Week 2: Logic gates

Computer hardware is comprised of binary logic systems, which are made using logic gates.

There are three basic logic gates: AND, OR, NOT and the derived negated gates: NAND, NOR, XOR, XNOR. All logic systems may be built out of the first three, or out of NAND and NOR gates. These gates are implemented in standard configurations, and later on these in turn are combined to produce complete circuits.

- Computer hardware is made from logic gates
  - Basic logic gates: AND, OR, NOT
  - Derived negated gates: NAND, NOR, XOR, XNOR
- Any logic circuits can be build from combinations of just AND, OR, NOT
  - alternatively, use just NAND, NOR

AND gate

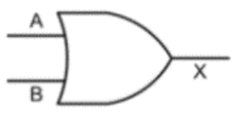
There are two inputs and one output. The output is true only when both inputs are true: when all inputs are 1, the output is also a 1. The AND Boolean expression is: A . B . In a logic diagram, it is represented by this symbol:

The behaviour of a gate may be expressed using a truth table. This defines the output for all possible combinations of inputs.

Inputs		Output
A	**B**	**X**
0	0	0
0	1	0
1	0	0
1	1	1

OR gate

There are two inputs and one output. The output of the gate is true when either of the inputs is true. The equivalent boolean expression is A + B . The corresponding symbol and truth table are:

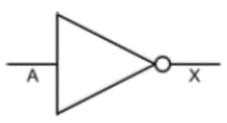


Inputs		Output
A	**B**	**X**
0	0	0
0	1	1
1	0	1
1	1	1

Logic design software (e.g. DigitalWorks) gives you the option of gates with more than two inputs (e.g. 3 or 4 inputs to an AND or OR gate). This often simplifies logic diagrams.

NOT gate

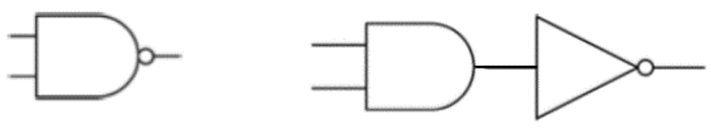
There is a single input and a single output. The output is the opposite state to the input, i.e. the output is the input inverted. The symbol and truth table for a NOT gate are as follows:



Input	Output
A	**X**
0	1
1	0

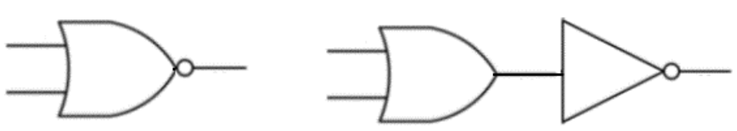
NAND gate

This is equivalent to the Boolean Expression: X = -(A . B) (i.e. NOT (A AND B)). The symbol and truth table for the NAND gate is:



NOR gate

This is equivalent to the Boolean expression X = -(A + B) (i.e. NOT (A OR B)). The symbol and truth table for the NOR gate is:



Inputs		Output
A	**B**	**X**
0	0	1
0	1	0
1	0	0
1	1	0

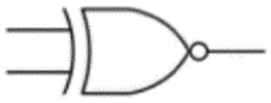
XOR gate

This is a slightly different gate, very commonly used in digital logic. It is called the Exclusive OR, written with the expression A → B. For this gate the output is true when the inputs are different, and it is false when the inputs are the same.

Inputs		Output
A	**B**	**X**
0	0	0
0	1	1
1	0	1
1	1	0

XNOR gate

This gate is the negation of the XOR gate, and so it corresponds to the Boolean expression -(A → B). Naturally, the output of the XNOR gate is 1 when both inputs are the same, as this is opposite of the XOR gate.



Inputs		Output
A	**B**	**X**
0	0	1
0	1	0
1	0	0
1	1	1