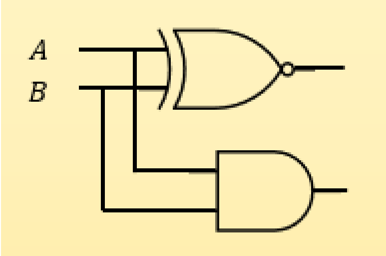
4.6.4 Logic Gates

Logic Gates and Truth Tables

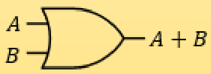
The binary values 1 and 0 can represent Boolean values true and false.

Logic gates take these true or false values, perform a logic operation and output true or false values.

These logic gates are linked together to form a circuit.



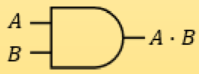
OR Gate



A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

If either of the inputs is 1, then the output is 1. Otherwise the output is 0.

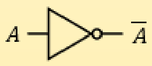
AND Gate



A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

If both of the inputs are 1, then the output is 1. Otherwise the output is 0.

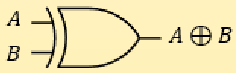
Not Gate



A	NOT A
0	1
1	0

Outputs the negation of the input.
If the input is 0, the output is 1. If the input is 1, the output is 0.

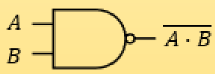
XOR Gate



A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

*If **only one** of the outputs is 1, then the output is 1. Otherwise the output is 0.*

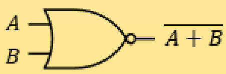
NAND Gate



A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

Outputs the negation of an AND gate.
If both of the inputs are 1, then the output is 0. Otherwise the output is 1.

NOR Gate



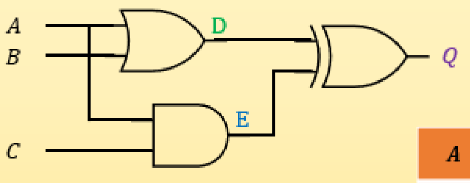
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

Outputs the negation of an OR gate.
If either of the inputs are 1, then the output is 0. Otherwise the output is 1.

Truth Tables

The output of larger circuits can be difficult to work out by sight.

A truth table can be used to find the output of a circuit for different input values by finding the intermediate logic gate outputs and building them towards the overall output.



The Boolean expression for this circuit is:

$(A \cdot B) \oplus (A + C)$

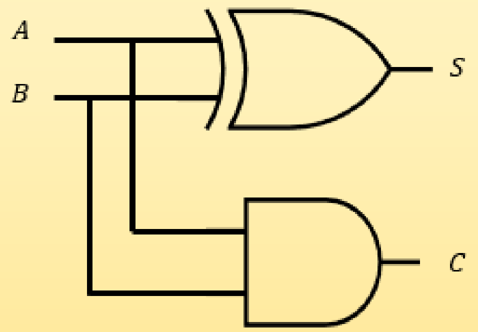
A	B	C	$D = A \cdot B$	$E = A + C$	$Q = (A \cdot B) \oplus (A + C)$
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	0	0	0
0	1	1	0	1	1
1	0	0	0	1	1
1	0	1	0	1	1
1	1	0	1	1	0
1	1	1	1	1	0

Half Adders

A half adder is a logic circuit that performs binary addition of two bits.

It takes two bits as an input and outputs the sum and carry values resulting from their binary addition.

Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1



A half adder can only add up two single-bit binary numbers. In order to add up two multiple bit binary numbers, we would need a more complex circuit called a full adder.

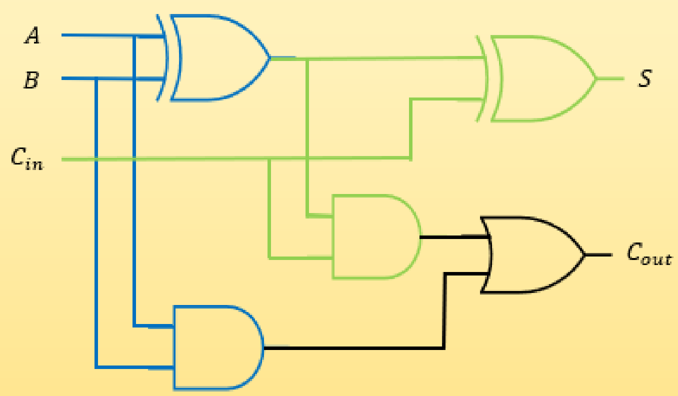
Full Adders

A full adder takes three bits as an input and performs binary addition.

The inputs are A, B and a Carry in (C_{in}). The output is the Sum and Carry out (C_{out}).

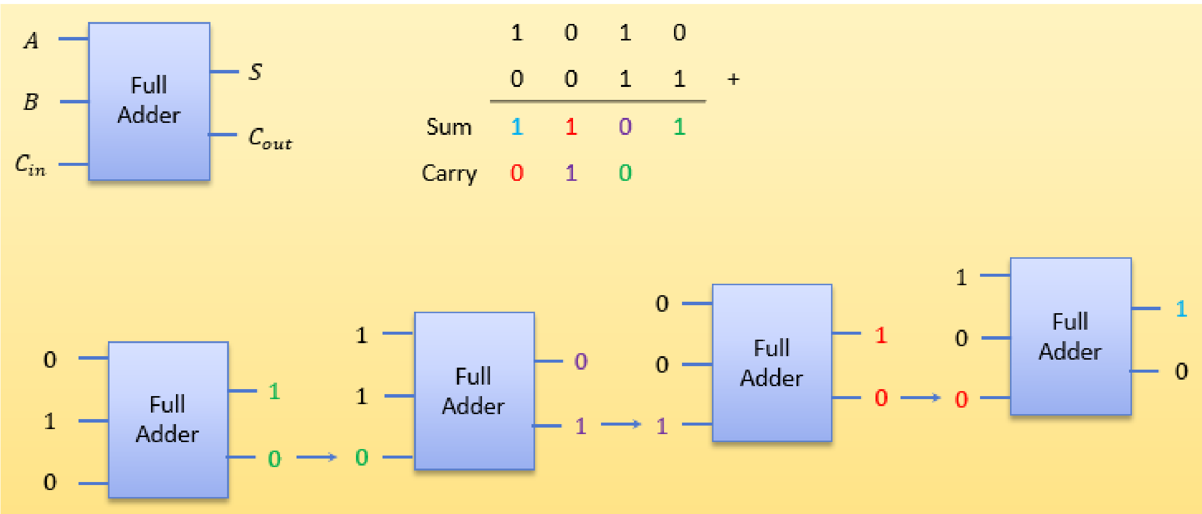
The circuit is constructed from two half adders joined by an OR gate.

Inputs			Outputs	
A	B	C_{in}	Sum	C_{out}
0	0	0	0	0
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1
0	0	1	1	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	1



Full adders can be connected together to add up multiple bit binary numbers.

To add two multi-bit numbers of n bits we would need n full adders connected together where the carry out of one full adder is the carry in of the next.



D-type Flip Flops

A D-type flip flops is a circuit that can **store 1 bit of data**.

It has two inputs; a data stream (D) and a clock signal. On the rising edge of the clocking signal the value of the data input is stored and appears at the output (Q) until the next rising edge of the clock. The inverse of Q is also output as $\overline{Q}$.