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

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2020 Summer Semester (S2)

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

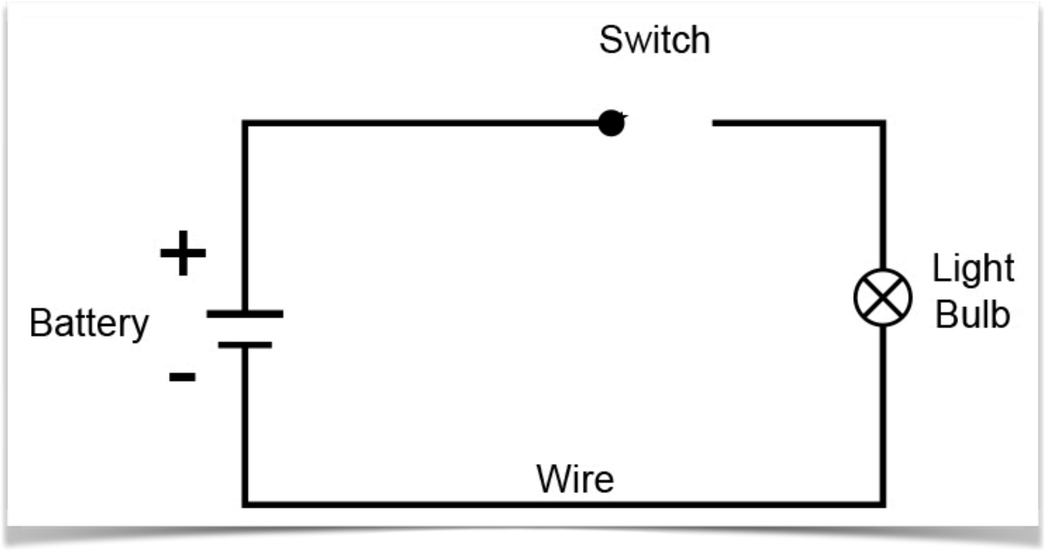
What is a Logic Gate?

- 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

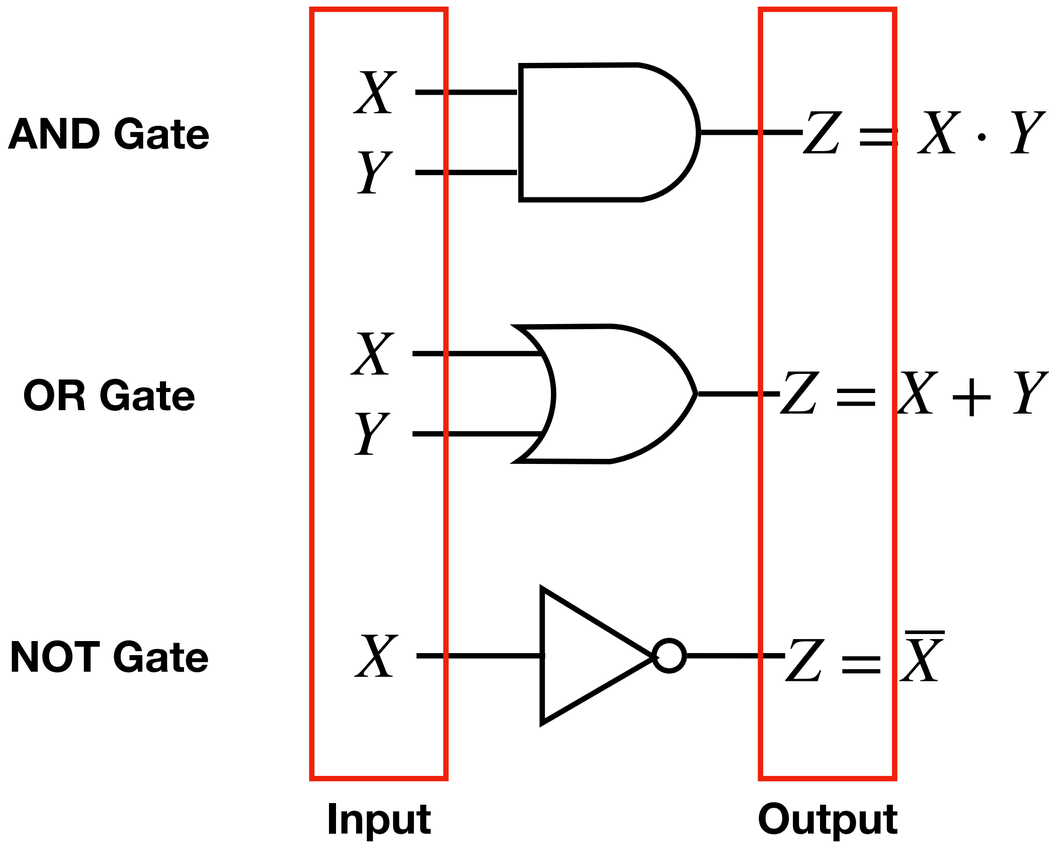
What is a Logic Gate?

- 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.



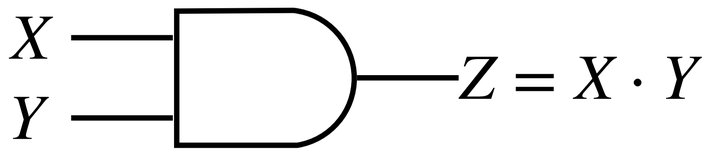
Concept

First 3 Gates



Concept

AND Operator and Boolean Algebra / Binary Logic

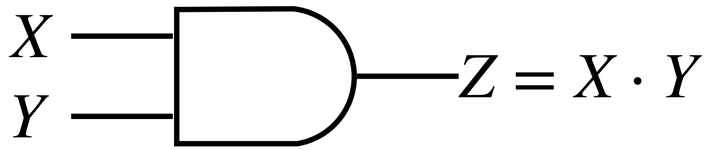


- Boolean Algebra
  - Each variable can only have one of two values:
    - TRUE/ON/1
    - False/OFF/0
- AND: Z is equal to X AND Y
  - Operator: $\cdot$ (`\cdot`)

Concept

P1
Logic Gates

AND Operator and Boolean Algebra



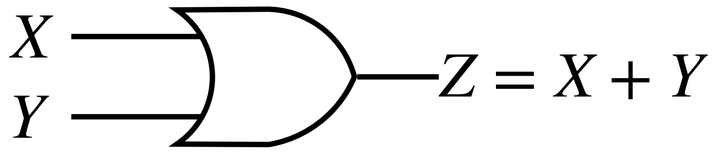
AND Truth Table

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



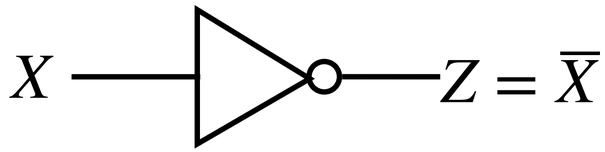
OR Truth Table

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!

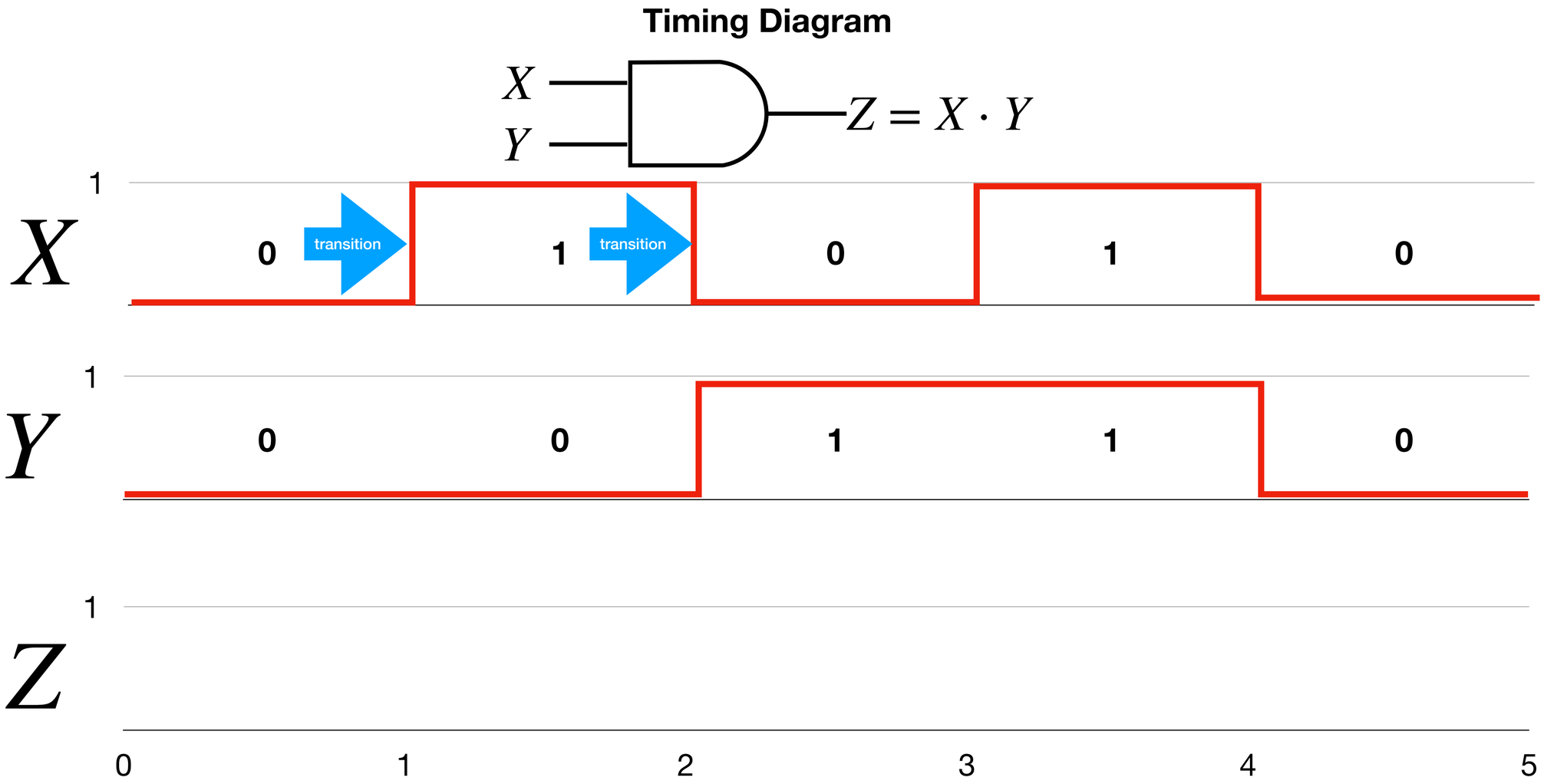
Concept

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

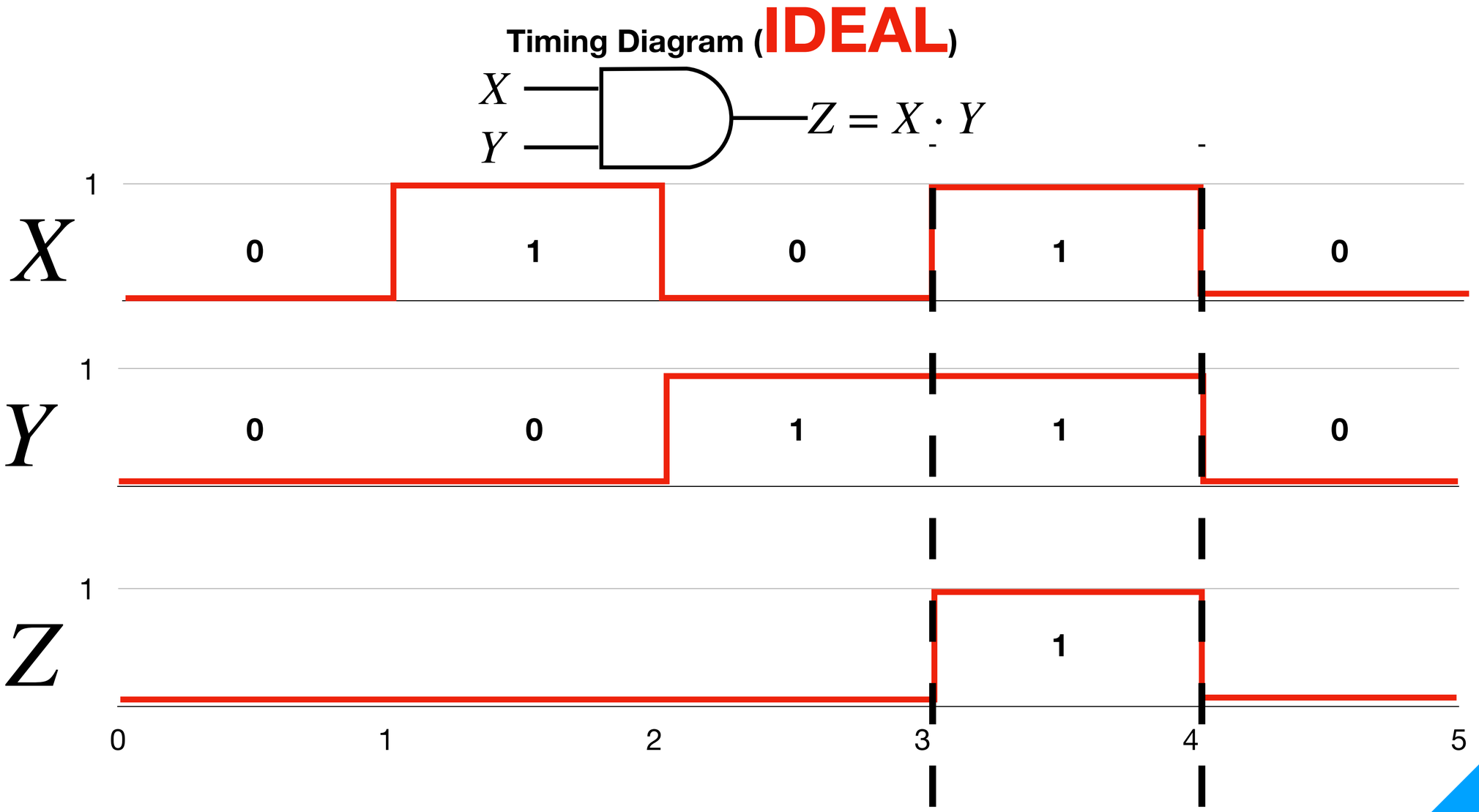


Technical

P1
Logic Gates

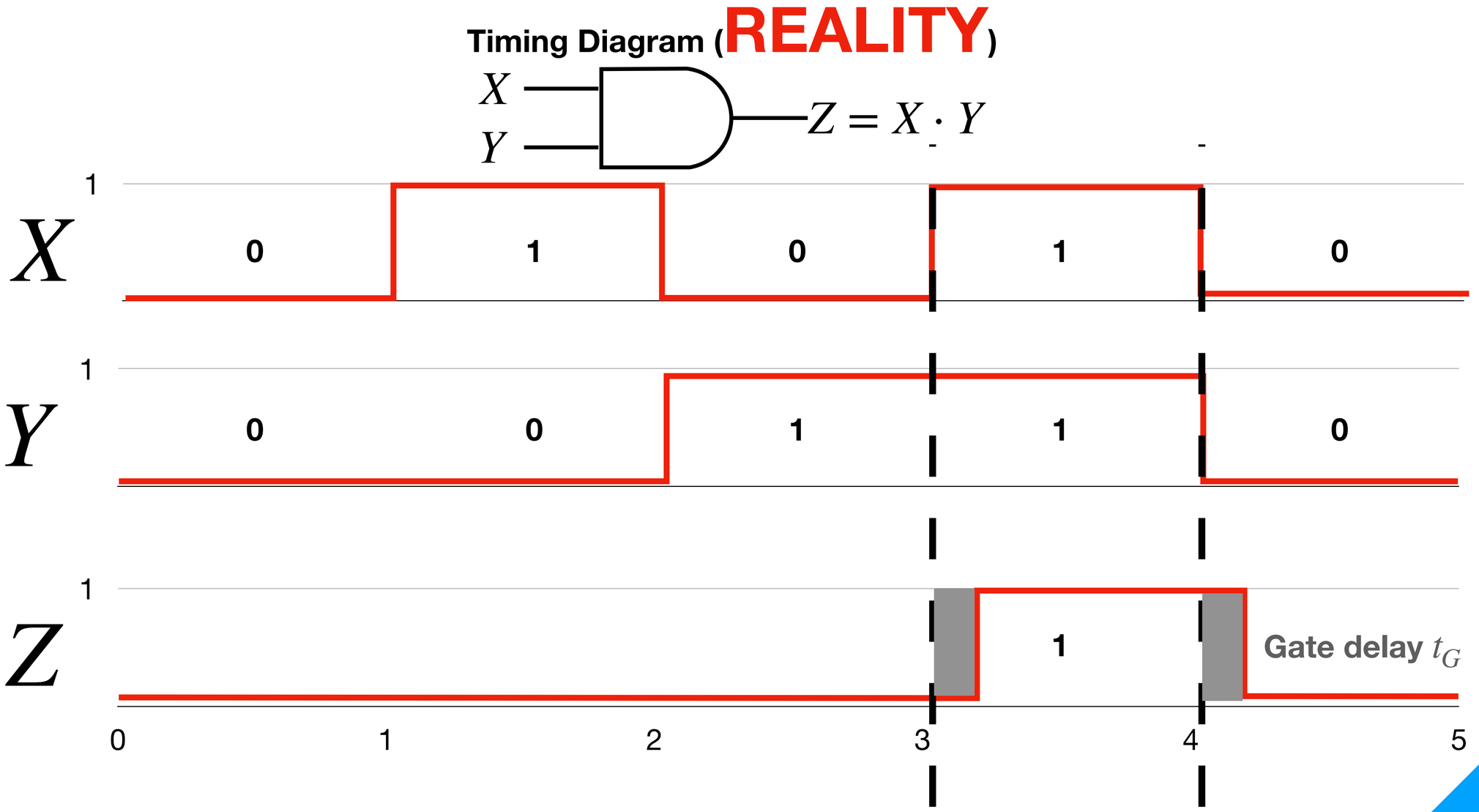
Digital Logical Gates

Timing Diagram (IDEAL)



Technical

Digital Logical Gates



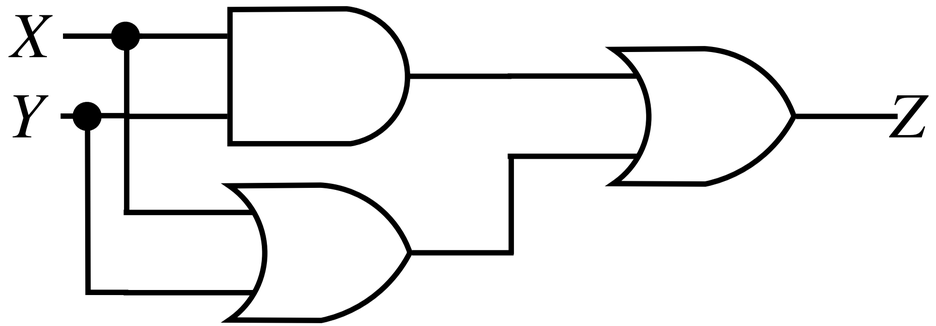
Gate Delay

- 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	



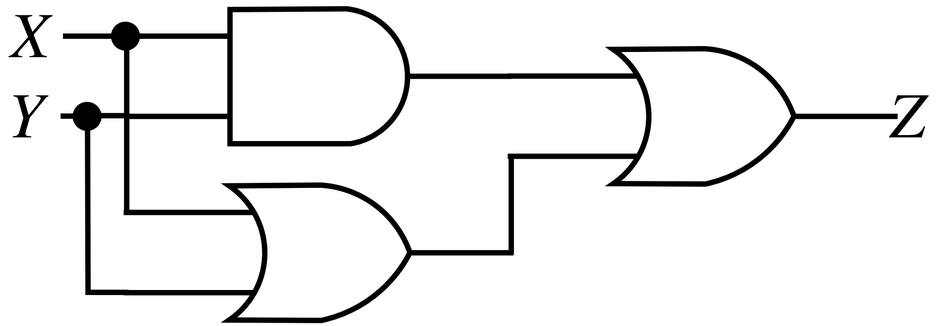
Example

P1
Logic Gates

Simulation 1

Truth Table

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

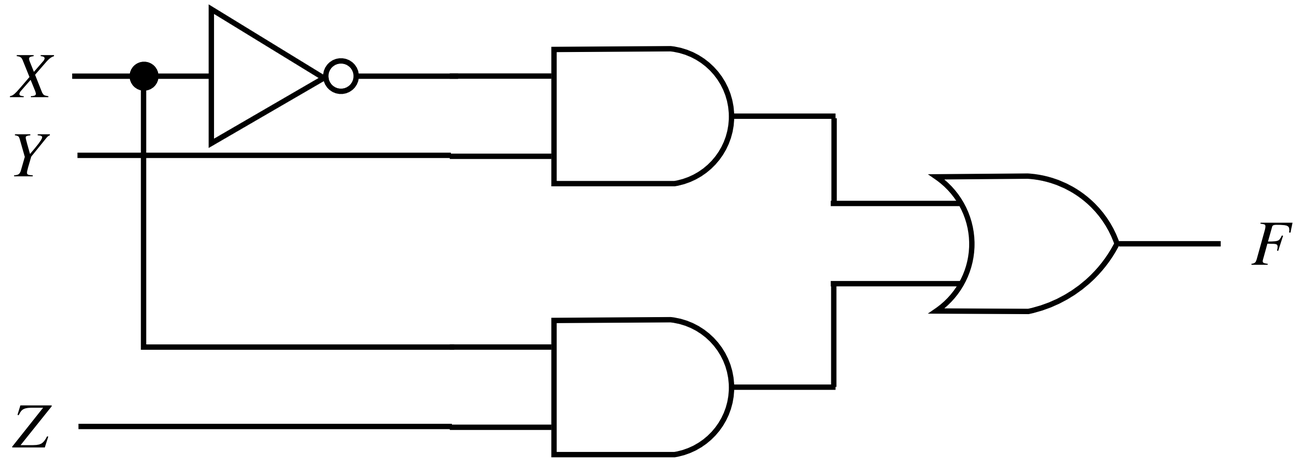


Example

Simulation 2

Truth Table

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

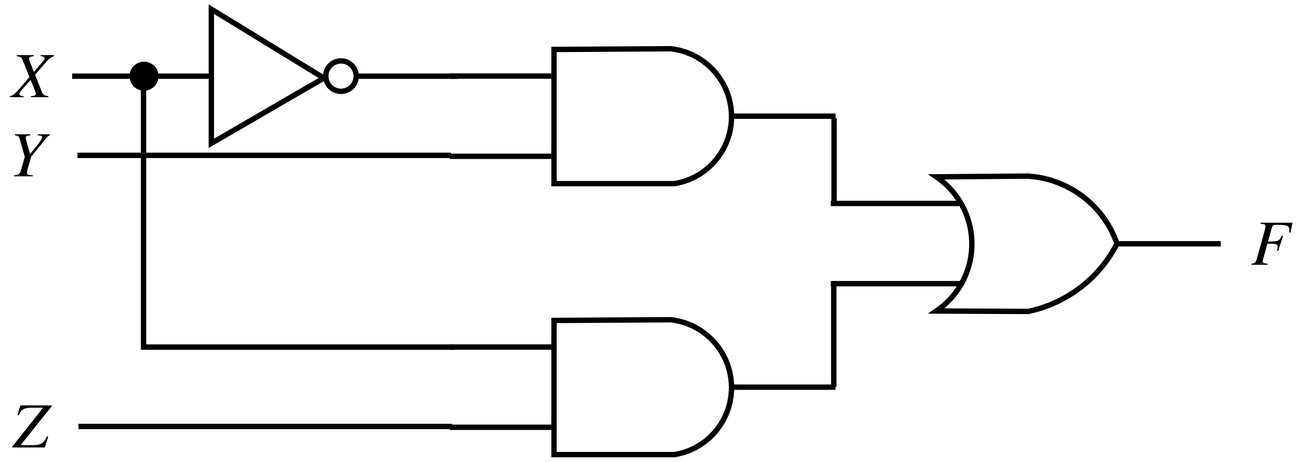


Example

Simulation 2

Truth Table

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

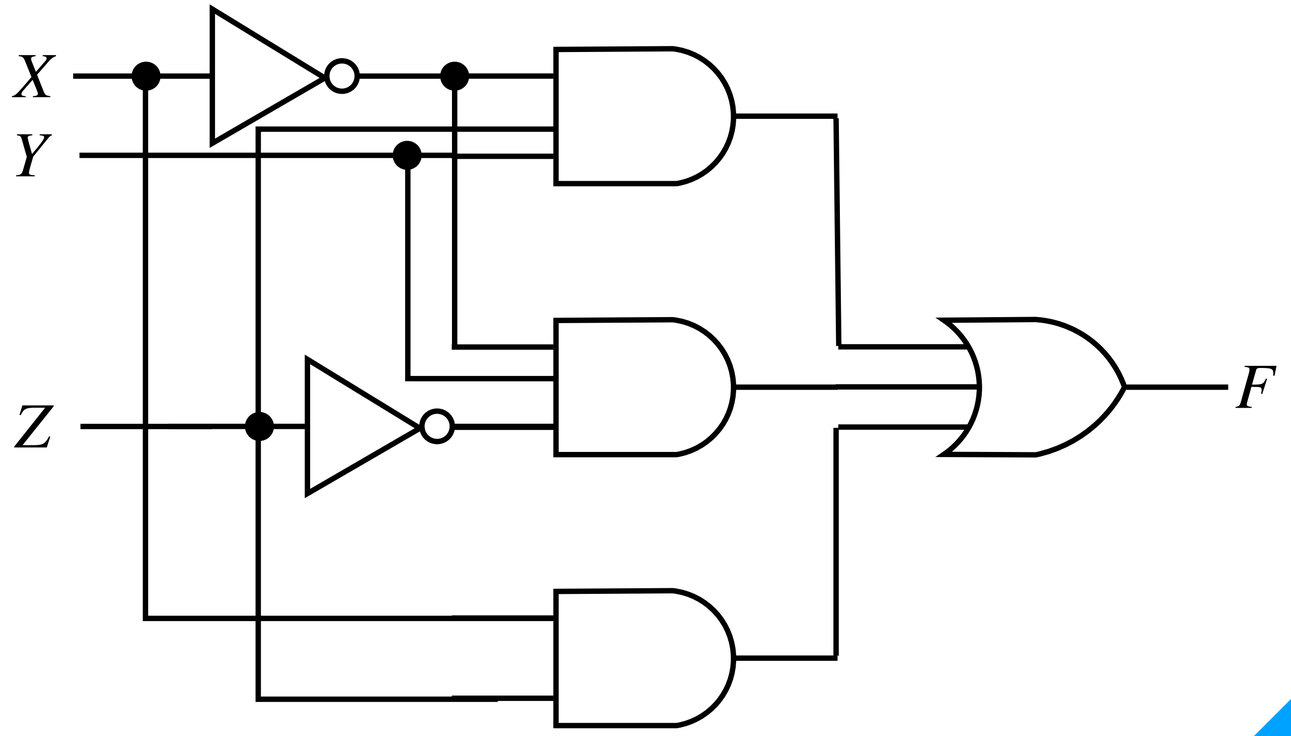


Example

Simulation 3

Truth Table

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

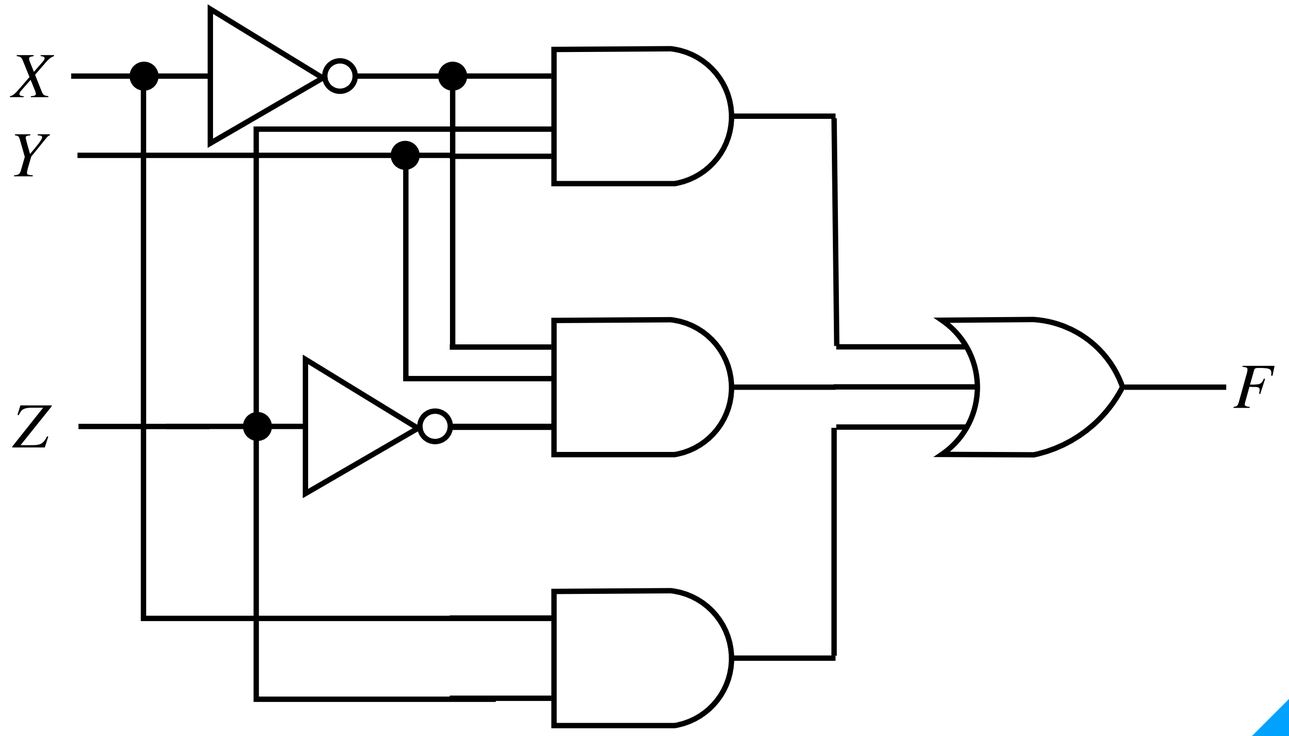


Example

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
1	0	0	0
1	1	0	0
0	0	1	0
0	1	1	1
1	0	1	1
1	1	1	1



Example

Summary

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

Review

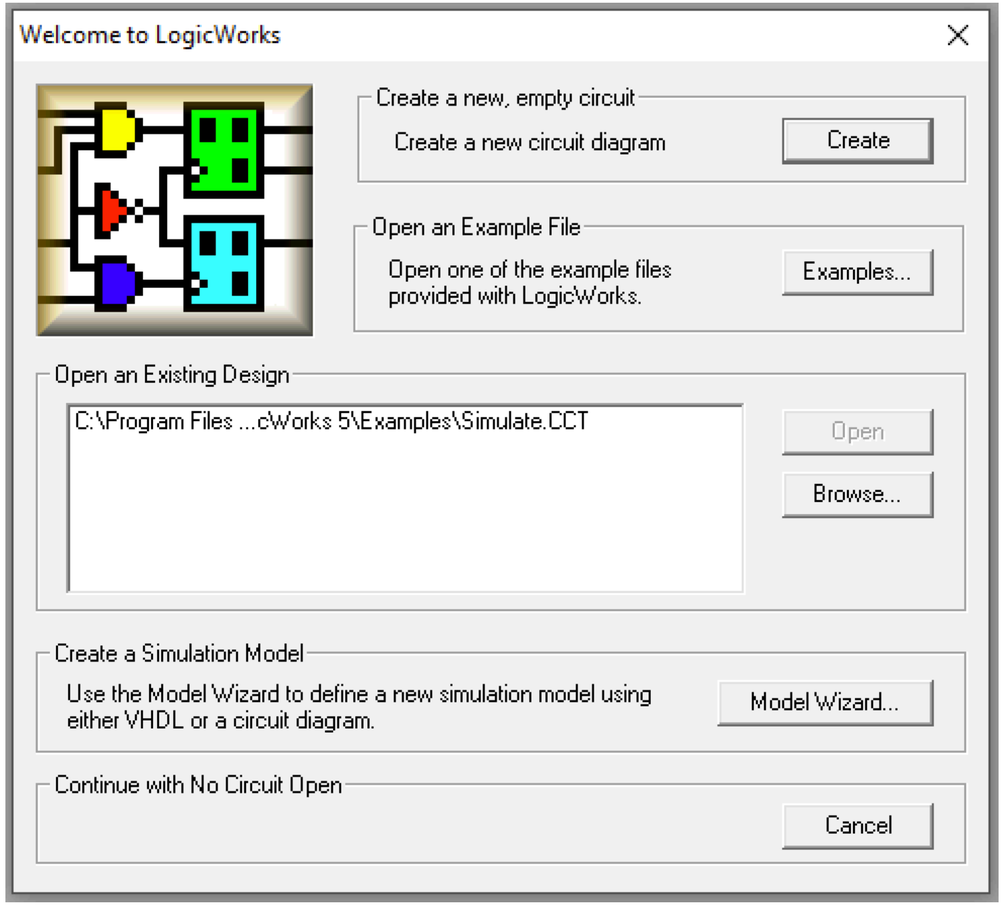
P2
Tutorial

LogicWorks

Fire up your computer please!

Summary

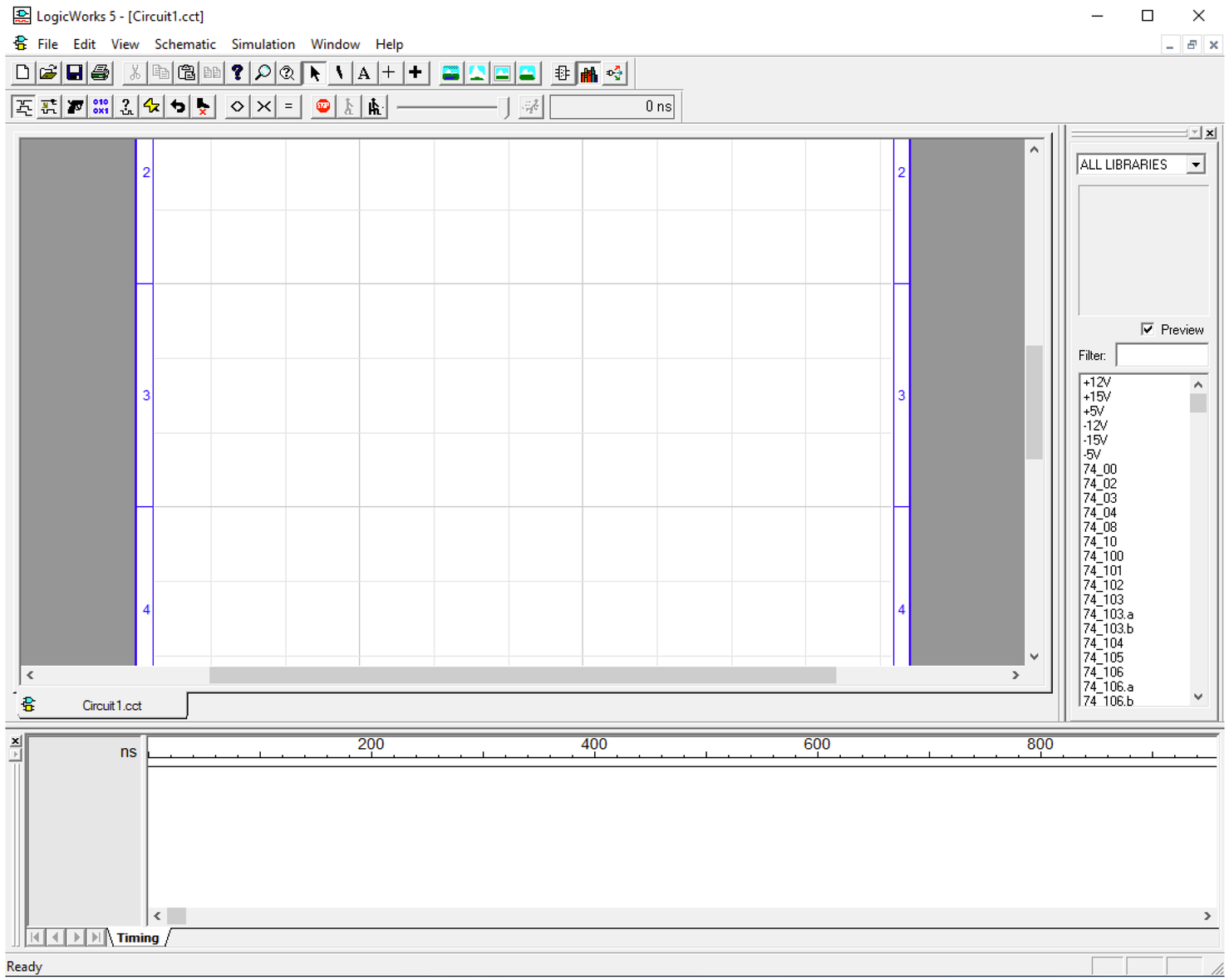
P2
Tutorial



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

Demo

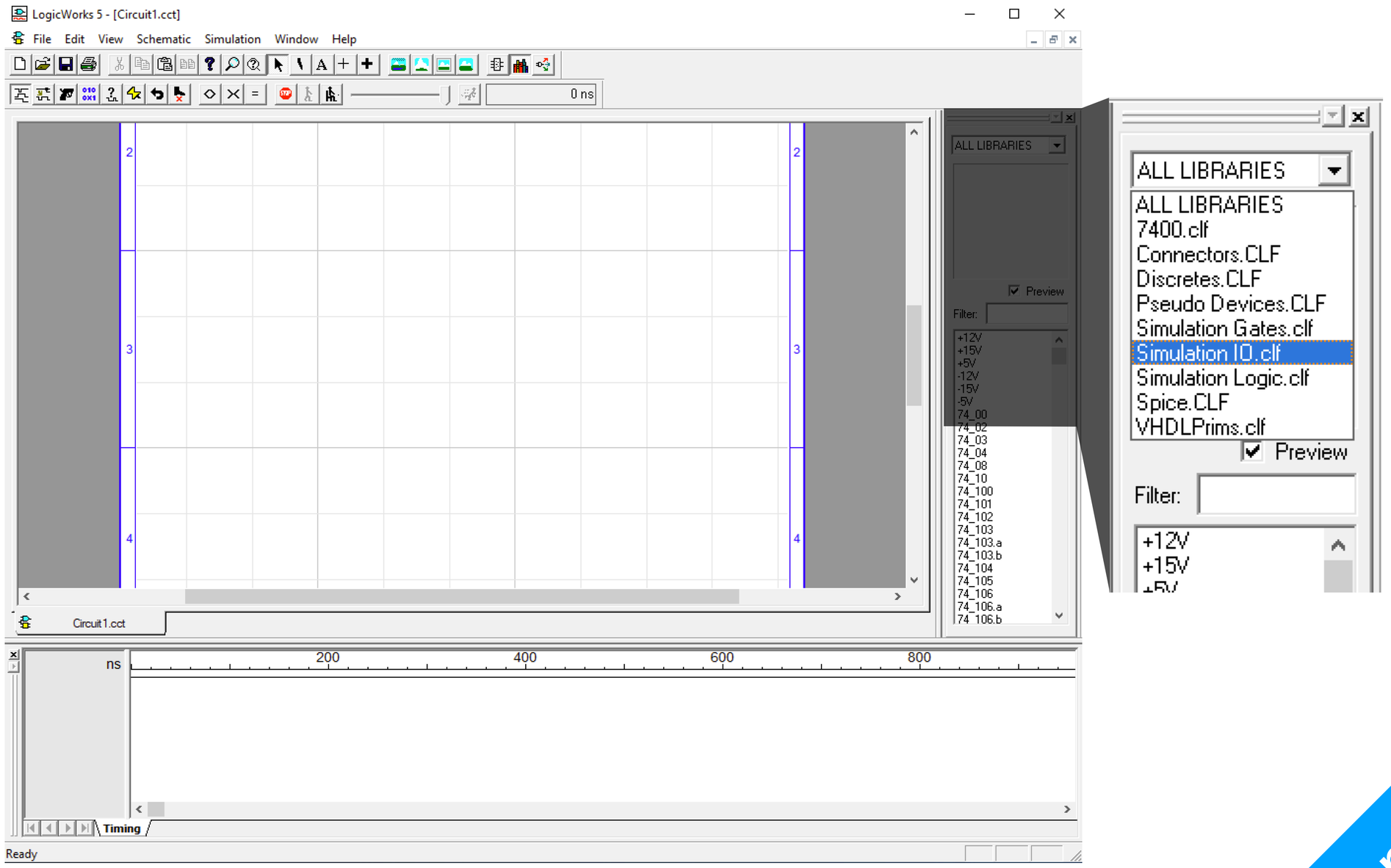
P2
Tutorial



1. This is the main interface

Technical

P2
Tutorial



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

Technical

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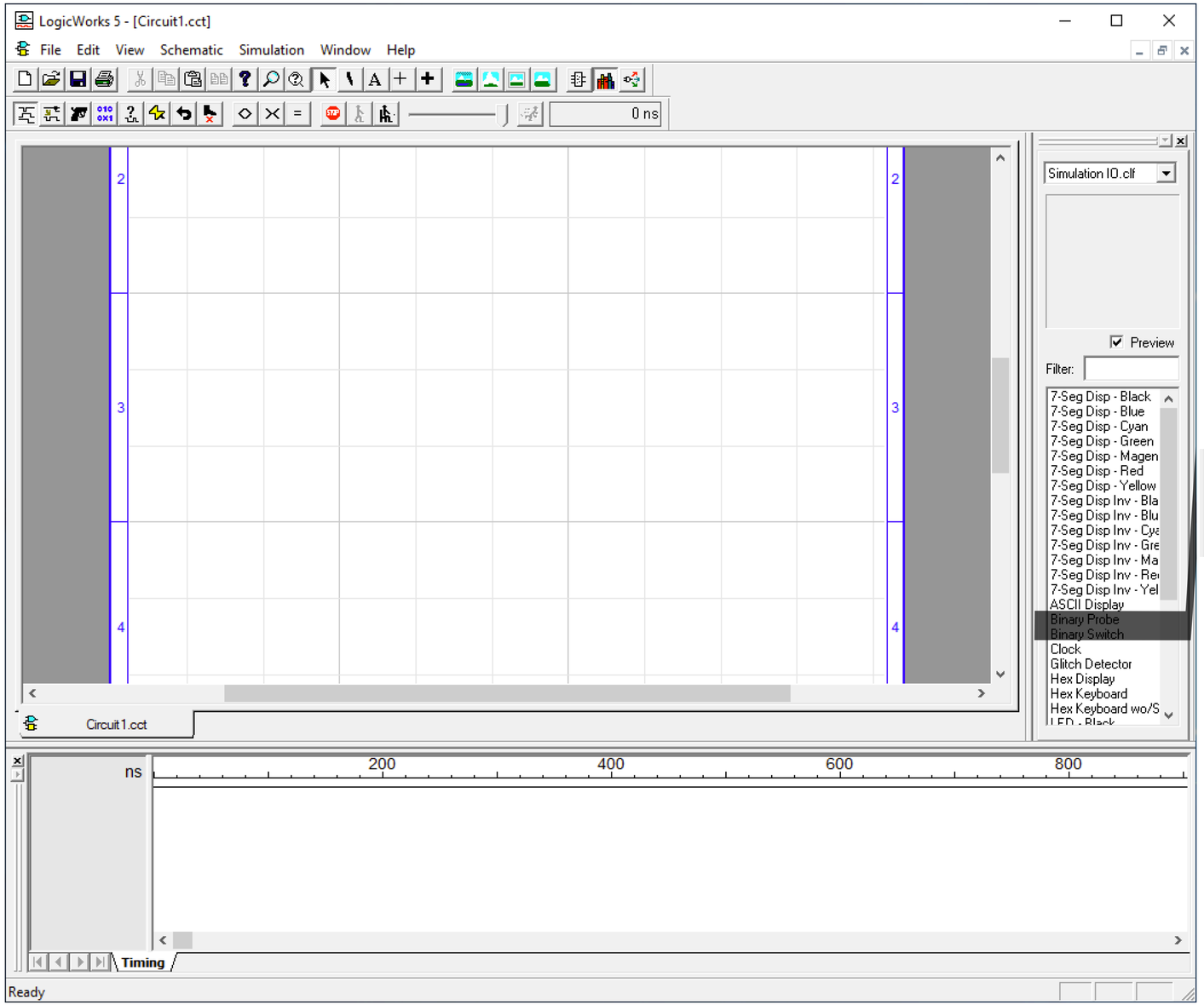
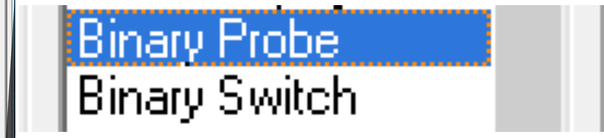
Tutorial





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

Technical

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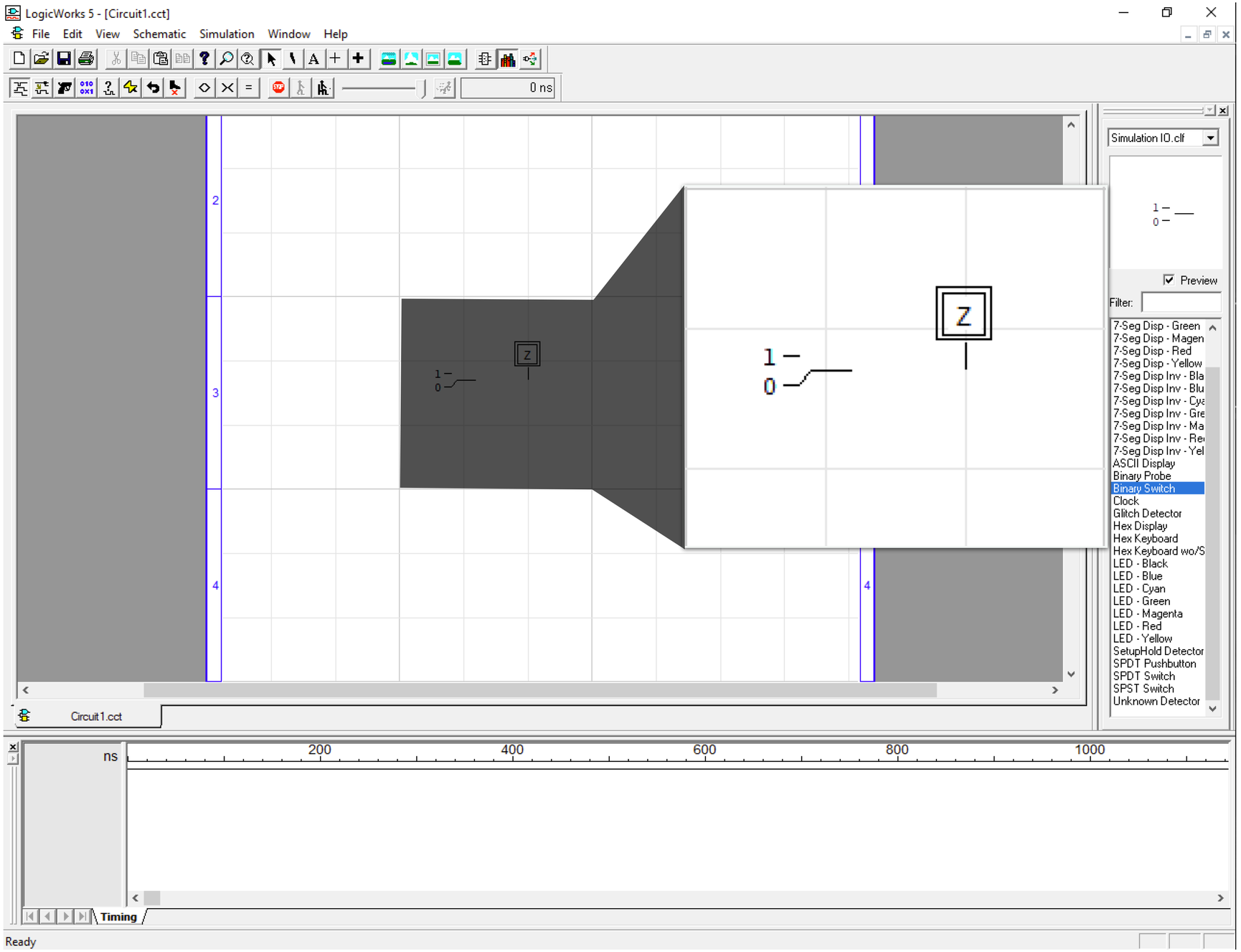
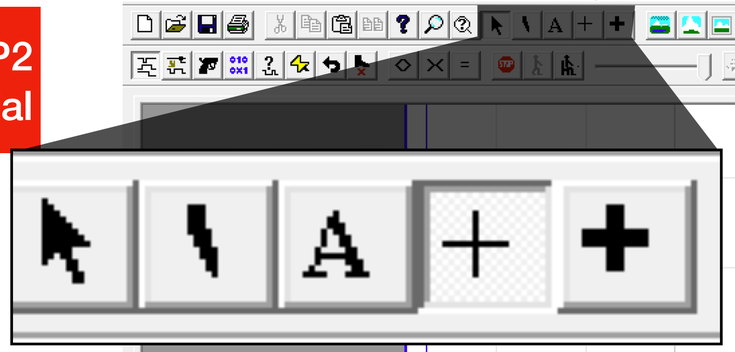
Tutorial



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

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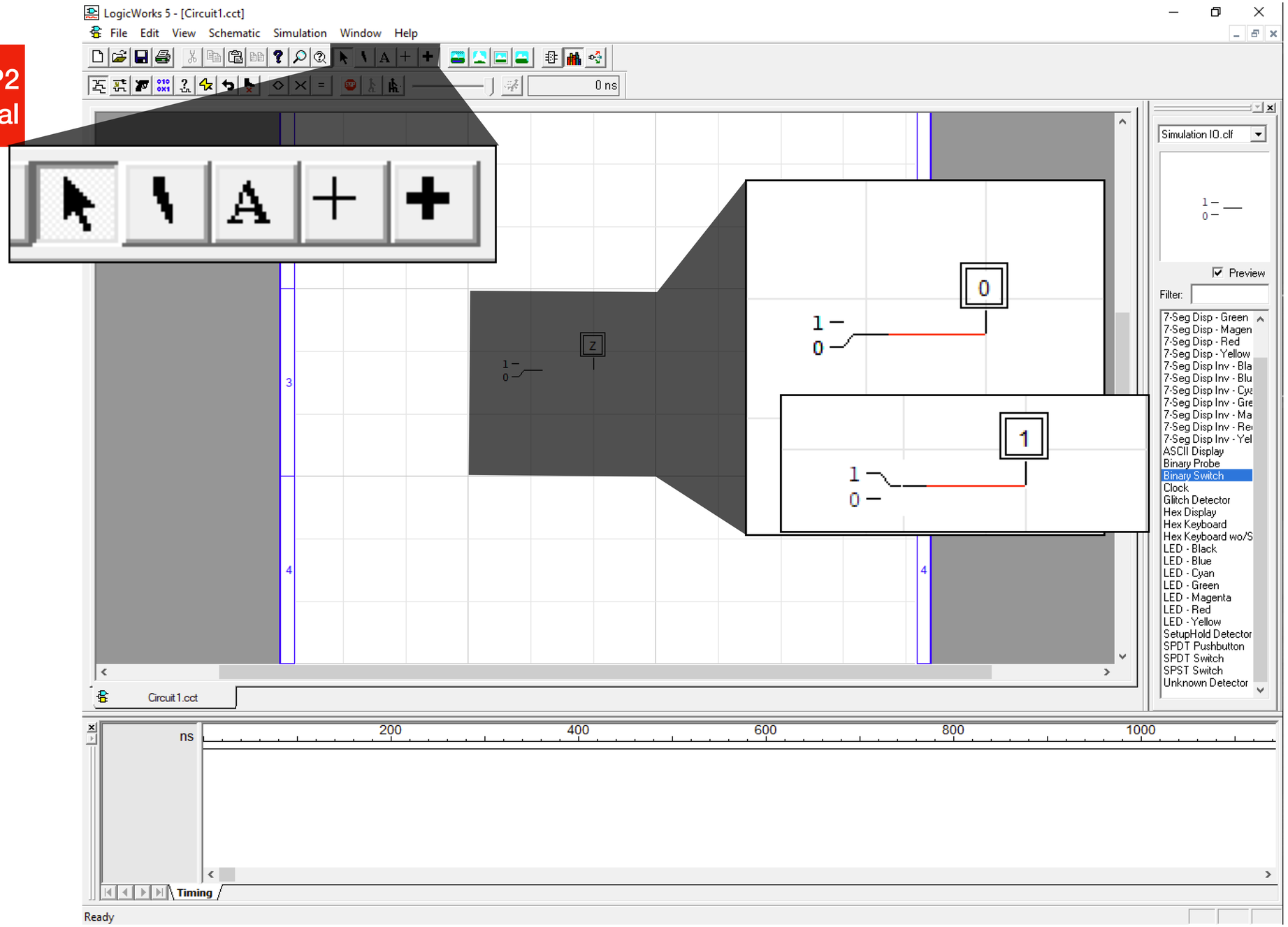
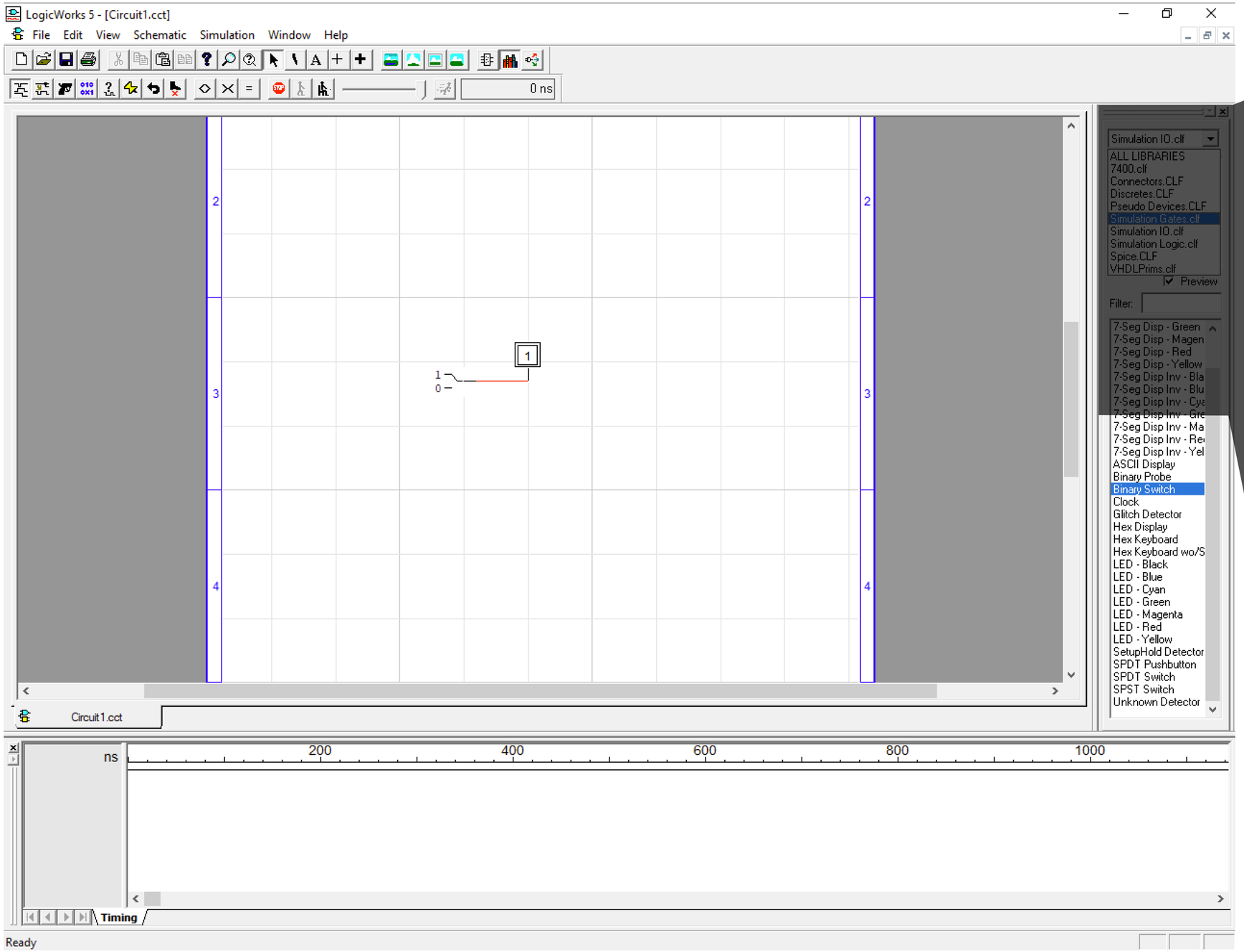
Tutorial



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

Technical

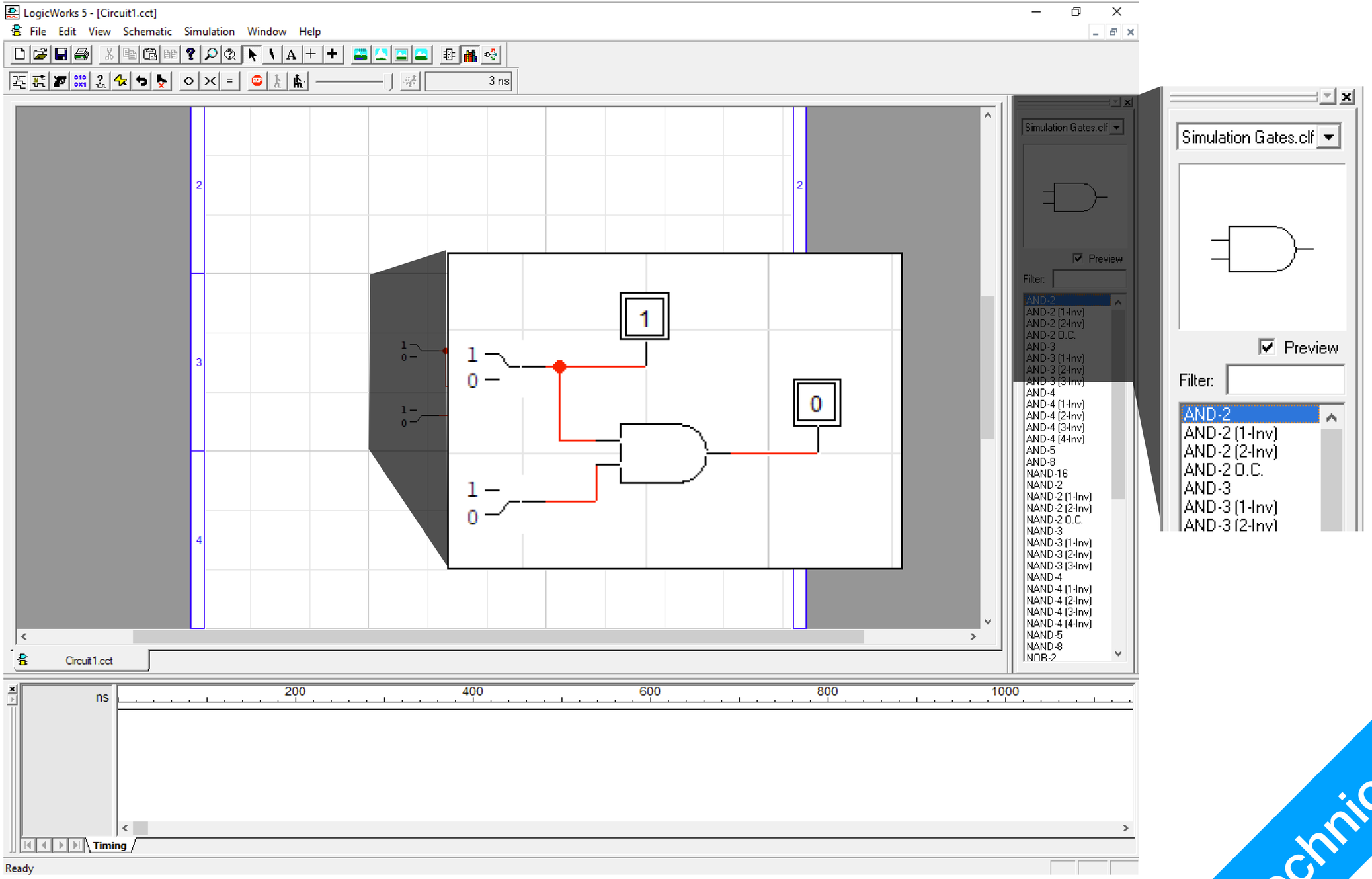
P2
Tutorial



1. Select **Simulation Gates**

Technical

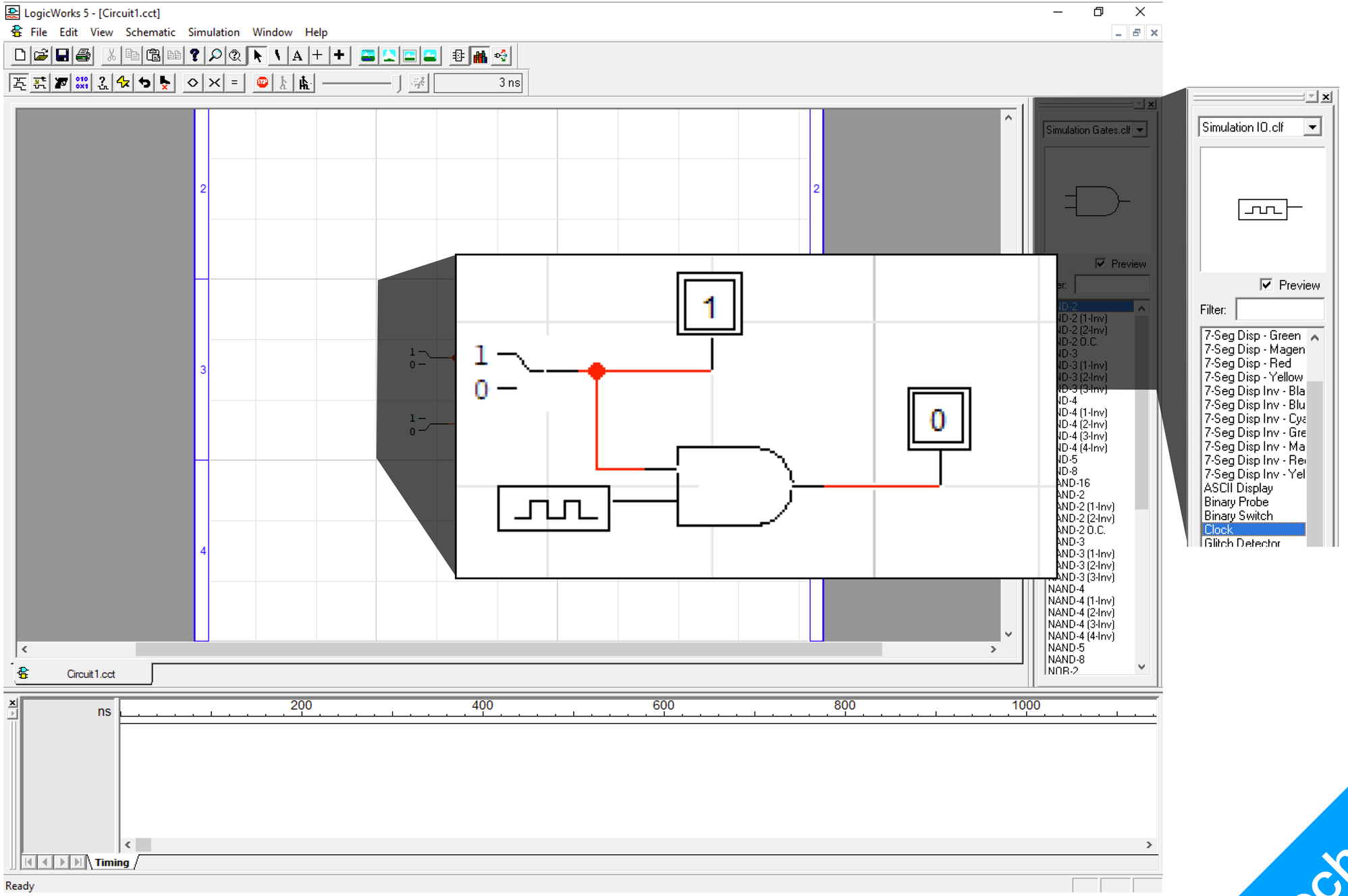
P2
Tutorial



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

Technical

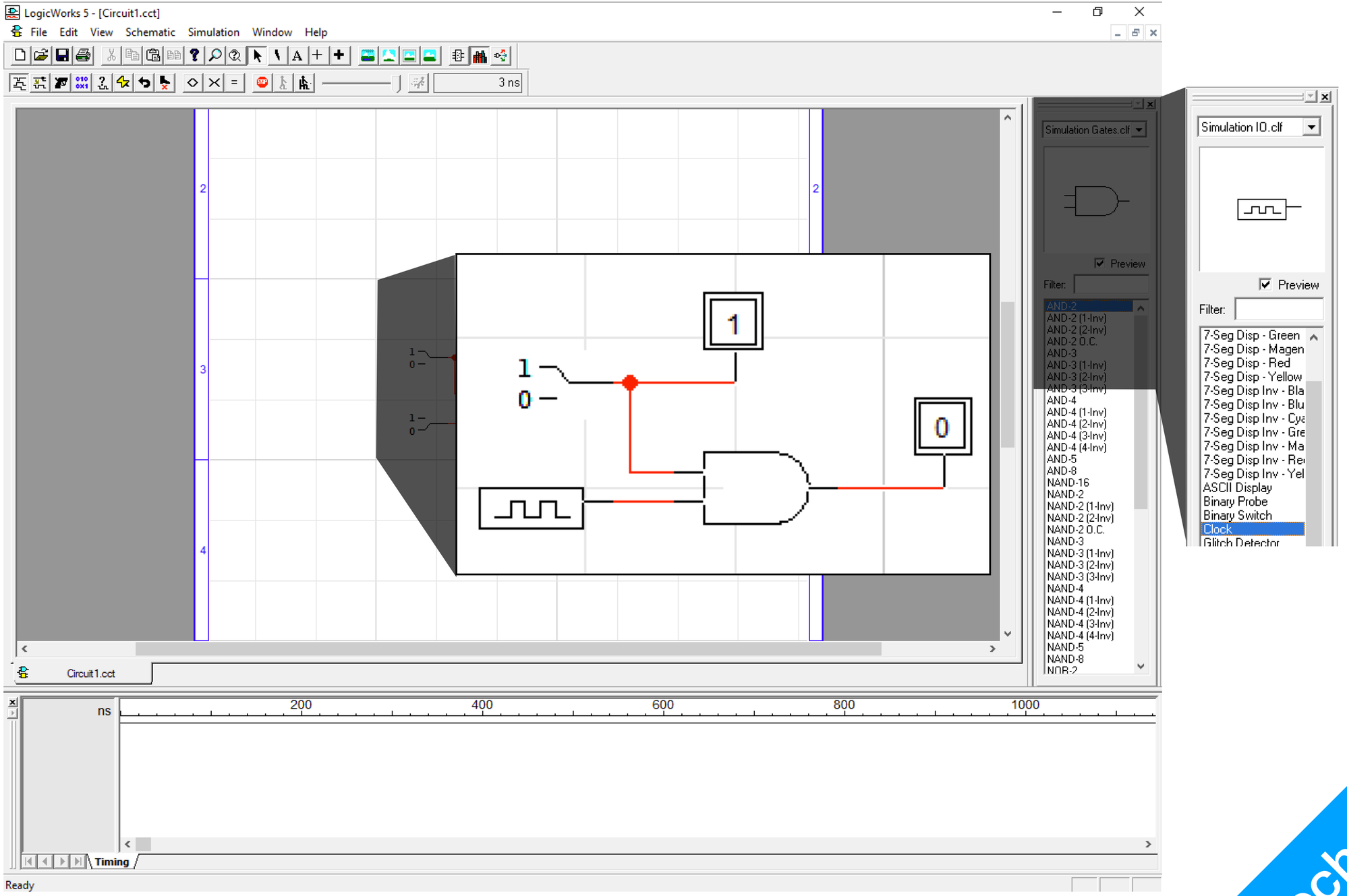
P2
Tutorial



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

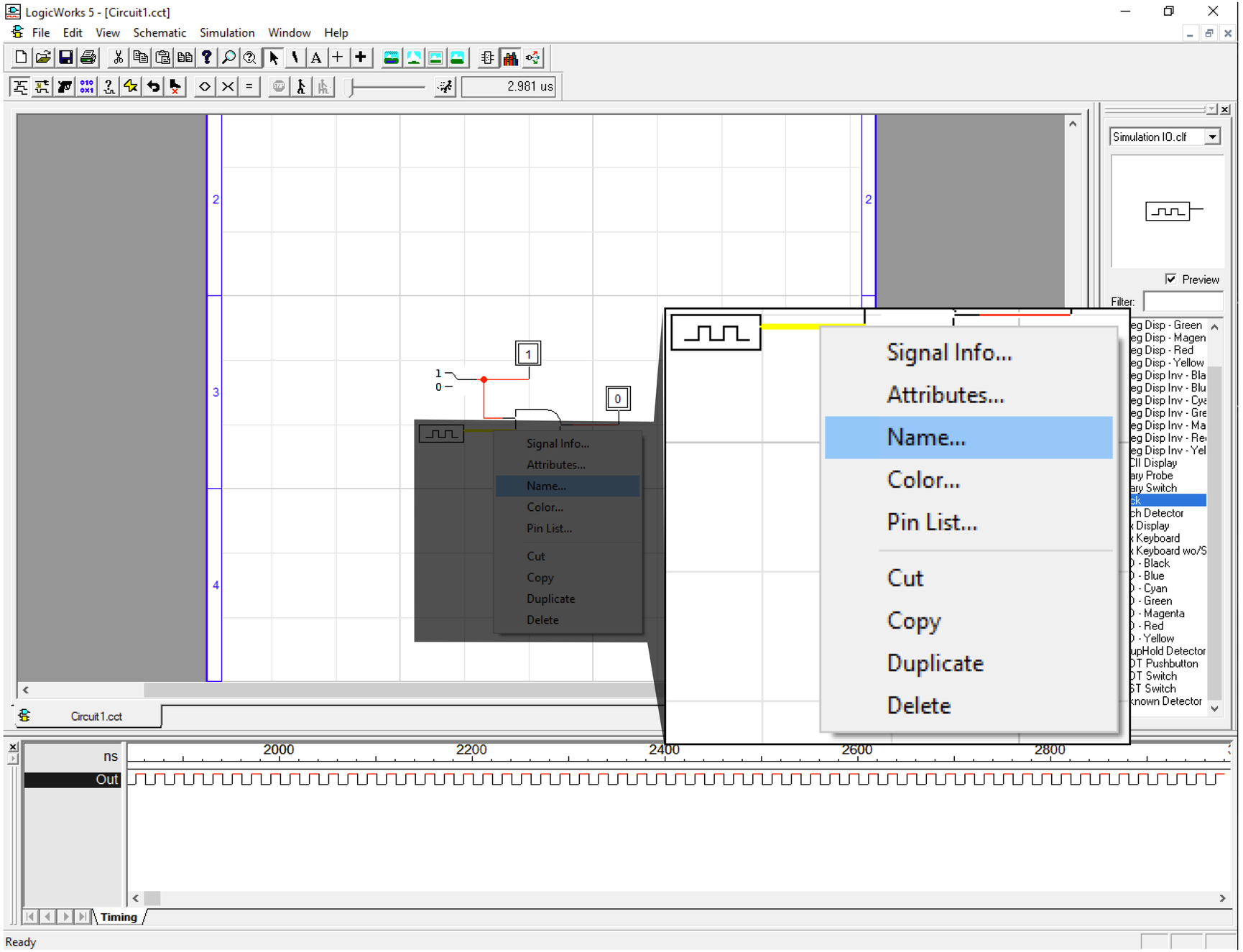
P2
Tutorial



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

Technical

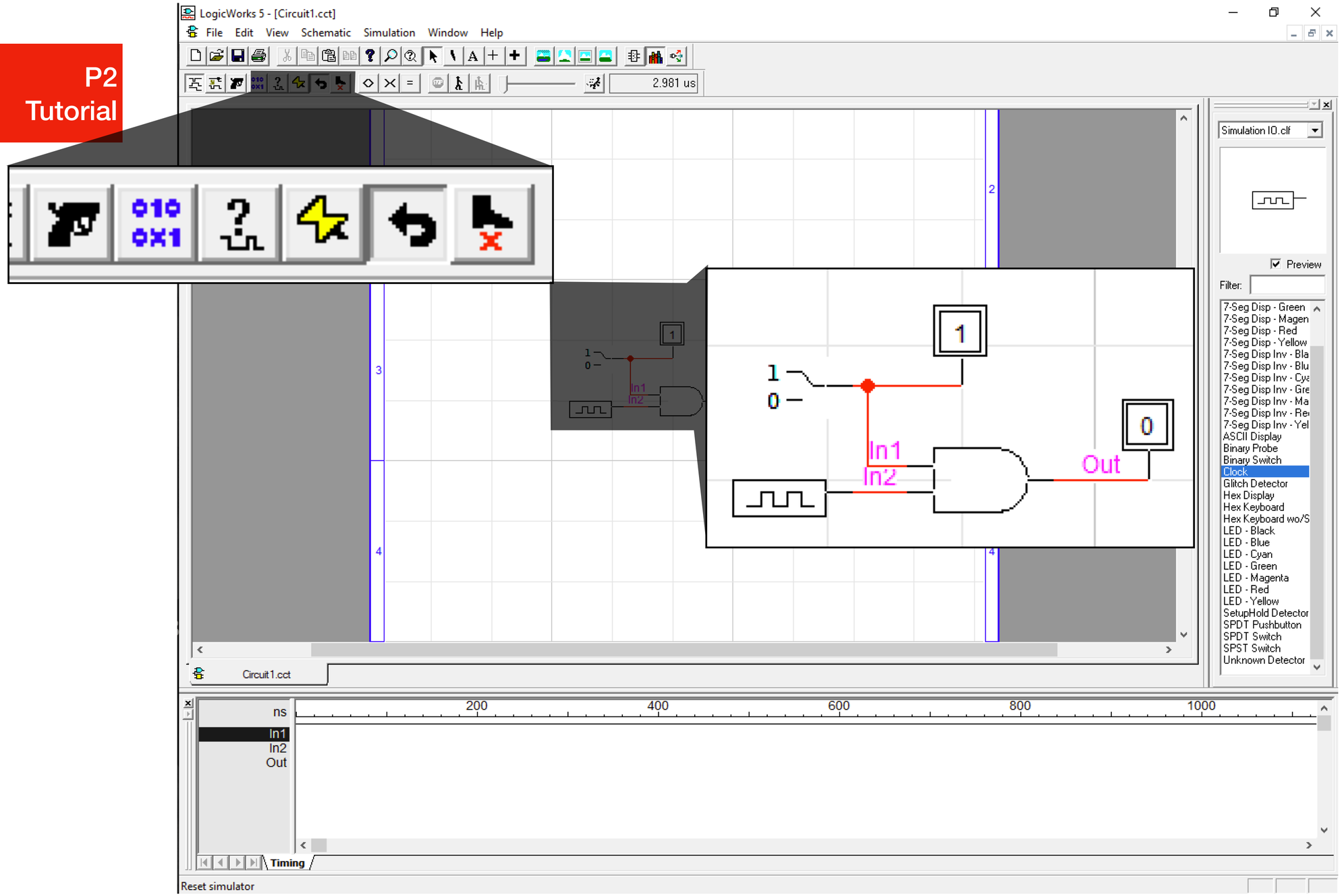
P2
Tutorial



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

Technical

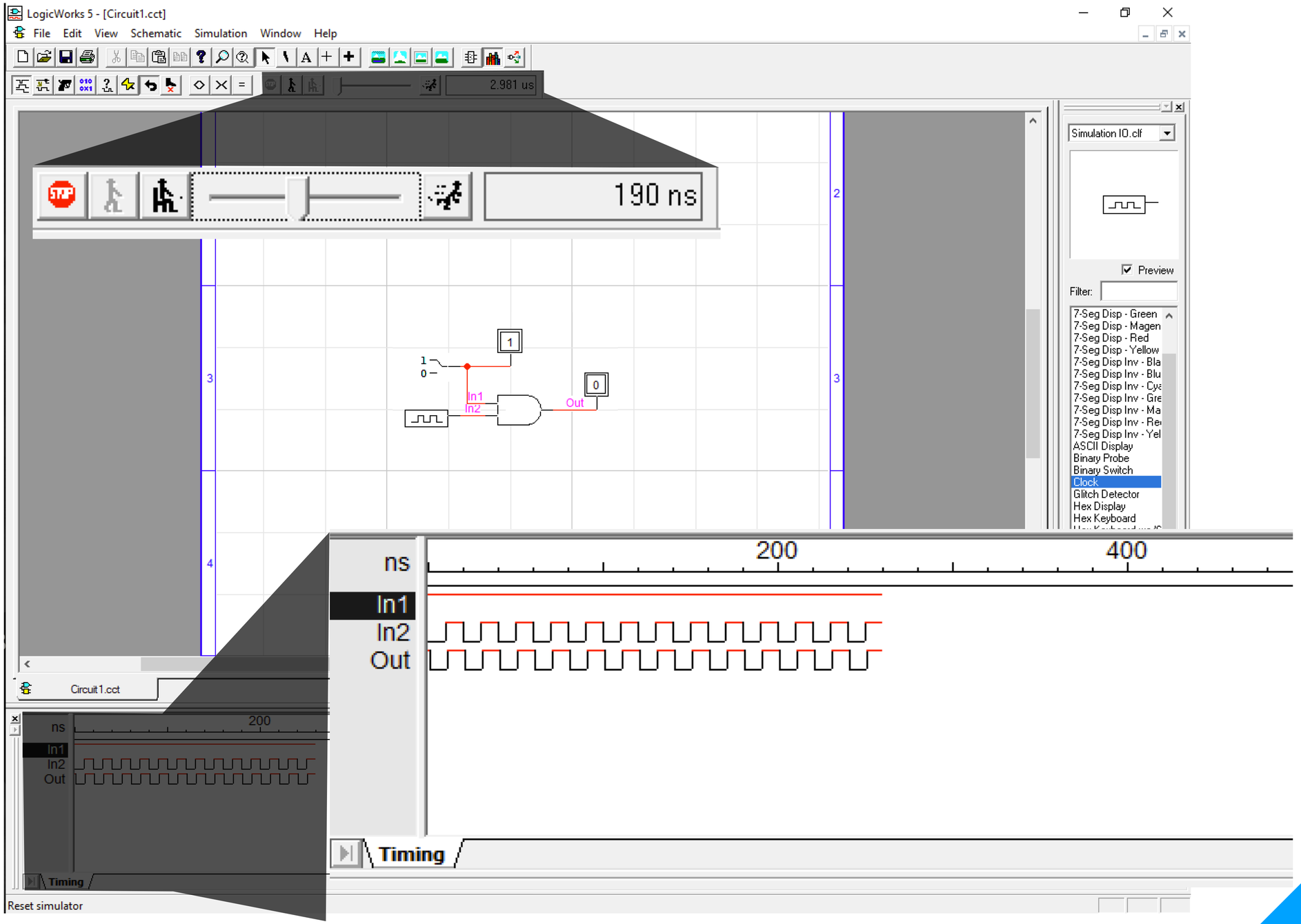
P2
Tutorial



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