CSCI 150
Introduction to Digital and Computer System Design
Lecture 3: Combinational Logic Design I

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Overview

- Focus: Methodology
- Architecture: Combinatory Logical Circuits
- Textbook v4: Ch3 3.1; v5: Ch3 3.1
- Core Ideas:

  1. Light Reading followed by My Lunch Break

P0
Review

Lecture 1 & 2

- Lecture 1
  - What is digital (logic) circuit
  - How information is represented in digital (logic) circuit
- Lecture 2
  - Atomic components of digital (logic) circuit: Gates, I/O
  - Boolean Algebra

Review

Overview

- Focus: **Methodology**
- Architecture: Combinatory Logical Circuits
- Textbook v4: Ch3 3.1; v5: Ch3 3.1
- Core Ideas:
  1. How to **systematically use** what you've learned in Lecture 2
  2. **practice practice practice**

Design Procedure

You, design this!

Summary

P1
Design Procedure

Know the Problem

1. Specification of the Problem
2. Basic Design, a functional Beta Implementation
3. Optimisation, Optimisation
   Harder, Better, Faster, Stronger

Review

P1
Design Procedure

Systematic Design Procedures

(Universal)

1. **Specification**: Write a specification for the circuit
2. **Formulation**: Derive relationship between inputs and outputs of the system e.g. using truth table or Boolean expressions
3. **Optimisation**: Apply optimisation, minimise the number of logic gates and literals required
4. **Technology Mapping**: Transform design to new diagram using available implementation technology
5. **Verification**: Verify the correctness of the final design in meeting the specifications

Concept

P1
Design Procedure

Systematic Design Procedures

1. **Specification**: Write a specification for the circuit
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Concept

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Curtain Motors Revisited

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1. Specification

- Curtain Motor Control

Input
- **Sensor1: 1 when curtain is fully closed**

Input
- **Sensor2: 1 when curtain is fully open**

Input
- Button1: 1 when user wants to open the curtain

Input
- Button2: 1 when user wants to close the curtain

Output
- Output1: 1 to make the motor open the curtain

Output
- Output2: 1 to make the motor close the curtain

Output
- Light: motor is active

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

Demo

P2
An Example

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1. Specification

- Curtain Motor Control

Switch
- **Sensor1: 1 when curtain is fully closed**

Switch
- **Sensor2: 1 when curtain is fully open**

Switch
- Button1: 1 when user wants to open the curtain

Switch
- Button2: 1 when user wants to close the curtain

Prob
- Output1: 1 to make the motor open the curtain

Prob
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Prob
- Light: motor is active

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

Demo

P2
An Example

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2. Formulation

- Curtain Motor Control

Switch
- **Sensor1: 1 when curtain is fully closed**

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Switch
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Prob
- Output1: 1 to make the motor **open** the curtain

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Prob
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$$\mathrm{FullyClosed} = \mathrm{Sensor1}$$
$$\mathrm{FullyOpened} = \mathrm{Sensor2}$$

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

Demo

P2
An Example

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$$\begin{aligned}\text{FullyClosed} &= \text{Sensor1}\\ \text{FullyOpened} &= \text{Sensor2}\\ \text{Light} &= \text{Out1} + \text{Out2}\end{aligned}$$

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

Demo

P2
An Example

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$$\text{Out1} = \text{Bu1} \cdot \overline{\text{FullyOpened}}$$

$$\text{Out2} = \text{Bu2} \cdot \overline{\text{FullyClosed}}$$

Cond

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

Demo

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$$\mathrm{Out1} = \mathrm{Bu1} \cdot \overline{\mathrm{FullyOpened}} \cdot \overline{\mathrm{BothPressed}}$$

$$\mathrm{Out2} = \mathrm{Bu2} \cdot \overline{\mathrm{FullyClosed}} \cdot \overline{\mathrm{BothPressed}}$$

$$\mathrm{BothPressed} = \mathrm{Bu1} \cdot \mathrm{Bu2}$$

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

Demo

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3. Optimisation

$$
\begin{aligned}
\text{FullyClosed} &= \text{Sensor1} \\
\text{FullyOpened} &= \text{Sensor2} \\
\text{Light} &= \text{Out1} + \text{Out2}
\end{aligned}
$$

$$\text{Out1} = \text{Bu1} \cdot \overline{\text{FullyOpened}} \cdot \overline{\text{BothPressed}}$$

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$$\text{Light} = \text{Out1} + \text{Out2}$$

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$$\text{Out2} = \text{Bu2} \cdot \overline{\text{Sensor1}} \cdot \overline{\text{Bu1} \cdot \text{Bu2}}$$

Demo

P2
An Example

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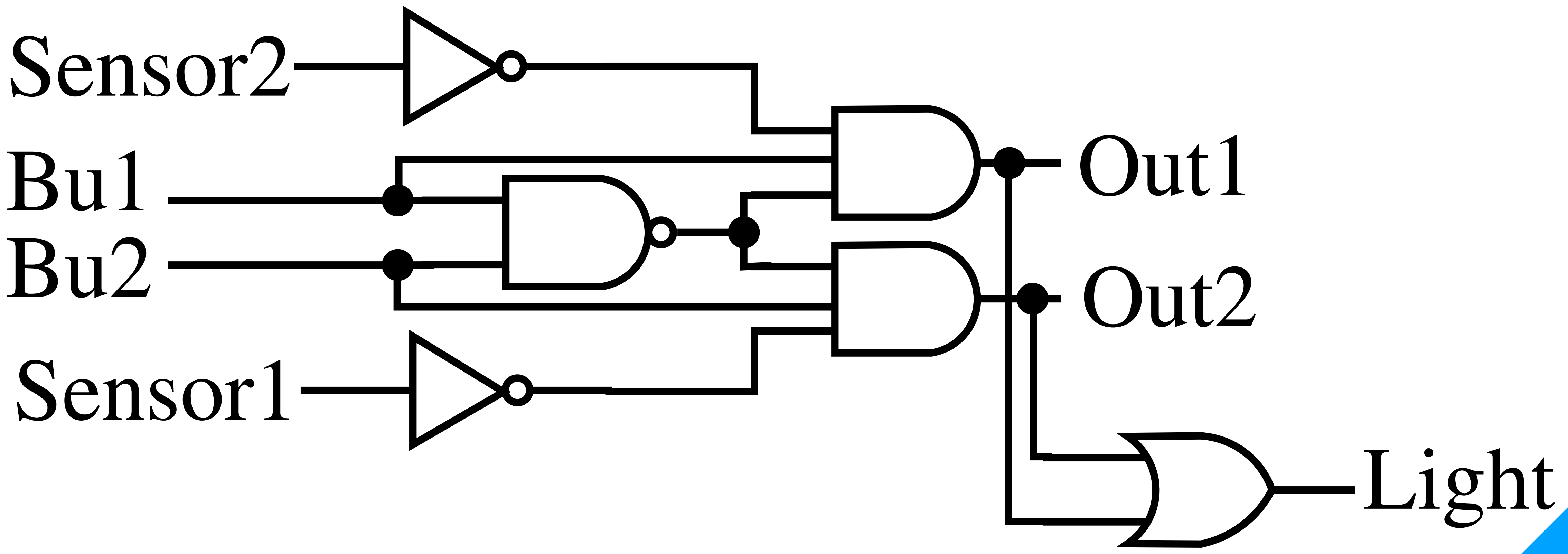
4. Technology Mapping

$$\mathrm{Light} = \mathrm{Out1} + \mathrm{Out2}$$

$$\mathrm{Out1} = \mathrm{Bu1} \cdot \overline{\mathrm{Sensor2}} \cdot \overline{\mathrm{Bu1} \cdot \mathrm{Bu2}}$$

$$\mathrm{Out2} = \mathrm{Bu2} \cdot \overline{\mathrm{Sensor1}} \cdot \overline{\mathrm{Bu1} \cdot \mathrm{Bu2}}$$

- Available Components (Technology)
  - AND, NAND, OR, NOT gate; Switch, Prob



Demo

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- Available Components (Technology)
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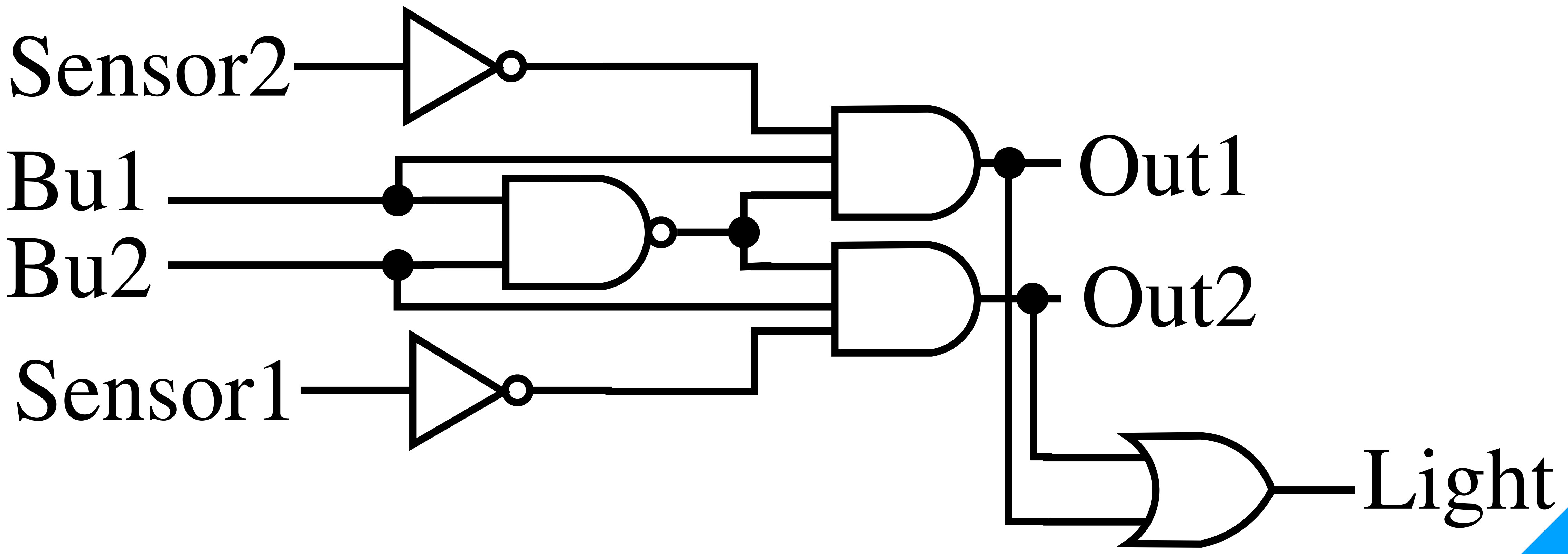
NO NOT GATE!



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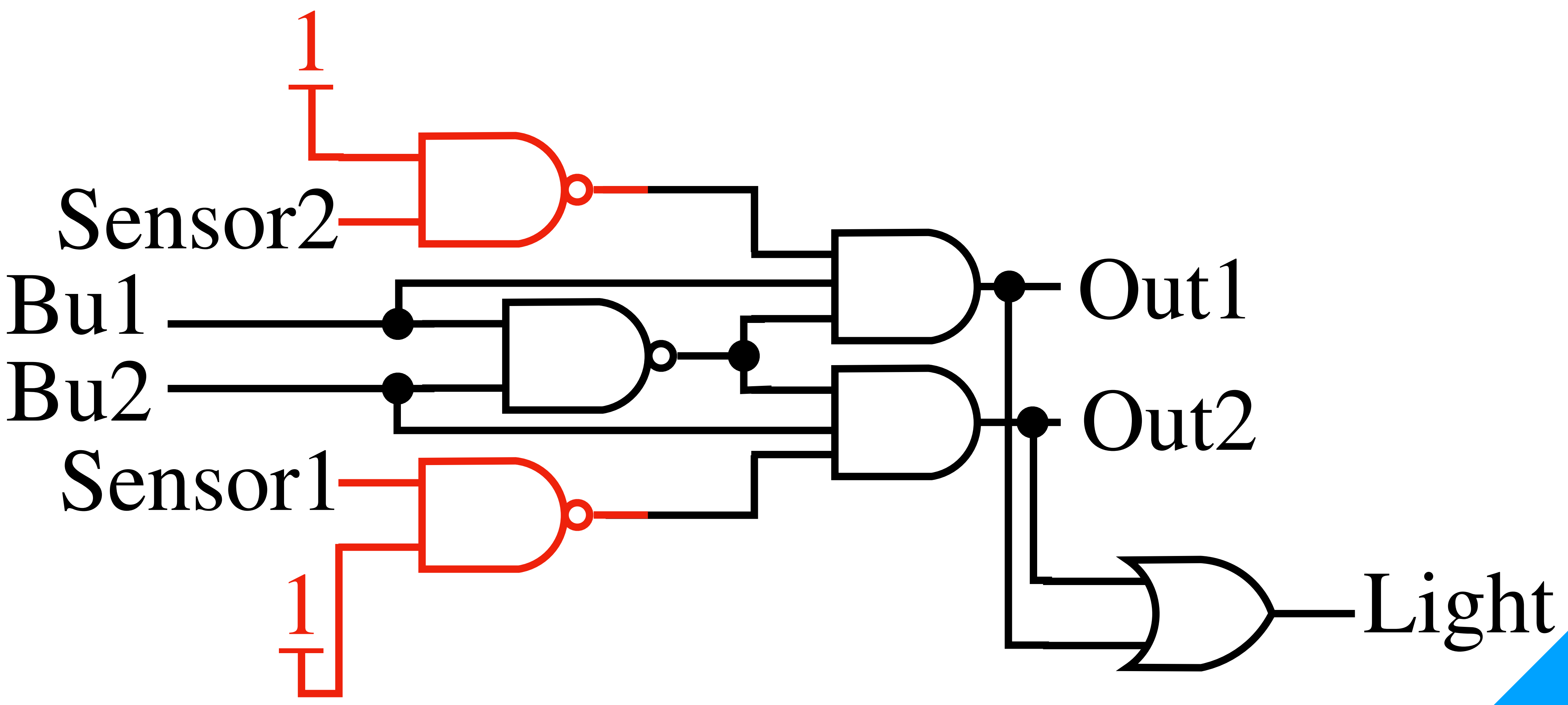

Demo

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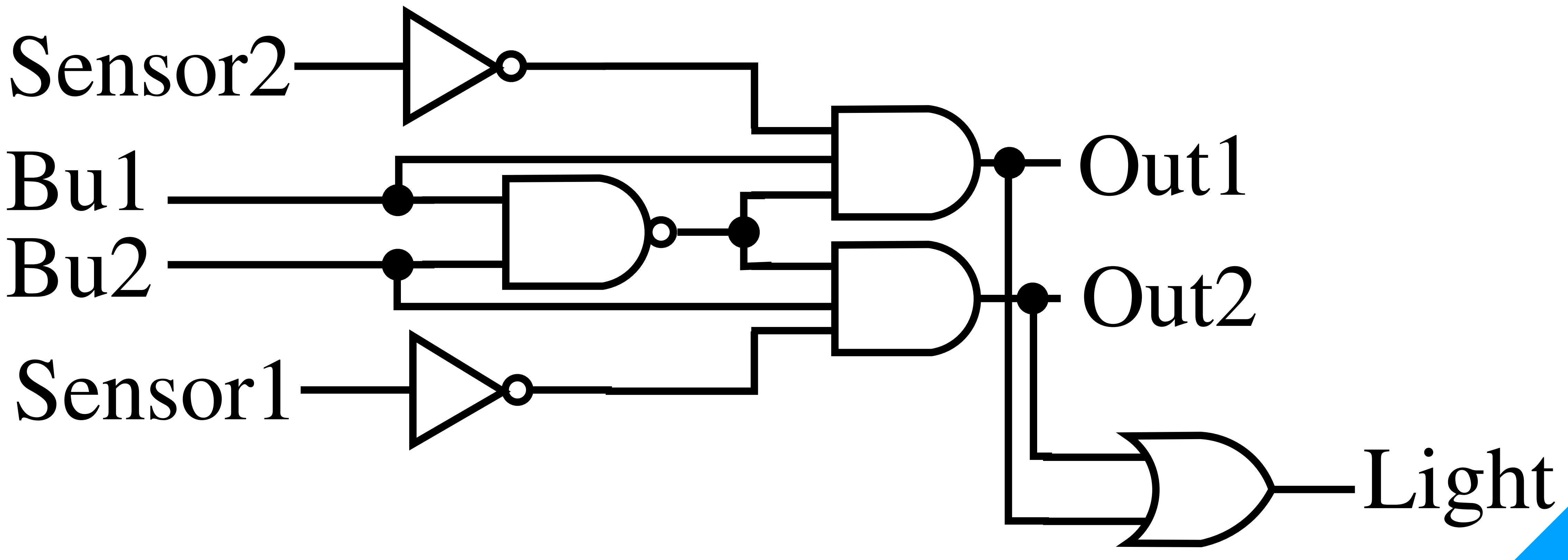

Demo

P2
An Example

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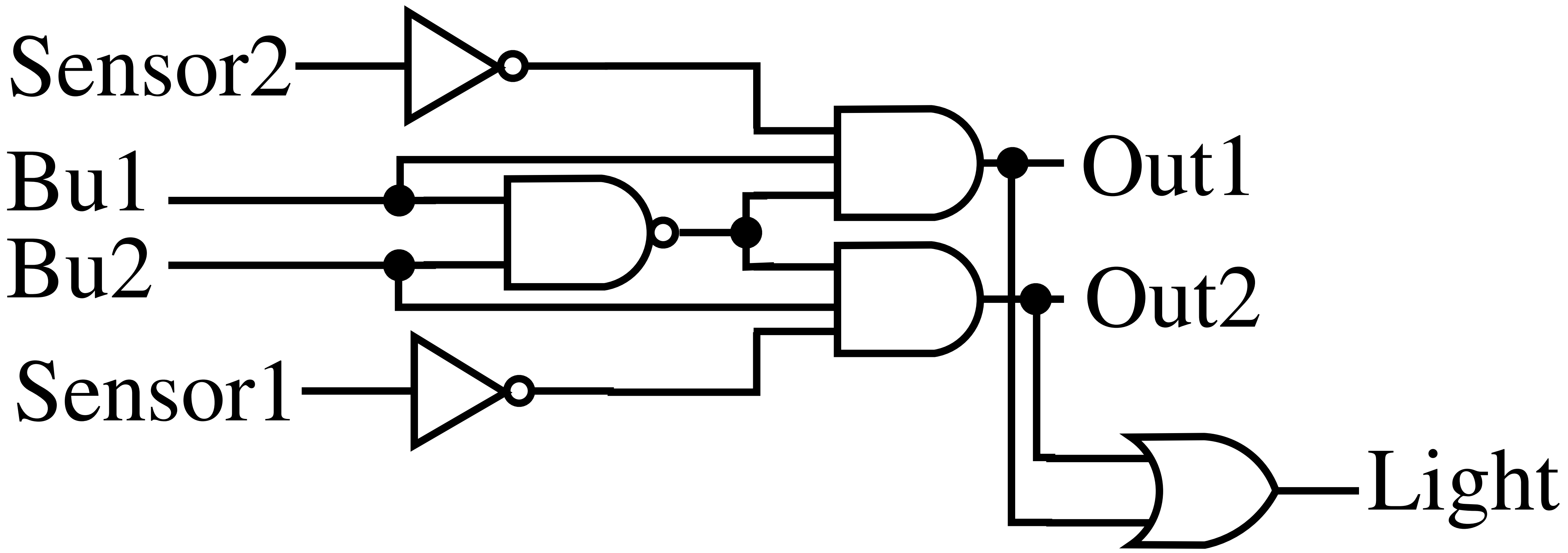
5. Verification



- Design test cases
  - Sensor2, Bu1 on
  - Sensor1, Bu2 on
  - Bu1, Bu2 on
  - Bu1 on
  - Bu2 on
  - etc…

Demo