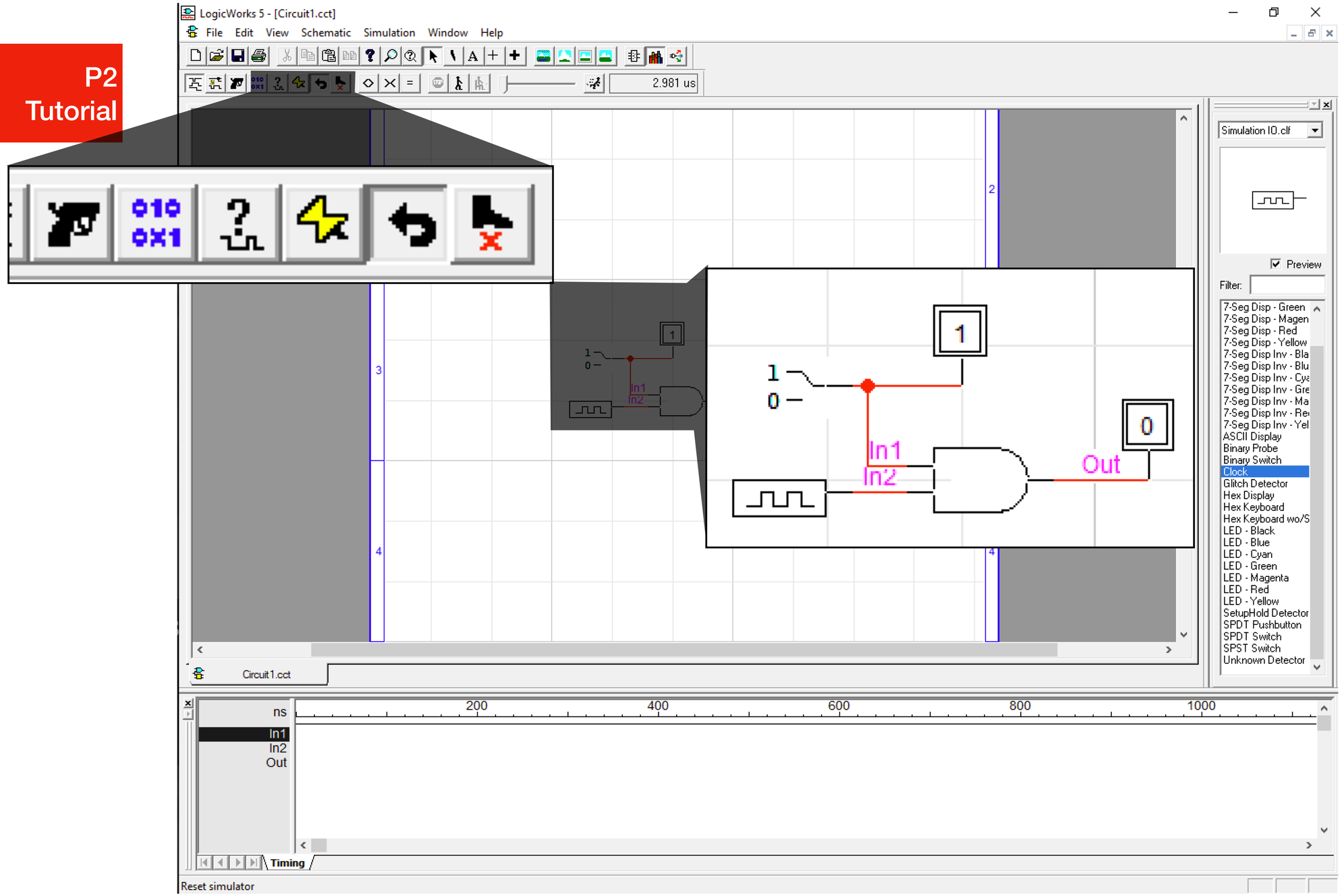
P2
Tutorial



1. Right click the **Red Wire**, select **Name**

Technical

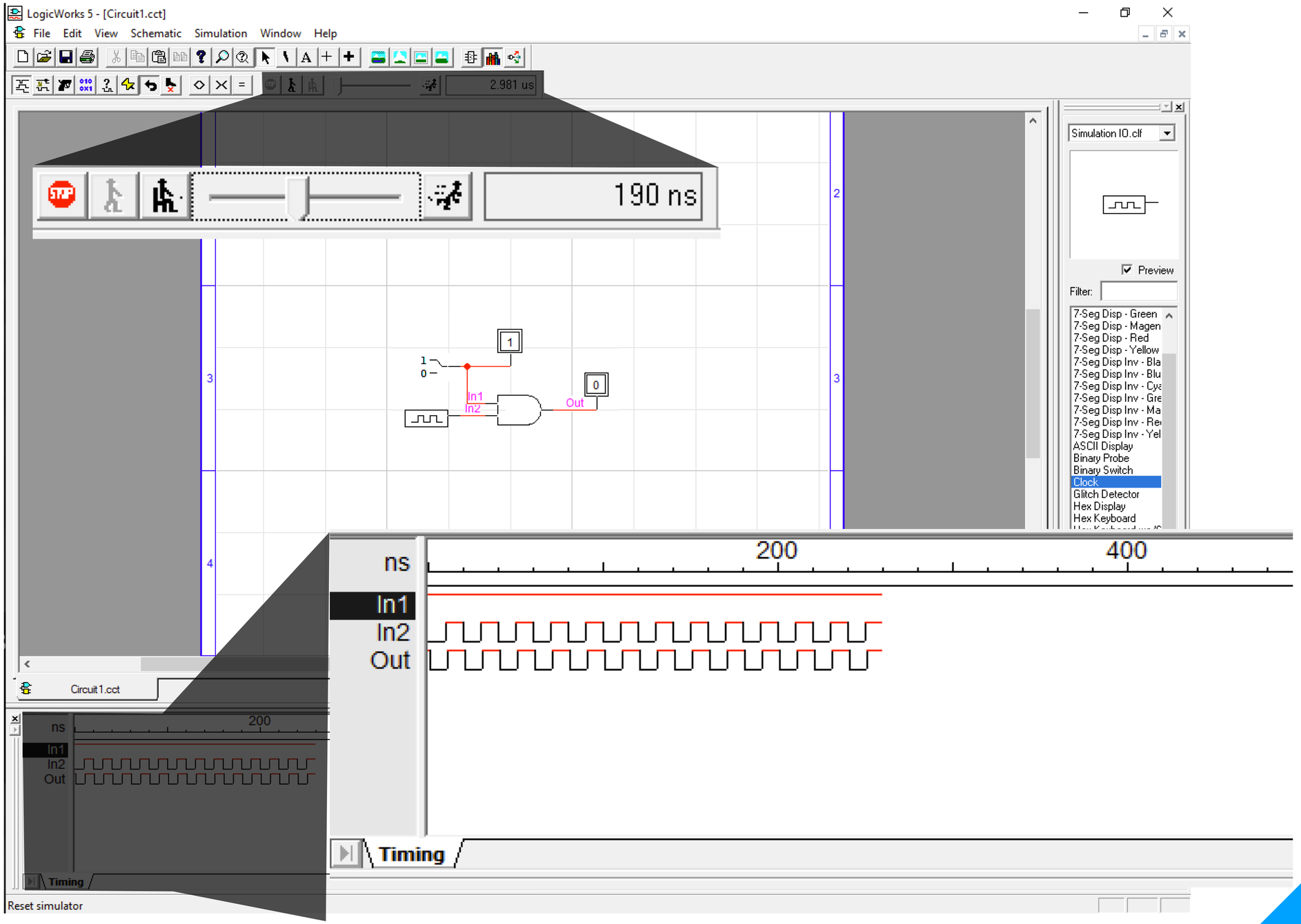
P2
Tutorial



1. Complete the diagram like above, then click **Reset Simulation**

Technical

P2
Tutorial



1. Use the **Simulation Panel** to control the speed of simulation, then you will see the **Timing Diagram**!

Technical

P2
Tutorial

Exe 1

- Curtain Motor Control
  - Button1: 1 when user wants to open the curtain
  - Button2: 1 when user wants to close the curtain
  - Output1: 1 to make the motor open the curtain
  - Output2: 1 to make the motor close the curtain
  - Light: motor is active

- When both buttons are pressed, motors do nothing

Exercise

P2
Tutorial

Exe 2

- Curtain Motor Control
  - **Sensor1: 1 when curtain is fully closed**
  - **Sensor2: 1 when curtain is fully open**
  - Button1: 1 when user wants to open the curtain
  - Button2: 1 when user wants to close the curtain
  - Output1: 1 to make the motor open the curtain
  - Output2: 1 to make the motor close the curtain
  - Light: motor is active

- Stop the motor when the curtain is already fully opened/ closed

Exercise

P2
Tutorial

Summary

- Simulation in LogicWorks
- Binary Probe / Binary Switch in LogicWorks
- Gates in LogicWorks
- Clocks in LogicWorks
- Timing Diagram in LogicWorks

Review