Teaching London Computing

Programming for GCSE
Topic 9.1: Logic Circuits

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Aims

- Show how computers are built from logic gates
  - Logic gates
  - … and truth tables
  - … and boolean algebra
  - …
  - *Circuit for Adding*

Teaching Issue

- How to provide a coherent, joined up view
  - Some curricula include logic circuits but it is not related to operation of a computer
  - Logic circuits → add binary numbers → *computer architecture*

Logic Gates

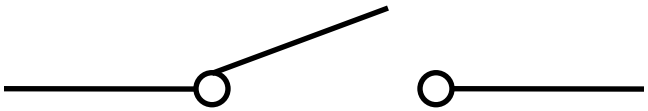
And, Or, Not

Logic Gates

- Logic gates are electronic components
  - Transistors

- Gates behave like switches
  - Two states
  - State represented by a boolean variable

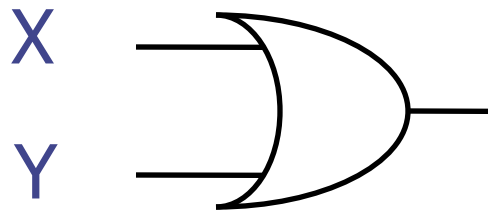
open, X = 0

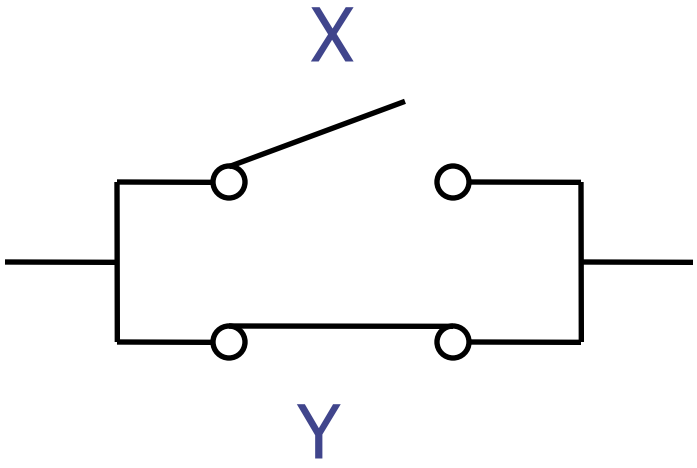


closed, X = 1

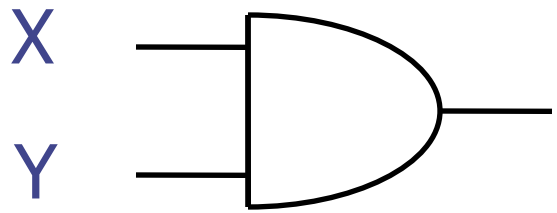
Basic Logic Gates

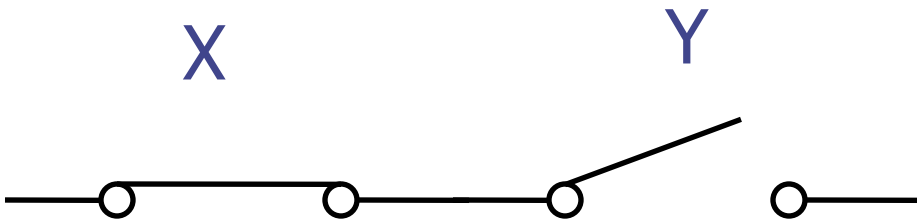
- OR gate



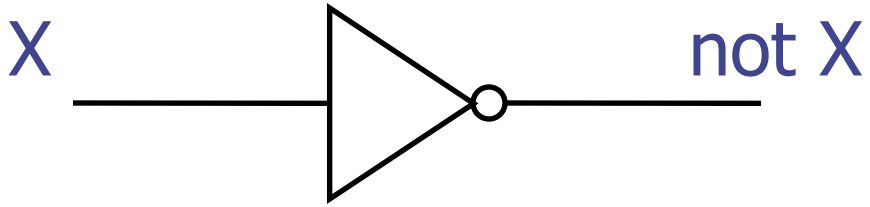


- AND gate

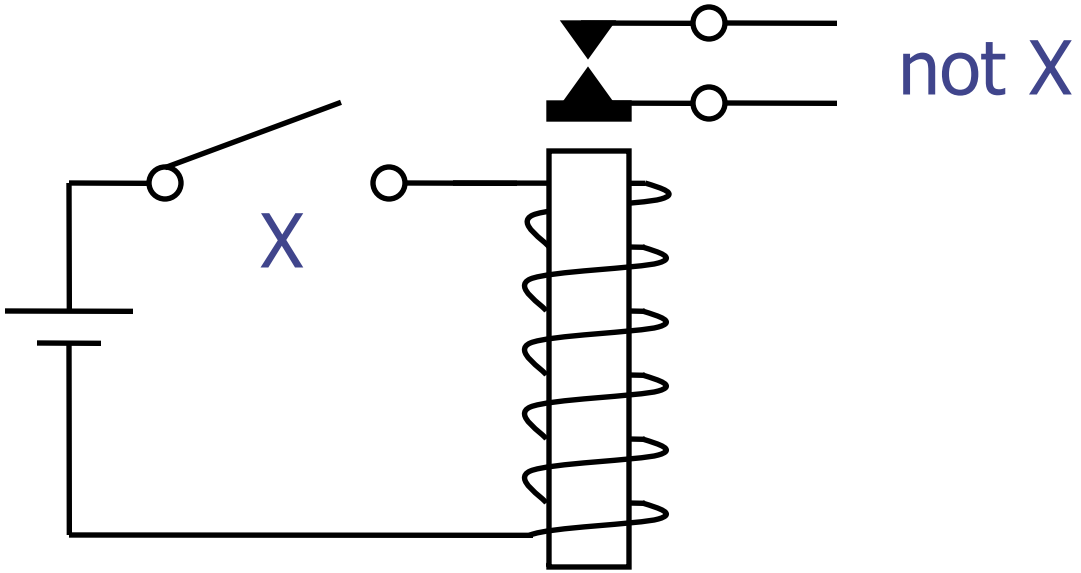




NOT Gate

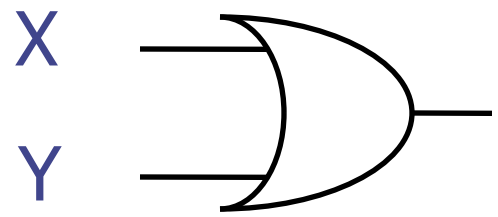


- Only 1 input

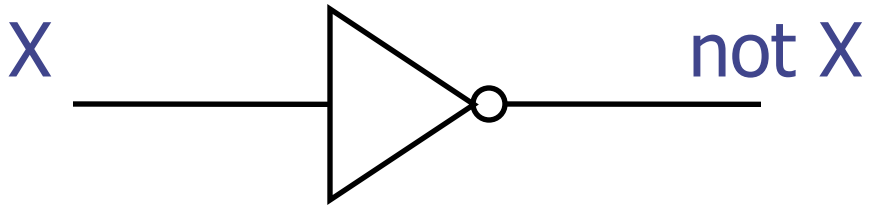


Basic Logic Gates

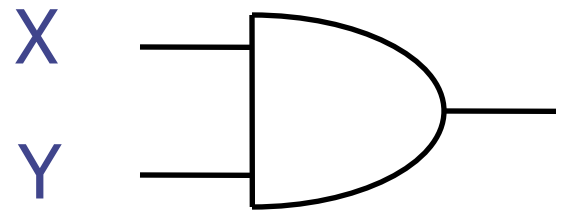
OR gate



NOT gate

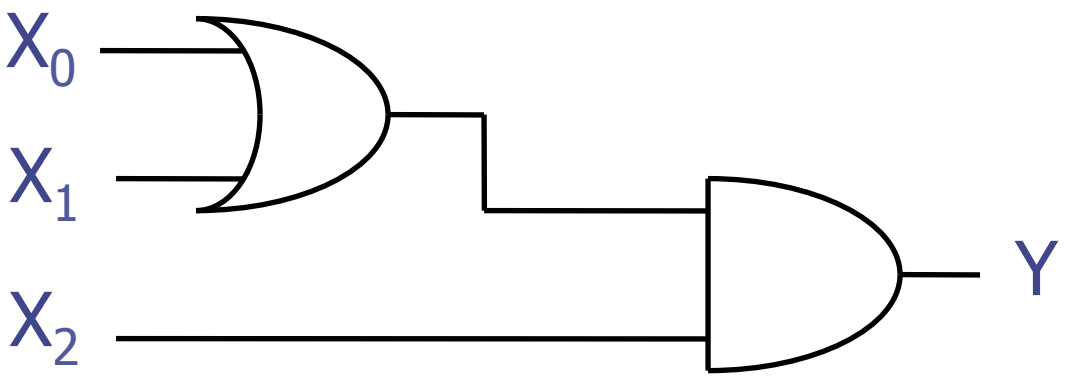


AND gate



Connecting Gates

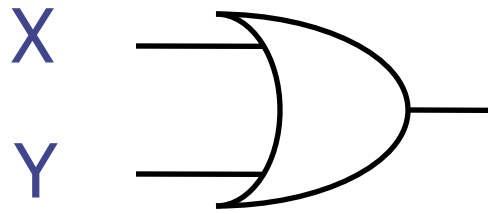
- Output of one gate connects to input for next



Truth Tables For Circuits

AND, OR

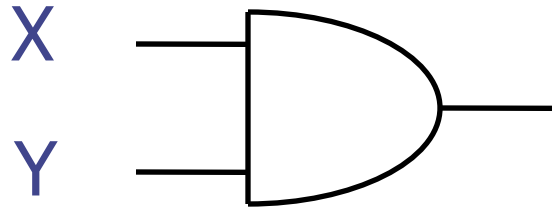
- OR gate



X	Y	X + Y
0	0	0
0	1	1
1	0	1
1	1	1

True when either X or Y true

- AND gate

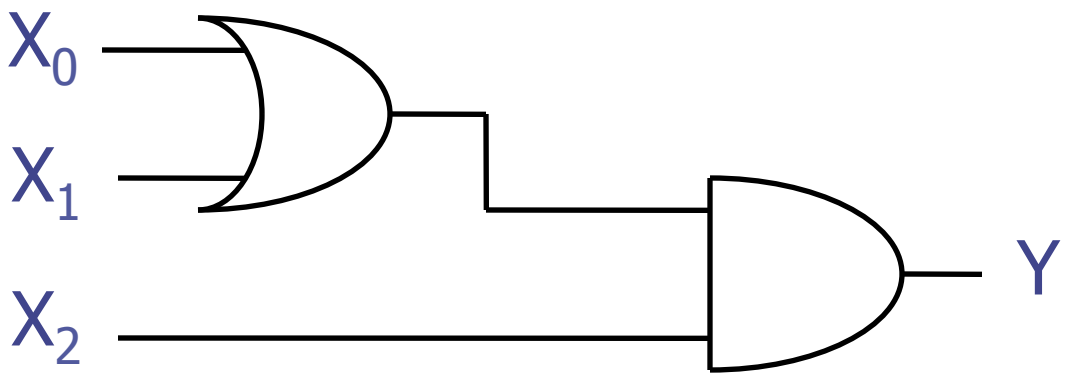


X	Y	X . Y
0	0	0
0	1	0
1	0	0
1	1	1

True when both X and Y true

Circuit to Truth Table

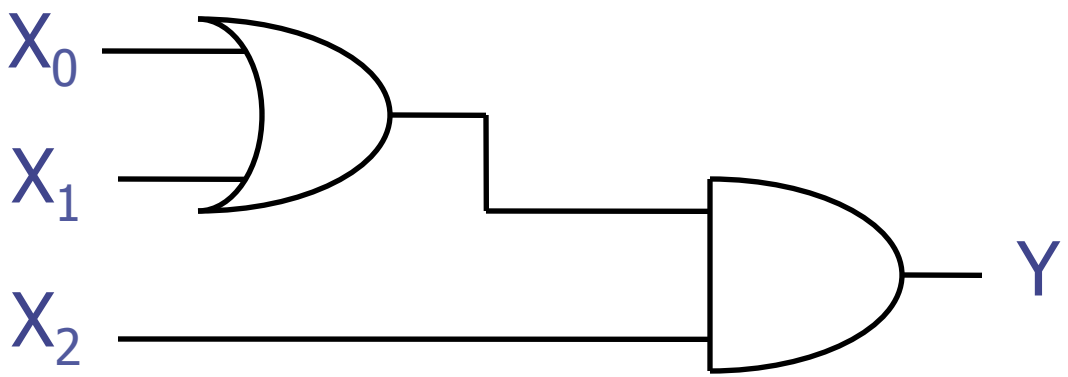
- Test a circuit



X2	X1	X0	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Circuit to Truth Table

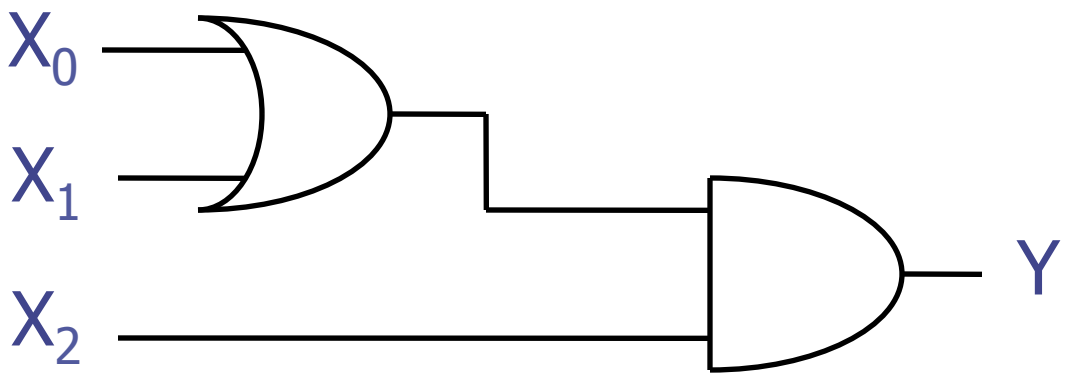
- Test a circuit



X2	X1	X0	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Circuit to Truth Table

- Test a circuit



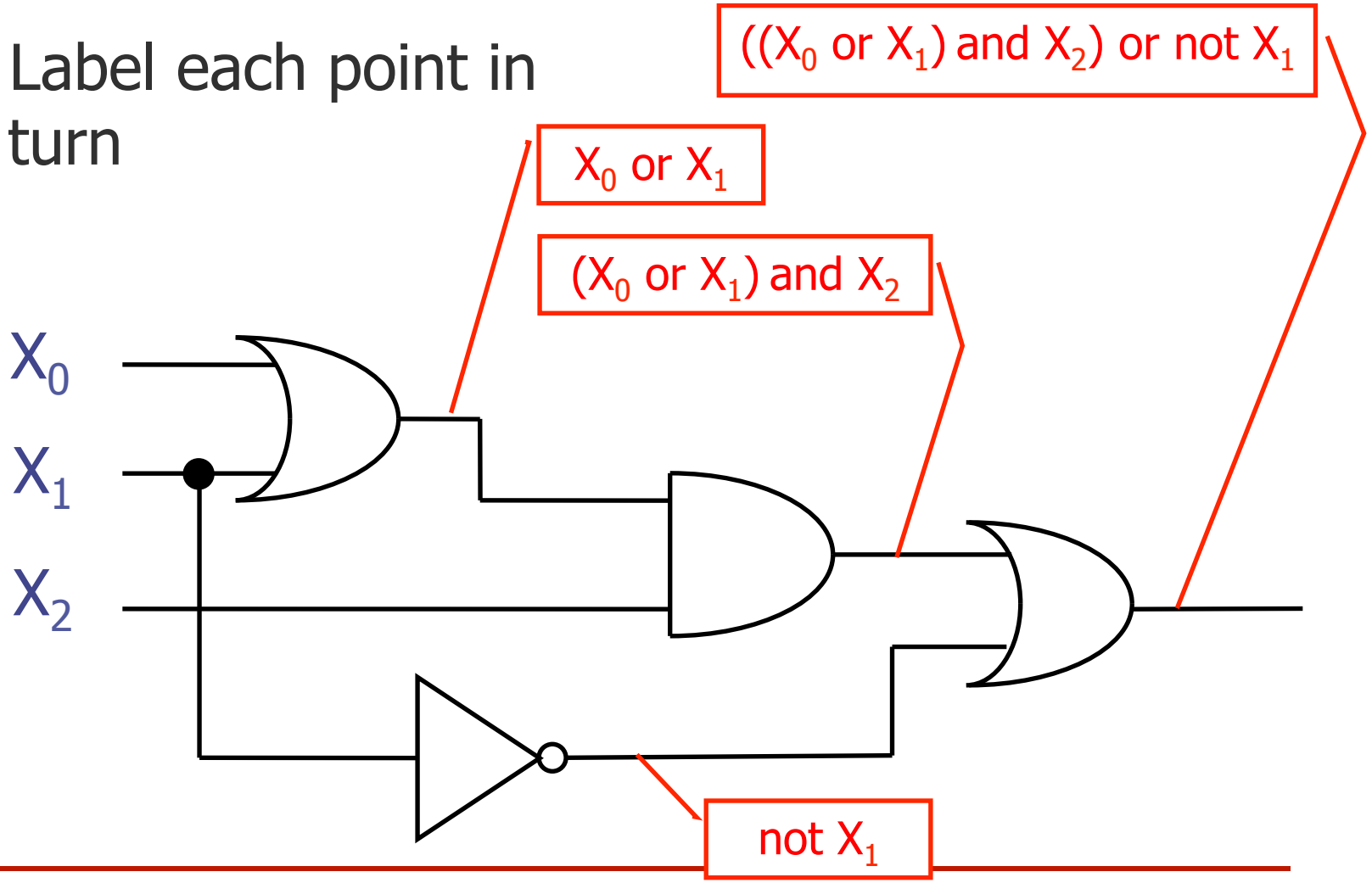
X2	X1	X0	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Two circuits equivalent if (and only if) they have the same truth table

Translating Circuits to Boolean Algebra

Circuit to Formula

- Label each point in turn



De-Morgan's Laws – Recap

- Important law for exchanging AND with OR

$$\overline{(A \cdot B)} = \overline{A} + \overline{B}$$

'A and B' is false when either A is false or B is false

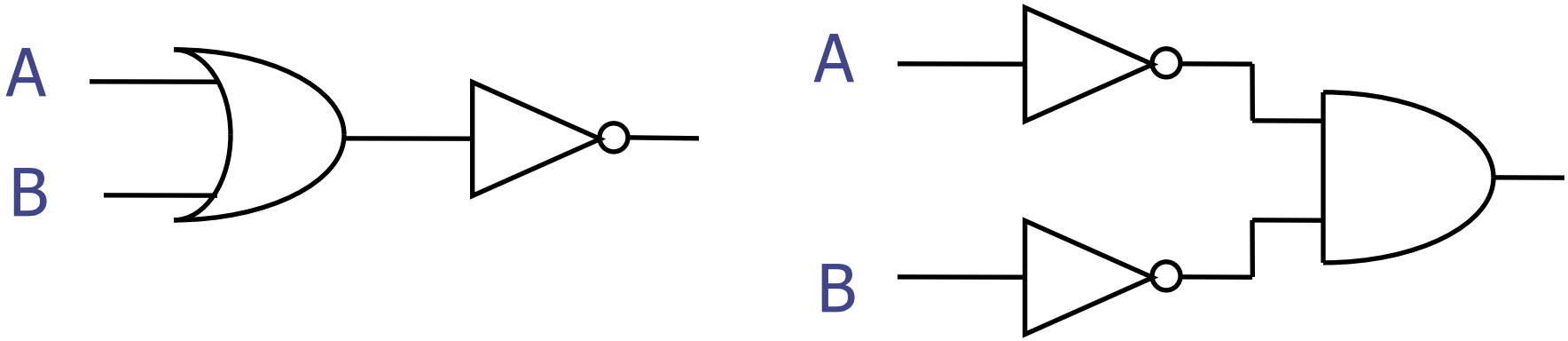
$$\overline{(A + B)} = \overline{A} \cdot \overline{B}$$

'A or B' is false when both A is false and B is false

De-Morgan's Law II

$$\overline{(A + B)} = \overline{A} \cdot \overline{B}$$

- Same with circuits

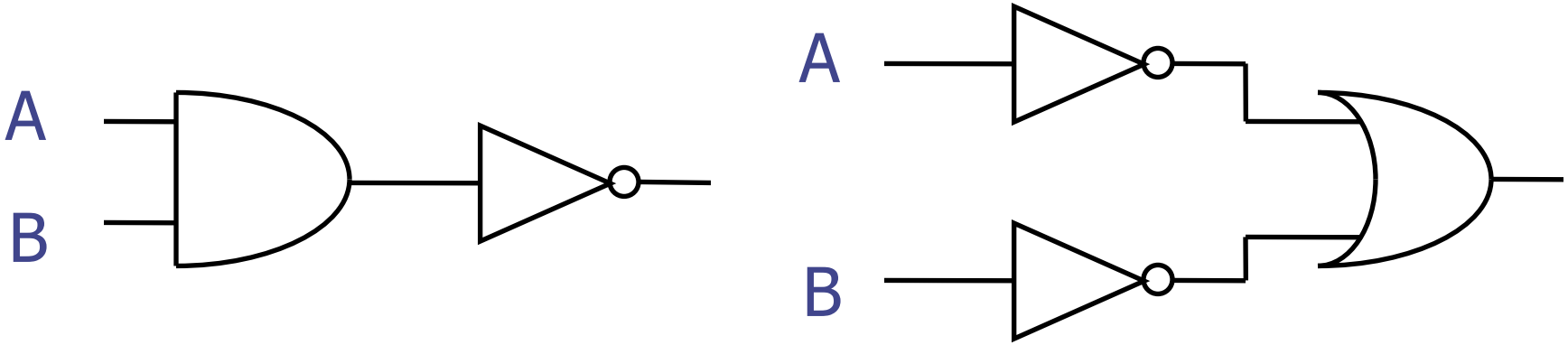


- Quiz: draw the other law as a circuit

De-Morgan's Law III

$$\overline{(A \cdot B)} = \overline{A} + \overline{B}$$

- Second law as a circuits



Summary

- Logic circuits
  - Build a computer
- Truth table
  - Specify a circuit
- Boolean expression (formula)
  - Algebraic rules

- All express same thing
  - Translate from one to other