3.3 Transistors and gates

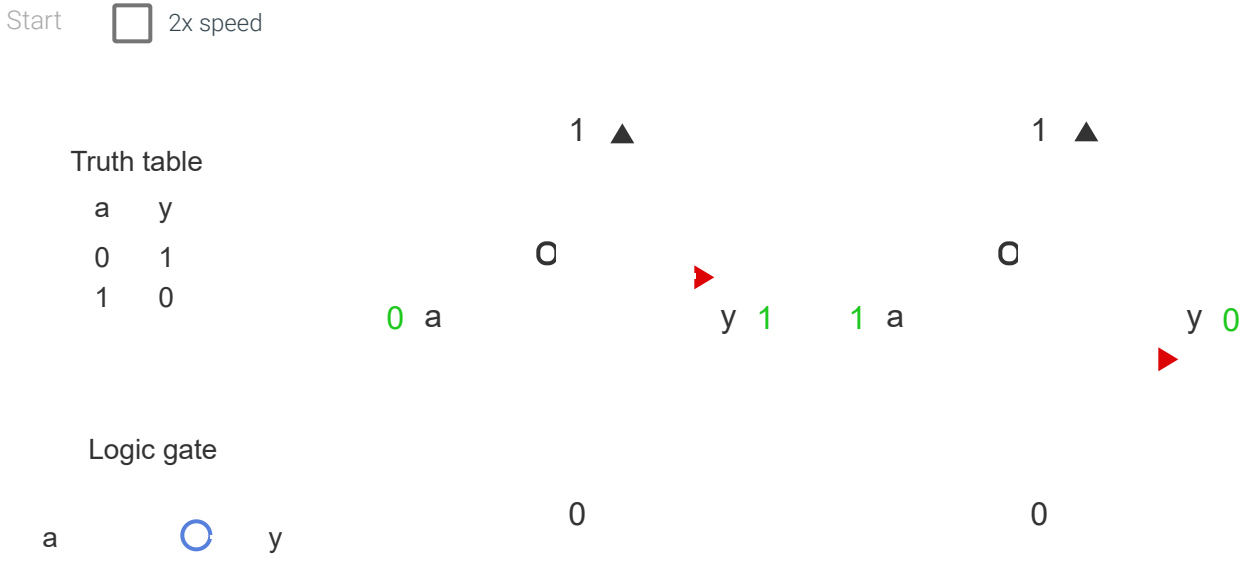
Building complex circuits from transistors is hard. In 1938, Claude Shannon described how transistor circuits could implem functions. Common ***logic functions*** include AND, OR, and NOT.

A ***logic gate*** (or just ***gate***) is a transistor circuit that implements a logic function. The usefulness of gates will be seen later.

NOT gate (inverter)

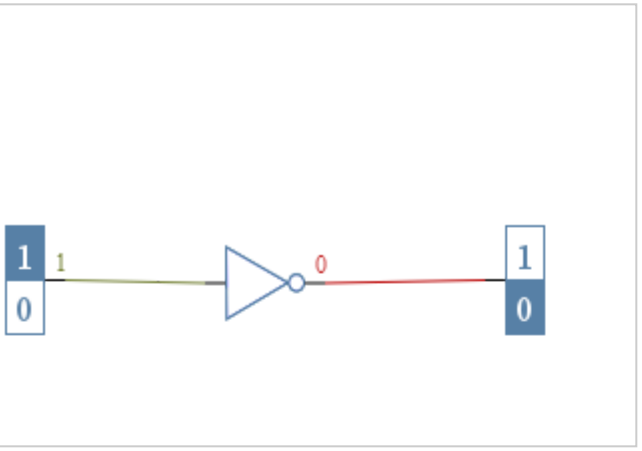
A ***NOT*** gate outputs 1 if the gate's input is 0, and outputs 0 if the input is 1. A NOT gate is also called an ***inverter***. The follow pMOS and an nMOS transistor implements a NOT gate.

PARTICIPATION ACTIVITY 3.3.1: NOT gate built from CMOS transistors.



PARTICIPATION ACTIVITY 3.3.2: NOT gate. Click the input on the left, observe the output.

Reset



PARTICIPATION ACTIVITY 3.3.3: NOT gate.

1) If the input is 1, a NOT gate outputs ____ .
   - 0
   - 1

2) If the input is 0, a NOT gate outputs ____ .
   - 0
   - 1

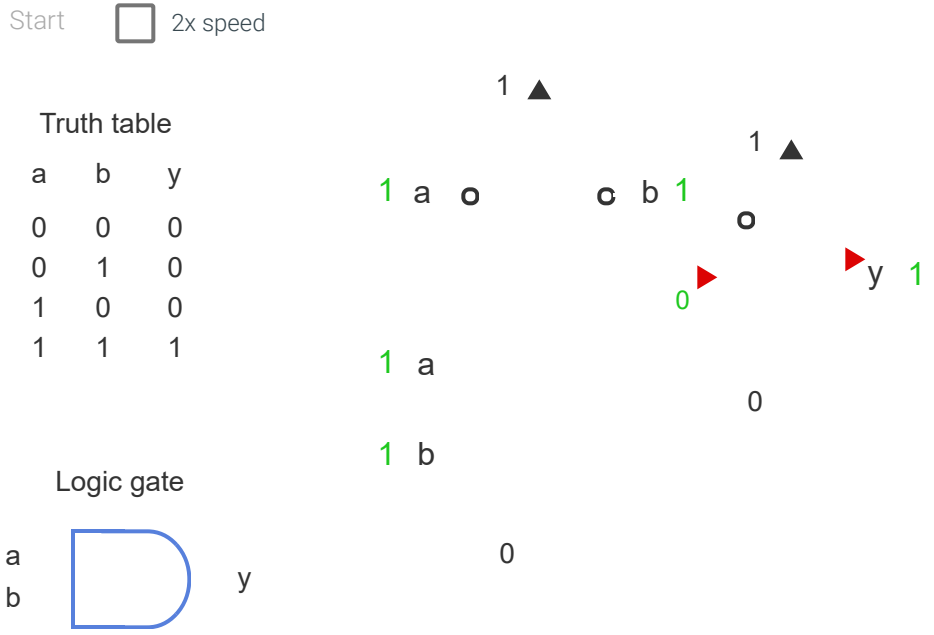
3) A NOT gate is also called an _____ .

- ○ oppositer
- ○ inverter

AND gate

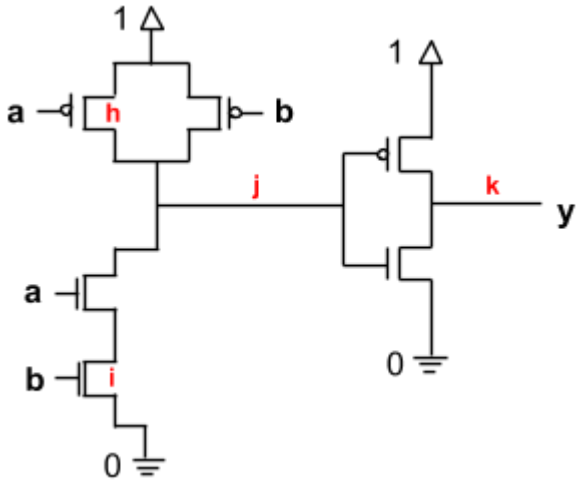
An ***AND*** gate outputs 1 only if both the gate's inputs are 1's. The following transistor circuit implements an AND gate.

PARTICIPATION ACTIVITY 3.3.4: AND gate built from CMOS transistors.



One might ask why the AND circuit isn't implemented more simply, with 0 at the top and 1 at the bottom, omitting the NOT answer is that pMOS is a poor conductor of 0's, and nMOS a poor conductor of 1's, for physics reasons beyond our scope.

PARTICIPATION ACTIVITY 3.3.5: CMOS AND gate.



Provide answers as: yes, no, 1, or 0.

1) If a = 0, b = 0, does h conduct?

Check Show answer

2) If a = 0, b = 0, does i conduct?

Check Show answer

3) If a = 0, b = 0, then j is ?

Check Show answer

4) If a = 0, b = 0, then k is ?

Check Show answer

5) If a = 1, b = 0, then j is ?

Check Show answer

6) If a = 1, b = 0, then k is ?

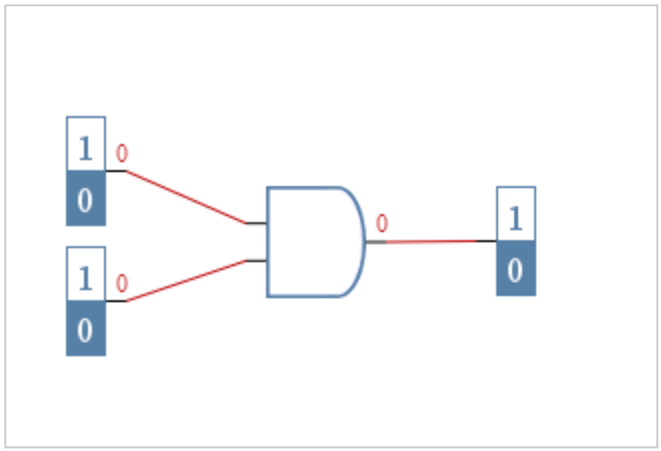
Check Show answer

7) If a = 1, b = 1, then k is ?

Check Show answer

PARTICIPATION ACTIVITY 3.3.6: AND gate with two inputs. Click inputs on left, observe output.

Reset



OR gate

An ***OR*** gate outputs 1 if either, or both, of the gate's inputs is a 1. The following transistor circuit implements an OR gate.

PARTICIPATION ACTIVITY 3.3.7: OR gate built from CMOS transistors.

Start 2x speed

Truth table

a	b	y
0	0	0
0	1	1
1	0	1
1	1	1

Logic gate

a
b
y

PARTICIPATION ACTIVITY 3.3.8: OR gate.

Refer to above OR gate animation.

1) If a = 0, b = 0, what is t (the output of the "NOR" circuit)?
   - 1
   - 0

2) If a = 0, b = 0, what does the OR gate output?
   - 1
   - 0

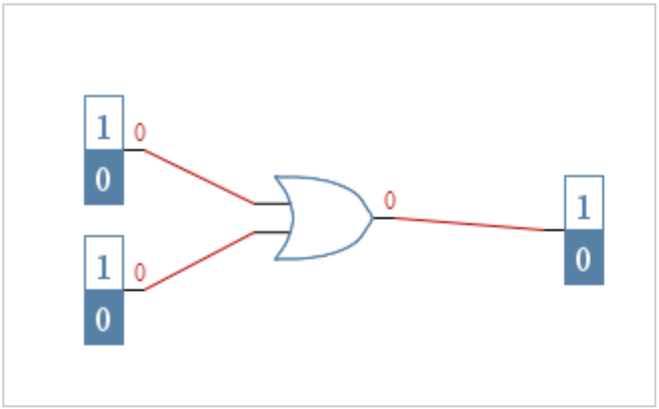
3) If a = 0, b = 1, what is t (the output of the "NOR" circuit)?
   - 1
   - 0

4) If a = 0, b = 1, what does the OR gate output?
   - 1
   - 0

PARTICIPATION ACTIVITY 3.3.9: OR gate with two inputs. Click inputs on

left, observe output.

Reset

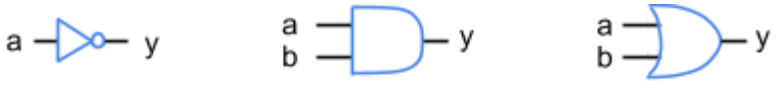


Logic gates summary

The following figure summarizes the NOT, AND, and OR gates.

Note: OR and AND gates may have more than two inputs. OR outputs 1 if at least one input is 1. AND outputs 1 only if all in

Figure 3.3.1: Logic gates and truth tables: NOT, AND, and OR.



NOT

a	y
0	1
1	0

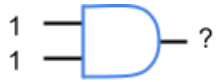
AND

a	b	y
0	0	0
0	1	0
1	0	0
1	1	1

OR

a	b	y
0	0	0
0	1	1
1	0	1
1	1	1

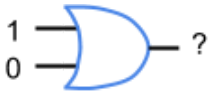
PARTICIPATION ACTIVITY 3.3.10: Logic gates: NOT, AND, and OR.

1) 

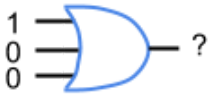
- 0
- 1

2) 

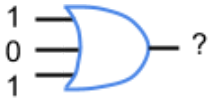
- 0
- 1

3) 

- 0
- 1

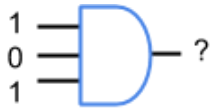
4) 

- 0
- 1

5) 

- 0
- 1

6)



- 0
- 1

PARTICIPATION ACTIVITY 3.3.11: Example systems implemented using one logic gate.

Indicate which one logic gate is best suited to implement the desired system functionality.

1)

If either of two windows is open, an alarm should sound.

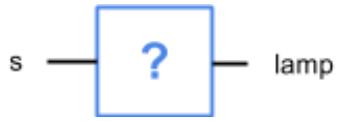
- NOT
- OR
- AND

2)

A plane enables its engines (output e = 1) as long as both pilots are seated (input s = 1, input t = 1).

- NOT
- OR
- AND

3)



A sensor detects sunlight (s = 0 means no sunlight, s = 1 means sunlight). Based on that sensor, a lamp should turn on (lamp = 1) only at night.

- NOT
- OR
- AND

4)

Disneyland's Little Mermaid ride automatically outputs a stop signal (s = 1) if a person is detected on any of numerous pressure-sensitive mats next to the ride's cars.

- OR
- AND

5)

A car has pressure sensors in each tire. If a tire's pressure is low, a warning light should illuminate.

- OR

AND

6)

An office has four space heaters. However, the office's electrical system can only support three being on at one time. An alarm sounds if all four are turned on.

- OR
- AND

Provide feedback on this section