DIGITAL ELECTRONICS

UNDERSTANDING HOW ELECTRONIC COMPONENTS COMBINE IN DIGITAL CIRCUITS.

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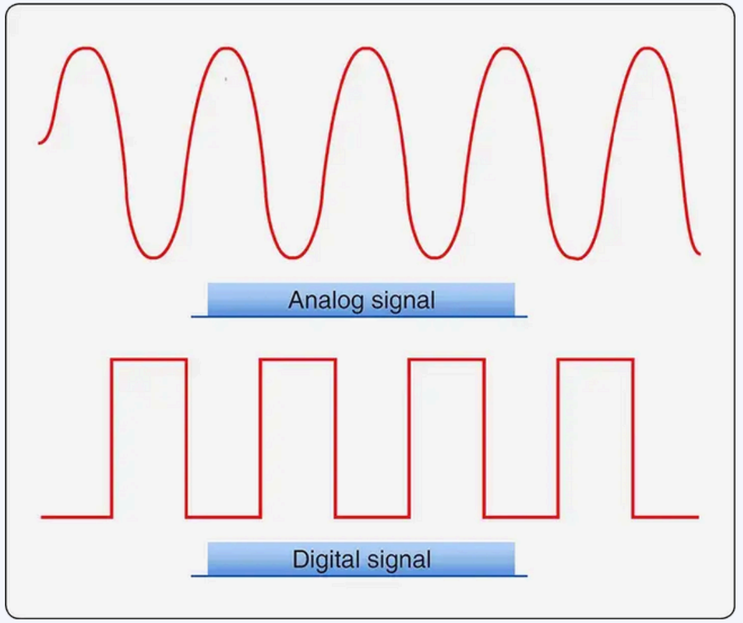
Learning Outcomes

- Understanding how resistors are used to make potential dividers in control and logic circuits (u, s)
- Understanding elementary logic and memory circuits that exploit devices such as bistable and astable switches, logic gates and resistors as potential dividers (u, s)
- Knowing that logic circuits are able to store and process binary information and that this can be exploited in an increasingly wide variety of digital instruments (k, u, s)

Introduction

The phones, computers, sensors,televisions and other electronic devices we use are all digital electronic devices, how do they work?, how can we improve them?

Digital electronics involves the study and application of digital signals to control electronic circuits and systems. Unlike analog electronics, where signals can vary continuously, digital electronics uses discrete levels to represent information. The most common representation is the binary system, where signals have two states: 0 (low) and 1 (high) .

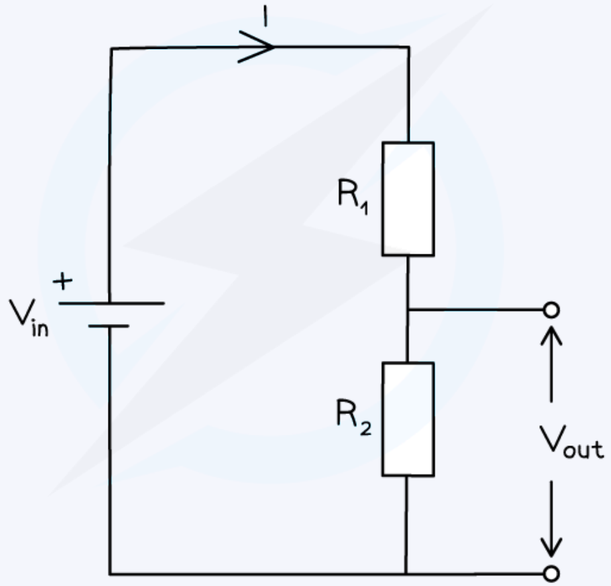


Potential Divider

A potential divider, also known as a voltage divider, is a simple and fundamental circuit in electronics used to produce a specific output voltage (Vout) that is a fraction of its input voltage (Vin). This is achieved by using two or more resistors connected in series across a voltage supply.

The potential divider works on the principle of distributing the input voltage among the resistors in proportion to their resistance values. This distribution follows Ohm's Law.

POTENTIAL DIVIDER EQUATION: $V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$



Activity

1) A potential divider consists of a 2 kΩ and a 1 kΩ resistor connected in series across a 9 V supply. Calculate the output voltage (Vo)

2) A thermistor with a resistance of 3 kΩ and a 1 kΩ resistor form a voltage divider across a 12 V supply.

(a) Calculate the voltage across the 1 kΩ resistor.

(b) What would happen to the output voltage if the thermistor's resistance decreases with heat?

3) A circuit uses a 6 V battery, with a 1.5 kΩ resistor and an unknown resistor Rx in series. If the LED needs exactly 2 V to switch on, calculate the value of Rx required to get 2 V across it.

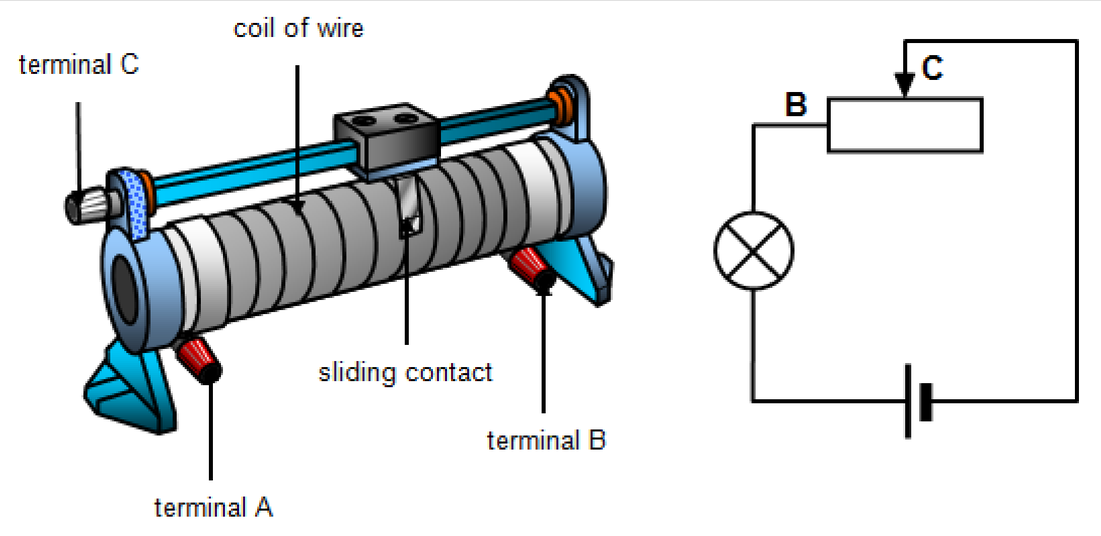
4) Design a voltage divider using a 12 V battery and one fixed resistor of 4 kΩ such that the output voltage is 3 V. What should be the value of the second resistor?

5) A transistor switches ON at 0.7 V. A potential divider made of a 5 kΩ and a 2 kΩ resistor is powered by a 5 V supply.

(a) Calculate the output voltage across the 2 kΩ resistor.

(b) Will this voltage be enough to activate the transistor?

Uses of potential dividers



- Used in radios, TVs, and speakers to adjust volume levels.
- Used to adjusts brightness in LED lights and household lighting.
- Used in thermostats, ACs, and refrigerators. A thermistor (temperature-dependent resistor) changes resistance with heat, changing the divided voltage to measure temperature.
- Light-Dependent Resistors (LDRs) change resistance with light intensity. At night, LDR resistance increases, changing the voltage divider output to switch on street lights.

Trial Item

Inside a refrigerator to switch on the cooling circuit when the temperature is high. A thermistor is connected in series with a cooling circuit with a voltage of 6V connected. The characteristics of the thermistor are given in the table below. The resistance of the cooling circuit is 5kΩ. In order for the cooling circuit to operate, it needs a pd of 5V or more. What temperature and resistance will the refrigerator be operational?

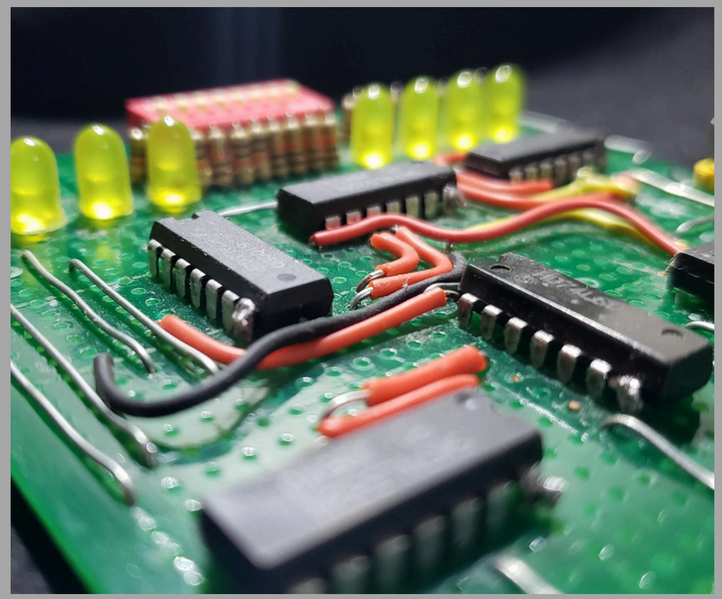
Temperature (°C)	Resistance of thermistor (Ω)
2	1500
3	1000
4	500

Binary system and logic gates.

The binary system is a base-2 numeral system that uses only two digits: 0 and 1. It is the fundamental language of computers and digital systems. Digits are called bits.

Logic gates are the building blocks of digital circuits. They perform basic logical functions and operate on binary inputs to produce a binary output. Eg AND gate, OR gate, NOR gate...

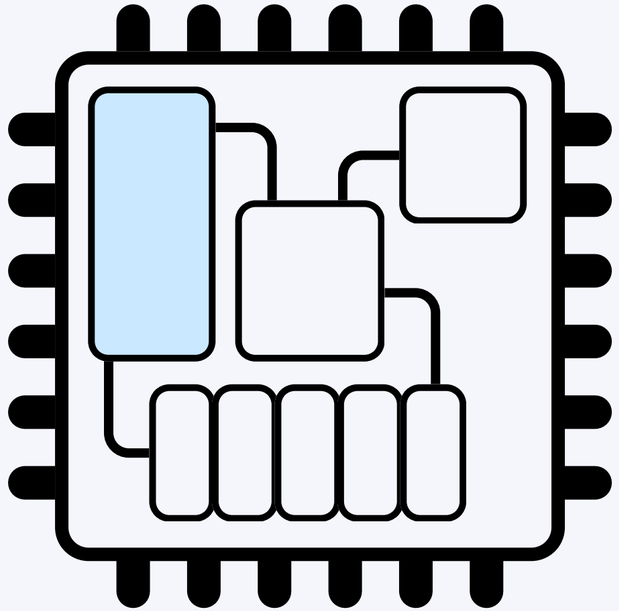
Each logic gate can be represented by a truth table.



Boolean algebra

The brain of any computer is the CPU (central processing unit). The CPU fetches instructions from main memory and executes them.

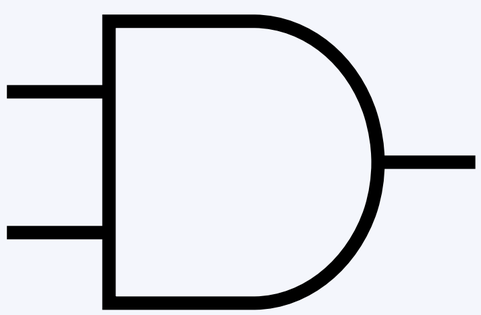
The ALU (arithmetic logic unit) is the component within the CPU where logical decisions are made. This decision making process is called Boolean logic.

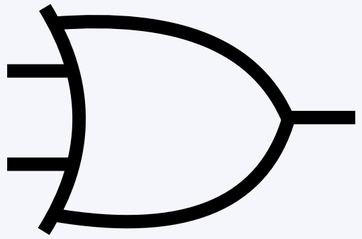


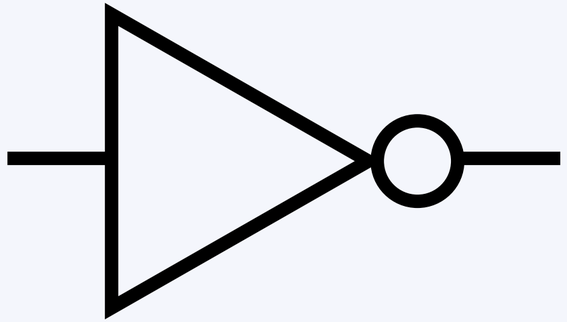
Logic Gates

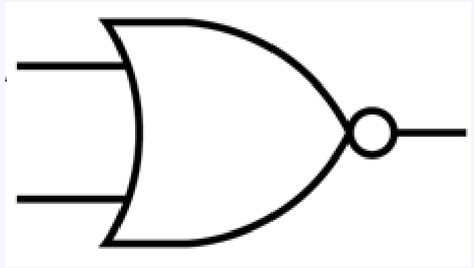
Boolean algebra is represented using logic gate symbols.

Logic gates use Boolean algebra to take one or more binary inputs and produce a single binary output.





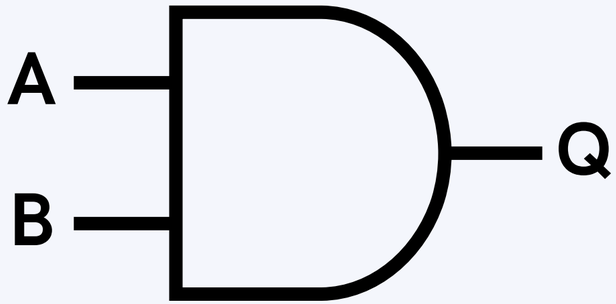




AND Gate

Both inputs must be true for a true output. It uses Boolean agebra:

$$A \times B = Q$$



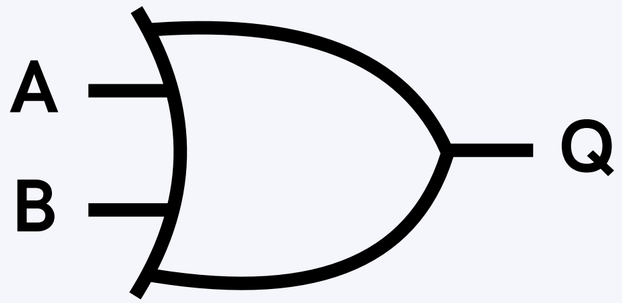
Input		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

Input		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

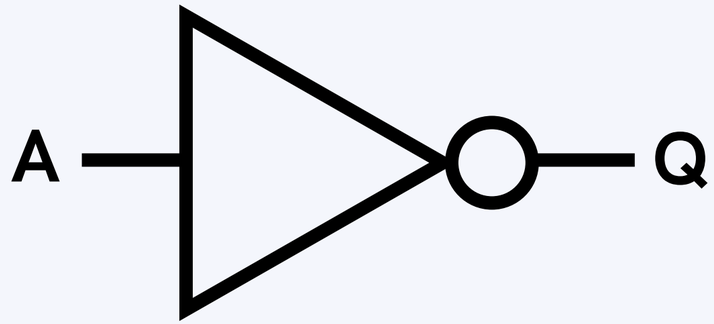
OR Gate

Only one input needs to be true for a true output. Uses boolean algebra:

$$A + B = Q$$



NOT Gate

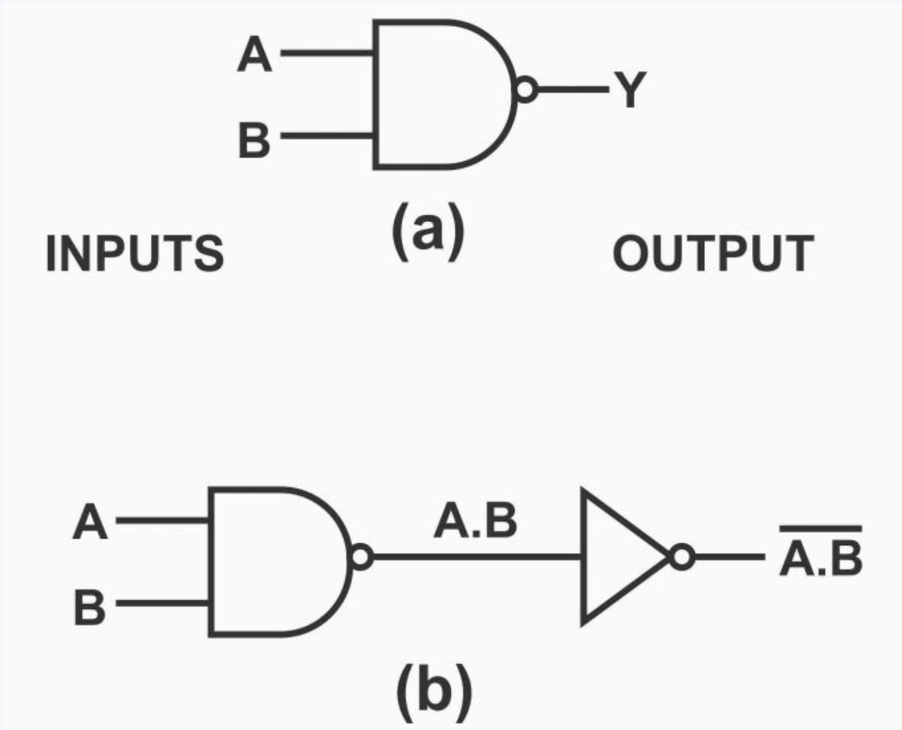


A single input is reversed for a single ouput.
also known as an inverter

Input	Output
A	Q
0	1
1	0

NAND Gate

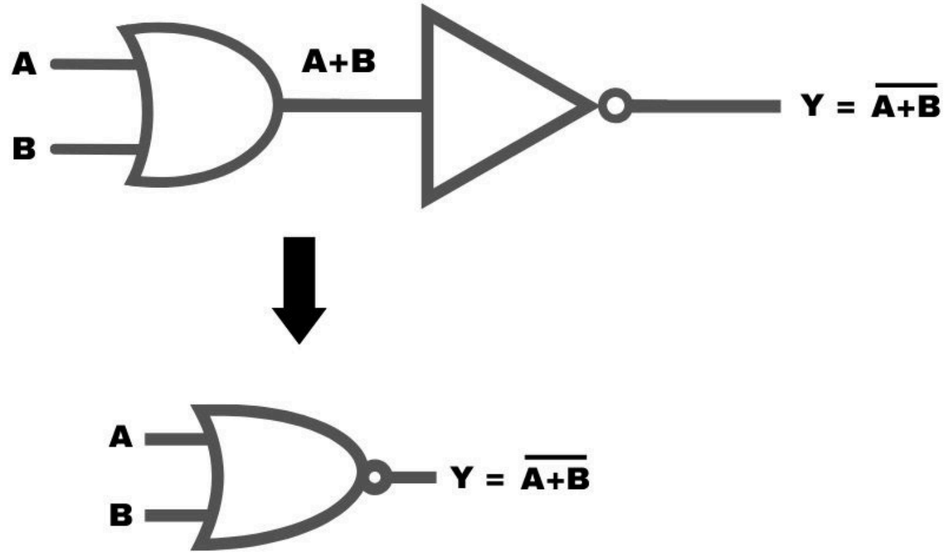
Input		Output
A	B	Q
0	0	
0	1	
1	0	
1	1	



Only one input can be true for a true output.

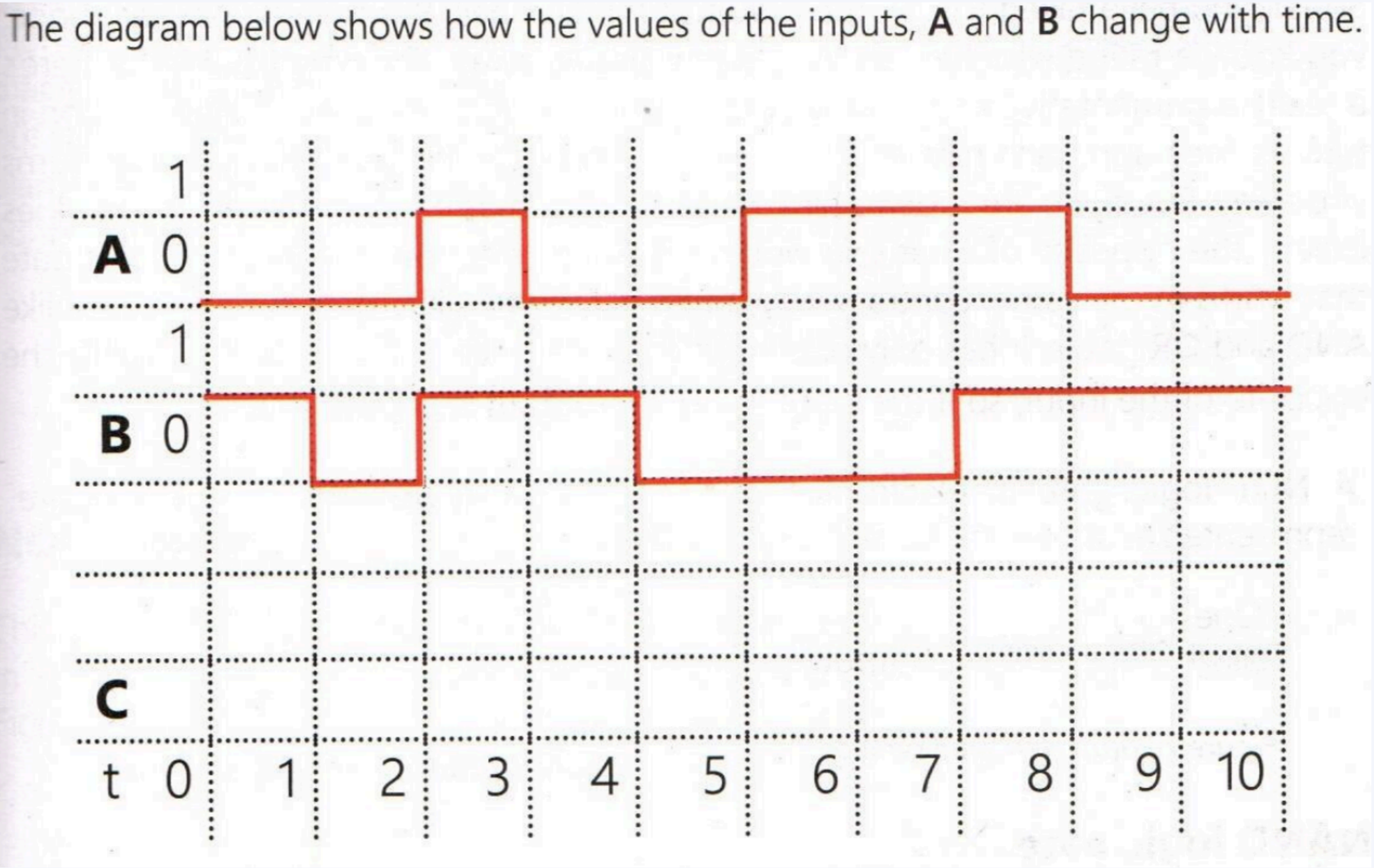
NOR Gate

Input		Output
A	B	Q
0	0	
0	1	
1	0	
1	1	0



Only one input can be true for a true output.

The diagram below shows how the values of the inputs, **A** and **B** change with time.



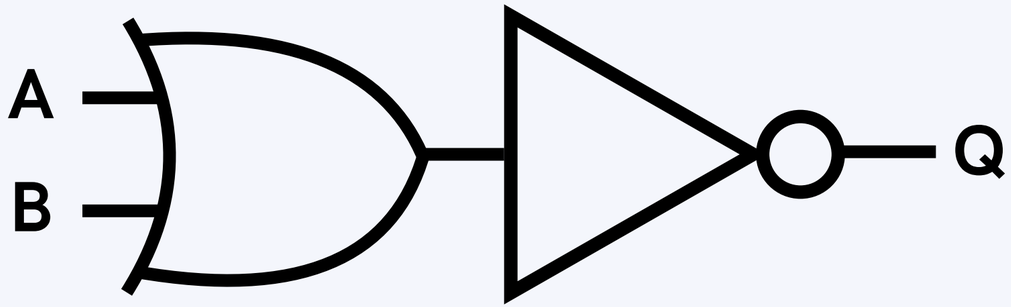
Activity

Input		Output
A	B	C
0	0	
0	1	
1	0	
1	1	

Determine the wave form for output C and determine the OR truth table for it.

Logic Circuits

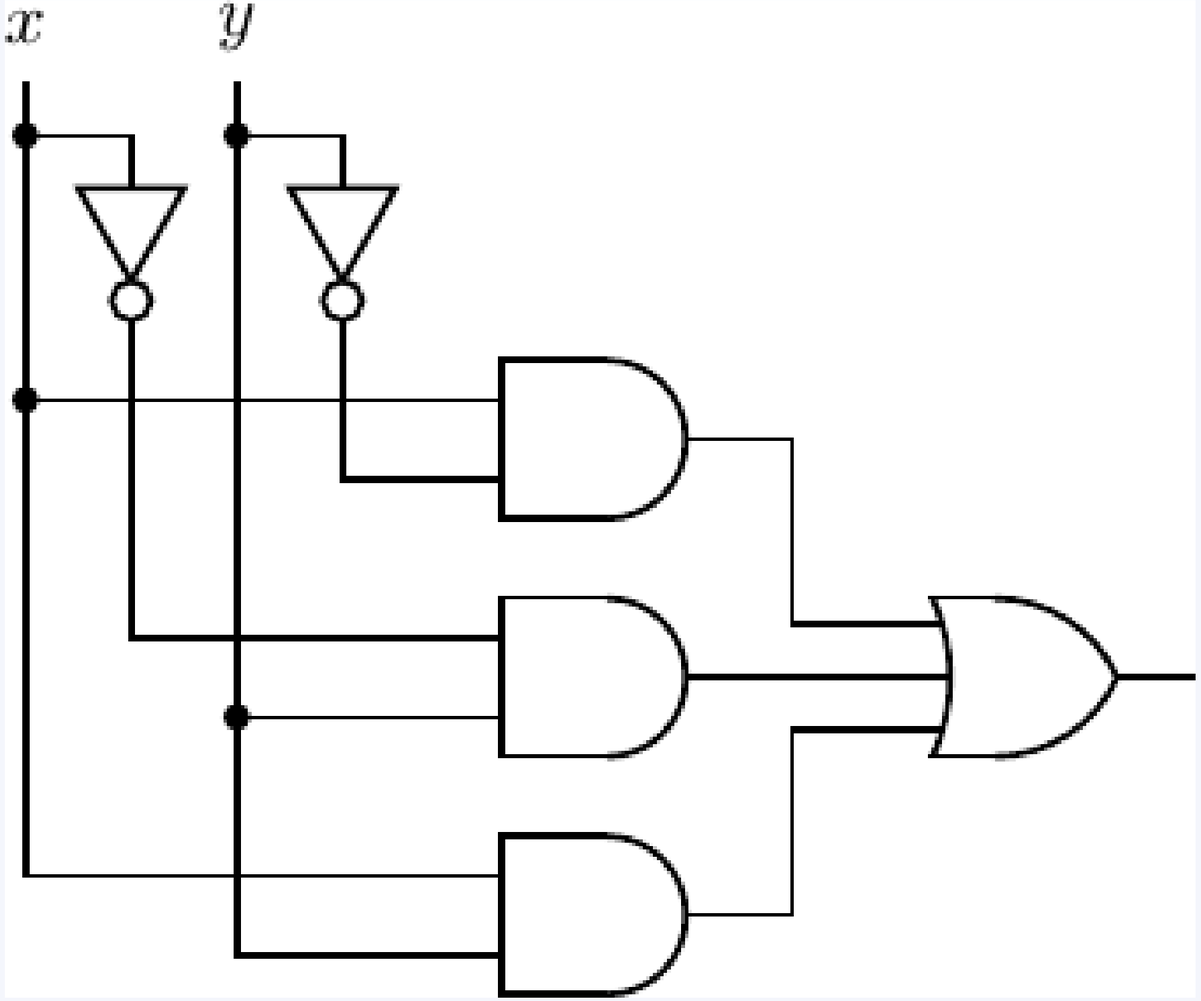
Multiple logic gates can be combined to create a logic circuit. In this example, the output of the OR gate is reversed through the NOT gate.



Input		Output
A	B	Q
0	0	
0	1	
1	0	
1	1	

Logic Circuits

x	y	Output C



Astable and Bistable switches.

An astable switch is a type of circuit that continuously oscillates between its two unstable states without requiring any external triggering. Because it has no stable state, it generates a continuous square wave output, making it useful for applications like clocks, timers, and pulse generators.

A bistable switch is a type of circuit that has two stable states. It remains in one state until an external trigger causes it to switch to the other state. Bistable circuits are fundamental in storing binary information, making them crucial for memory elements and data storage.