Microprocessor Design Bootcamp: Gentle Intro to Digital Circuits

December 16, 2025

Nursultan Kabylkas

Agenda

- Small lecture
- Labs!

How do computers make decision?

At the core of all digital circuits is a system of logic, which allows computers to perform complex tasks by making simple, binary decisions

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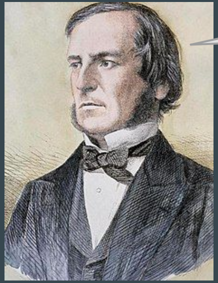

I wonder what is this system of logic?

Boolean algebra

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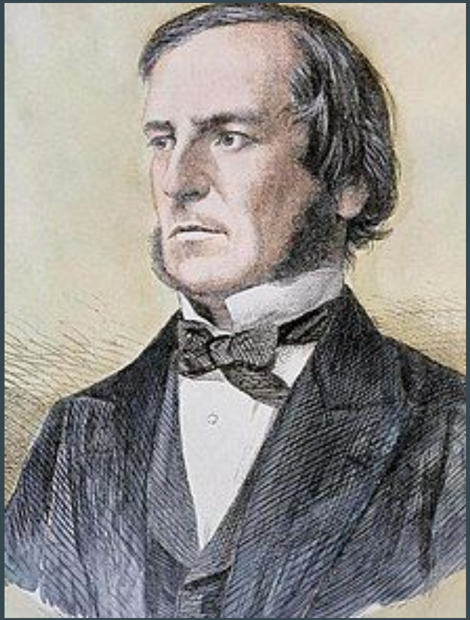

George Boole
1815 - 1864

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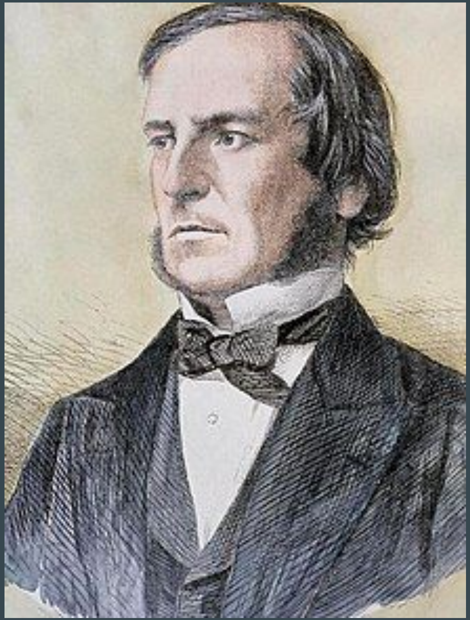

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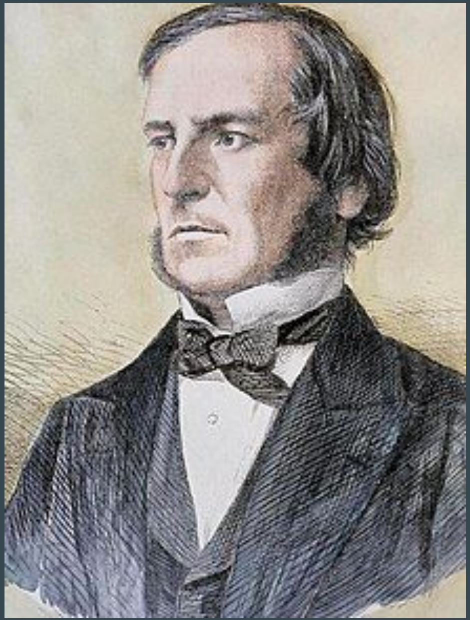
Boolean algebra

- Boolean algebra is a branch of mathematics that deals with operations on logical values: true and false.
- Introduced by George Boole, in the article “The Laws of Thought” in 1854.
- He basically said that we can express logic with algebraic expressions.
- Defined operations such as: AND, OR, NOT.



George Boole
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Example

- A: "I am tired."
- B: "I will take a nap."
- C: "I will drink coffee."

Let’s express as an equation: (A and B) or (not A and B). Interpretation: *If I am tired, I will take a nap OR if I am not tired, I will drink coffee.*

Example

Apply operations from boolean algebra to simplify:

Distributive law

$$A \cdot B + \neg A \cdot C = (A + \neg A) \cdot (B + C)$$

Complement law

$$(A + \neg A) \cdot (B + C) = 1 \cdot (B + C)$$

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$$B + C$$

Interpretation: "I will either take a nap OR drink coffee."

Example

Apply operations from boolean algebra to simplify:

Distributive law

Complement law

$A \cdot B + \neg A \cdot C$

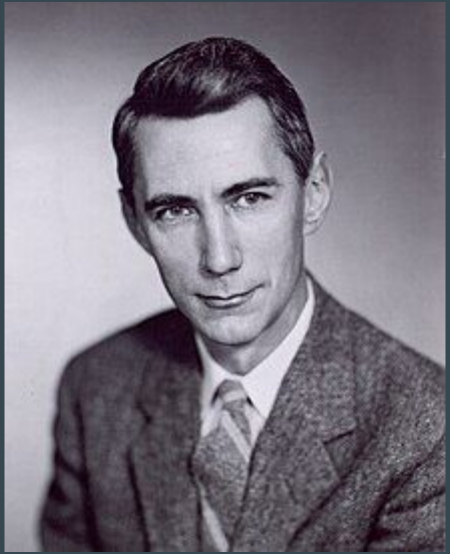
Key idea: “You can apply math on logic!”

$\Rightarrow B + C$

Interpretation: "I will either take a nap OR drink coffee."

Boolean algebra for digital circuits

- Claude Shannon was the first person to introduce the concepts of boolean algebra into electrical circuits.

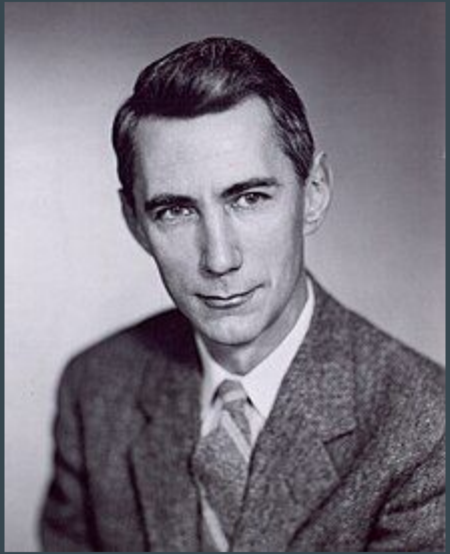


Claude Shannon
1916 - 2001

Boolean algebra for digital circuits

- Claude Shannon was the first person to introduce the concepts of boolean algebra into electrical circuits.

Probably the most impactful Master Thesis in history!
"A Symbolic Analysis of Relay and Switching Circuits". Less than 30 pages long.



Claude Shannon
1916 - 2001

AND operation

Theoretically

A	B	AB
F	F	?
F	T	?
T	F	?
T	T	?

AND operation

Theoretically

A	B	AB
F	F	F
F	T	F
T	F	F
T	T	T

AND operation

Theoretically

A	B	AB
F	F	F
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Information wise

A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

AND operation

Theoretically

A	B	AB
F	F	F
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Information wise

A	B	AB
0	0	0
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Physically

A	B	AB

AND operation

Theoretically

A	B	AB
F	F	F
F	T	F
T	F	F
T	T	T

Information wise

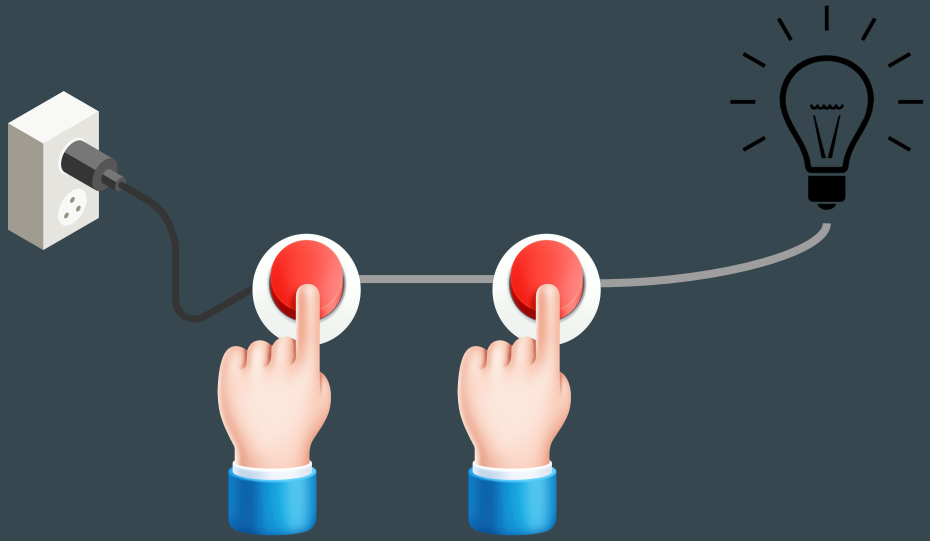
A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

Physically

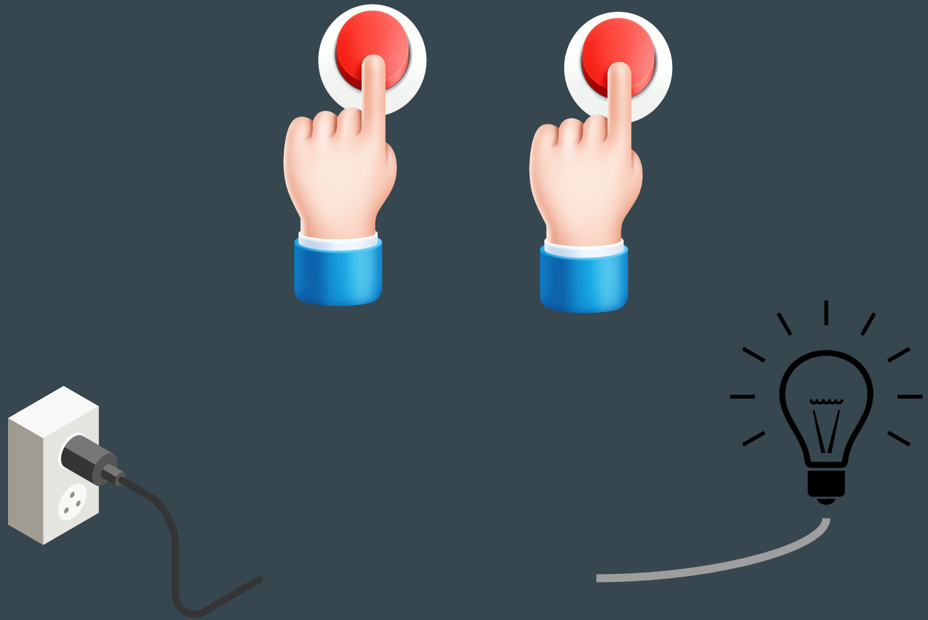
A	B	AB
0V	0V	0V
0V	5V	0V
5V	0V	0V
5V	5V	5V

AND operation

Pushing the button closes the circuit.



OR operation



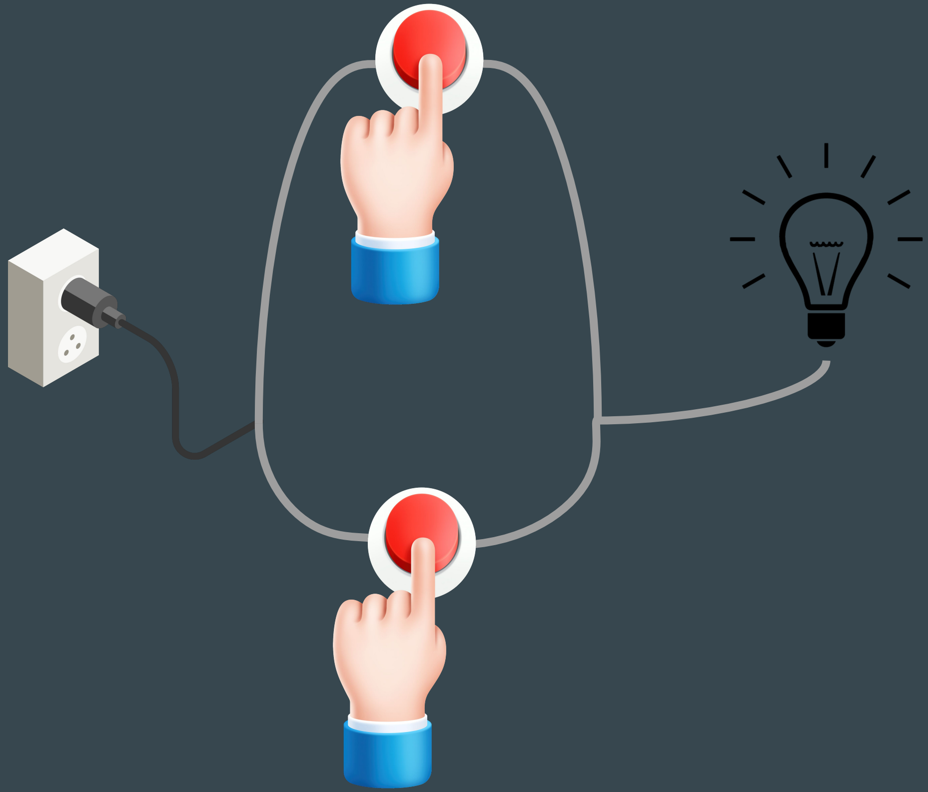
Pushing the button closes the circuit.

How would you place buttons to model OR operation?

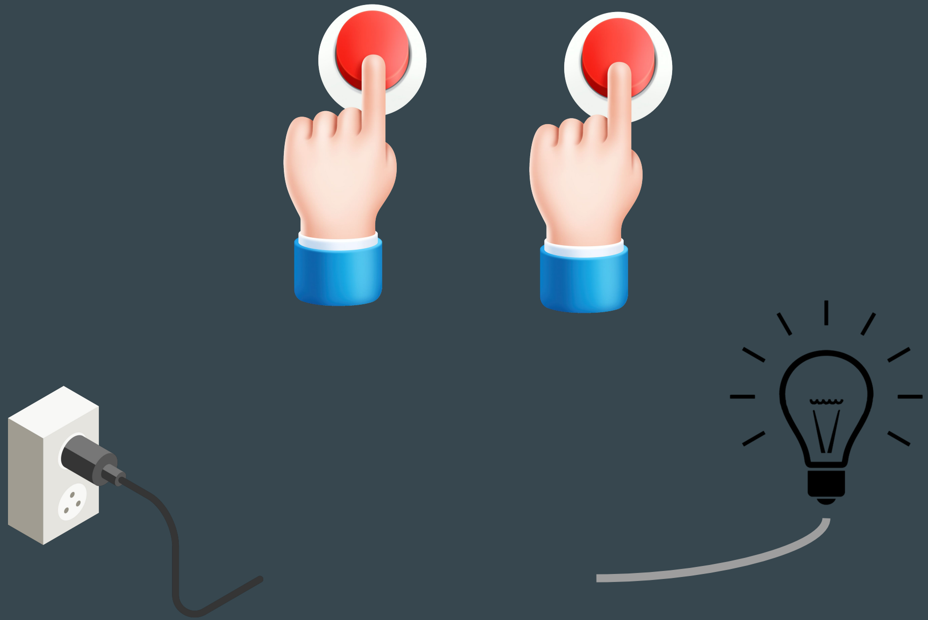
OR operation

Pushing the button closes the circuit.

How would you place buttons to model OR operation?



NOT operation

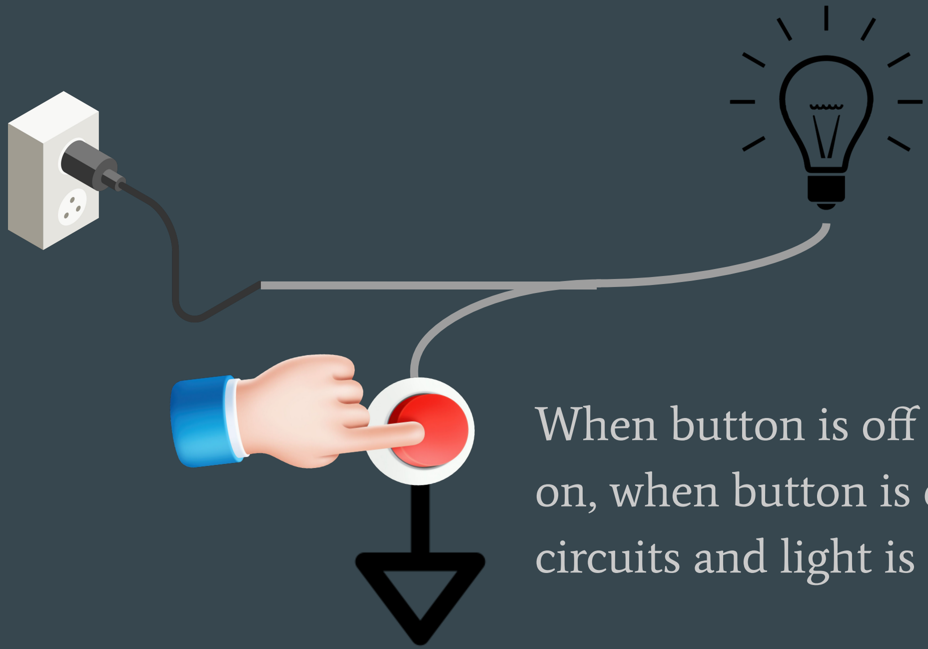


Pushing the button closes the circuit.

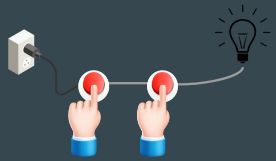
How would you place buttons to model NOT operation?

NOT operation

Pushing the button closes the circuit.



When button is off light is on, when button is on, short circuits and light is off.



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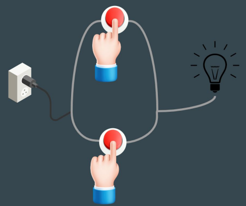

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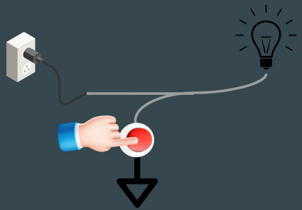
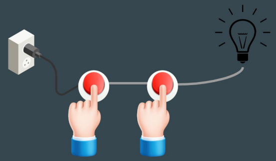


NOT

Obviously these configurations are far from the reality but the principle is true. We model the behaviour with electrical circuits.



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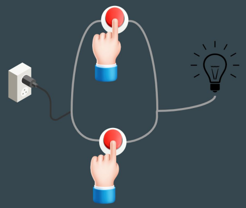

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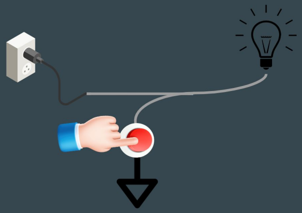

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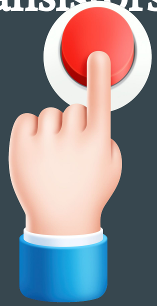

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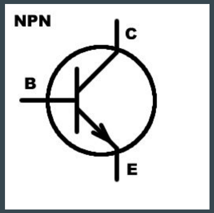

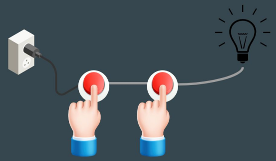

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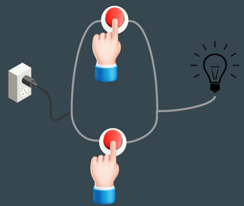

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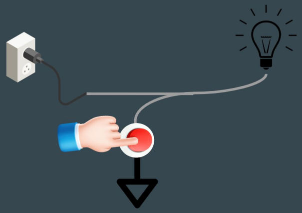

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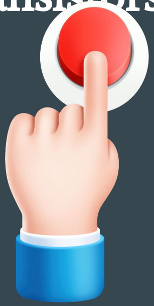

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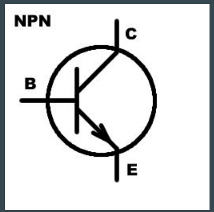
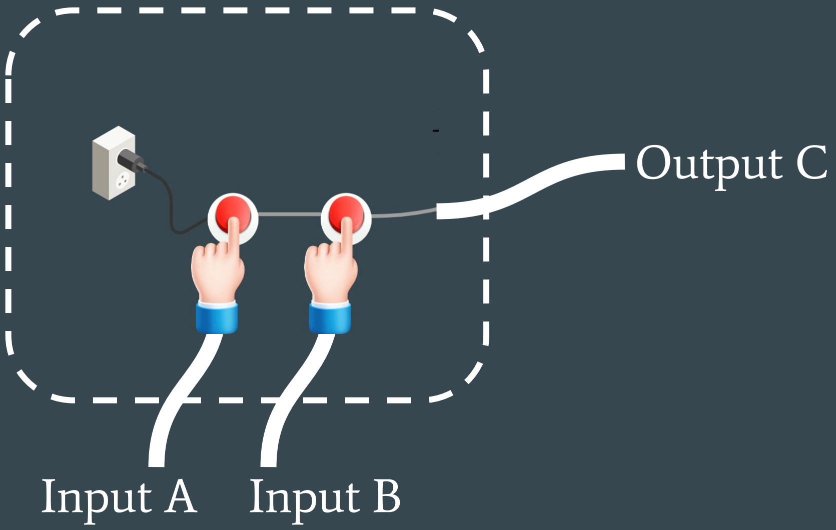


Let’s abstract



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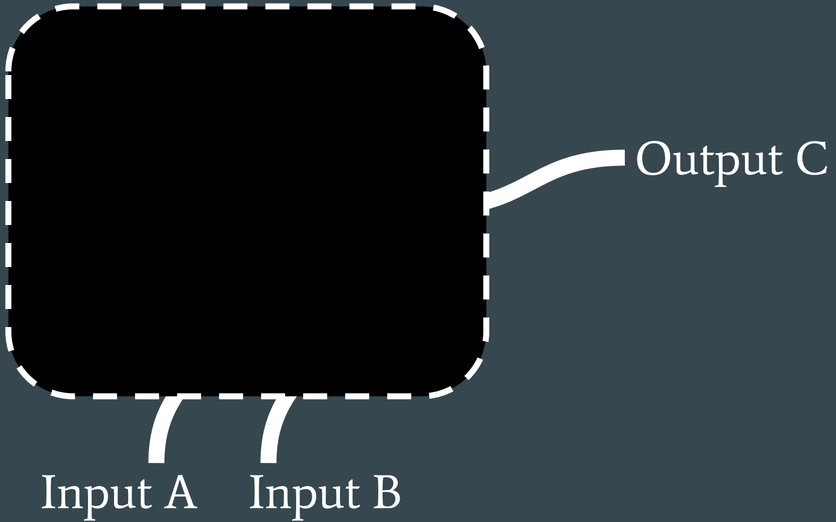

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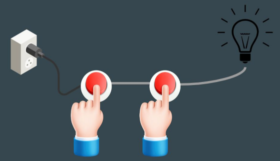
Let’s create a special symbol



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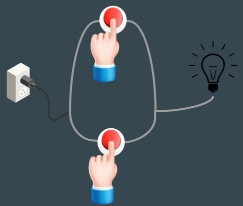

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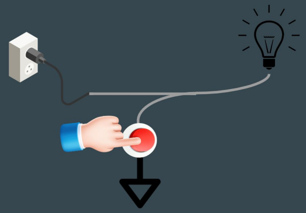

NOT

Problem Statement

You need to design a basic home security system that activates an alarm when certain conditions are met. The system has three inputs:

- Window Sensor (W): True (1) if the window is open, False (0) if closed.
- Door Sensor (D): True (1) if the door is open, False (0) if closed.
- Motion Detector (M): True (1) if motion is detected, False (0) if no motion is detected.

The alarm (A) should sound (output True or 1) if The window is open or the door is open and motion is detected.

Solution

Expression = (W or D) and M

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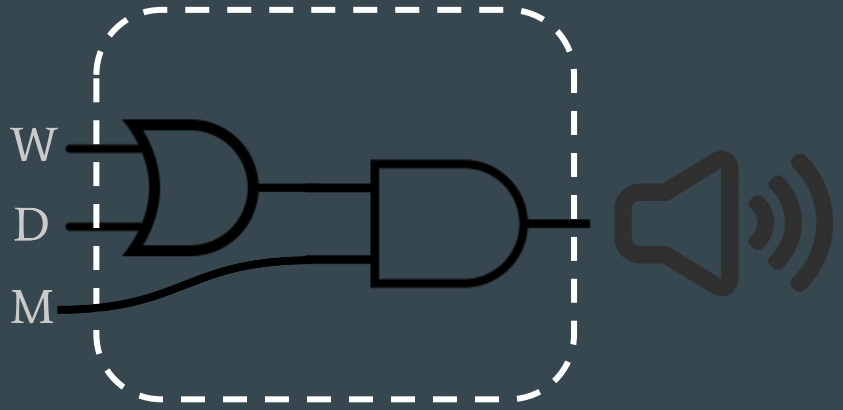

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