AQA Computer Science A-Level

4.6.4 Logic gates

Concise Notes

Specification:

4.6.4.1 Logic gates:

Construct truth tables for the following logic gates:

- NOT
- AND
- OR
- XOR
- NAND
- NOR

Be familiar with drawing and interpreting logic gate circuit diagrams involving one or more of the above gates.

Complete a truth table for a given logic gate circuit.

Write a Boolean expression for a given logic gate circuit.

Draw an equivalent logic gate circuit for a given Boolean expression.

Recognise and trace the logic of the circuits of a half-adder and a full-adder.

Construct the circuit for a half-adder.

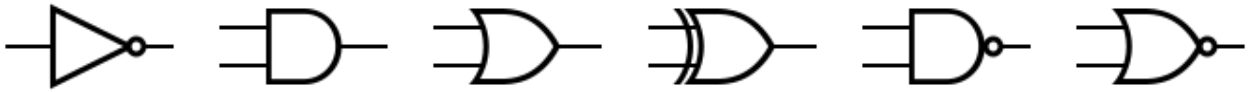
Be familiar with the use of the edge-triggered D-type flip-flop as a memory unit.

Logic Gates

- Billions of them make up processors
- Apply logical operations to one or more Boolean inputs
- Produce a single output
- Can be combined to form logic circuits

Logic Gate Symbols

- Logic gate symbols are internationally recognised
- Inputs are on the left
- Outputs are on the right



NOT AND OR XOR NAND NOR

Truth Tables

- Show every possible combination of inputs and the corresponding output
- Inputs are labelled alphabetically starting with A
- The output is usually labelled Q

NOT

- One input and one output
- The output is always the opposite of the input

A	Q
0	1
1	0

$$Q = \overline{A}$$

AND

- Has two inputs
- Outputs the product of the two inputs
- Only outputs TRUE when both inputs are TRUE

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

$$Q = A \times B$$

OR

- Has two inputs
- Outputs the sum of its inputs
- Only outputs FALSE when both inputs are FALSE

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

$$Q = A + B$$

XOR

- Short for exclusively or
- Outputs TRUE when strictly one input is TRUE
- Has the symbol ⊕

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

$$Q = A \oplus B$$

NAND

- Short for NOT AND
- A combination of two gates: NOT and AND
- The same as AND, but with reversed output

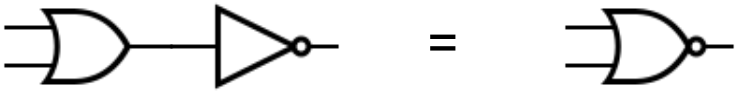
AND NOT NAND

A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

$$Q = \overline{A \times B}$$

NOR

- Short for NOT OR
- A combination of NOT and OR
- The same as OR, just with the output reversed



OR NOT NOR

A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

$$Q = \overline{A + B}$$

Combining Logic Gates

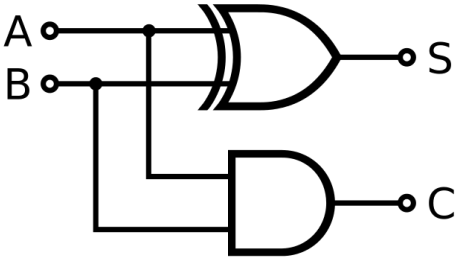
- Logic gates can be combined to form more complex circuits
- In order to create a truth table for a logic circuit:
    1. Fill in a table with all the possible permutations of inputs
    2. Add columns for each of the elements that make up the final output until you have made a column for the final output
    3. Remove columns used for working
    4. Rename the final column Q

Adders

- A logic circuit that can be used to add Boolean values
- Two types:
    1. Half adders
    2. Full adders

Half adders

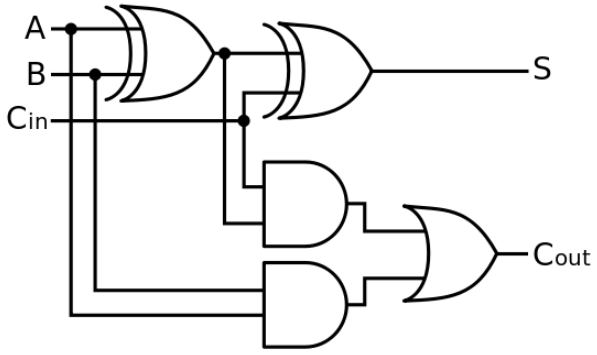
- Two inputs, two outputs and two logic gates
- Used to add two Boolean values
- Inputs labelled A and B
- Outputs labelled S and C
- S and C are short for sum and carry



A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

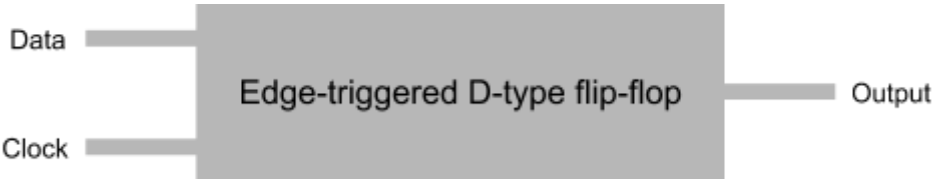
Full adders

- Three inputs labelled A, B and C_{in} for carry in
- Two outputs labelled S for sum and C_{out} for carry out
- Can input two Boolean values and a carry bit
- Carry bit taken from a previous, less significant operation



A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Edge-triggered D-type flip-flop



- Can be used as a memory unit
- Stores the value of a single bit
- Two inputs, one for data and another for a clock signal
- The clock signal:
  - Is generated by the computer
  - Alternates between 0 and 1
  - Alternates at a set frequency
  - Can be used to synchronise numerous flip-flops when they form part of a larger system
- One output, which holds the value of the stored bit
- The value of the stored bit is set with each change of the clock signal