Digital Circuit & Microprocessor

Digital Circuit

Digital circuits use transistors to create logic gates in order to perform Boolean logic. This logic is the foundation of *digital* electronics and computer processing.

Types of digital circuits: i) Combinational circuit
ii) Sequential circuit

i) Combinational circuit:

Combinational circuit is a circuit in which we combine the different gates in the circuit. Example: Adder, Subtractor, Encoder, Decoder, Multiplexer and De-multiplexer.

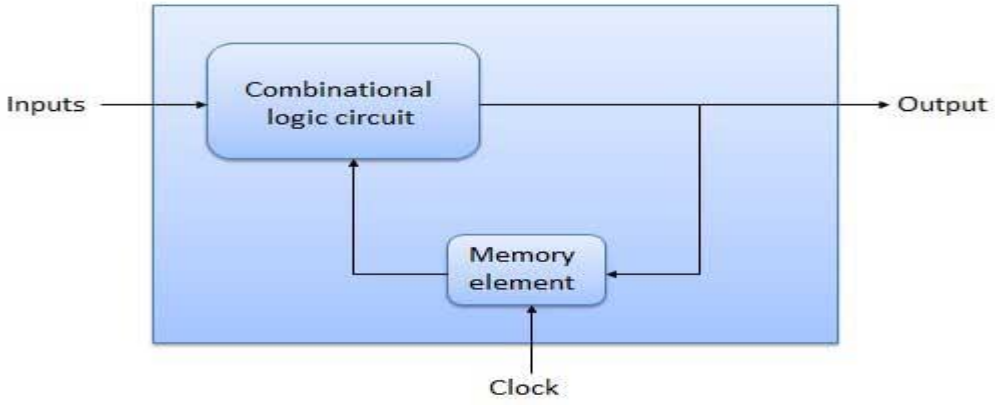
Some of the characteristics of combinational circuits are following −

- The output of combinational circuit at any instant of time, depends only on the levels present at input terminals.
- The combinational circuit do not use any memory. The previous state of input does not have any effect on the present state of the circuit.
- A combinational circuit can have an n number of inputs and m number of outputs.

ii) Sequential circuit:

The combinational circuit does not use any memory. Hence the previous state of input does not have any effect on the present state of the circuit. But sequential circuit has memory so output can vary based on input. This type of circuits uses previous input, output, clock and a memory element.

Example: Flip flop, Counter, Register



Combinational circuit

Adder

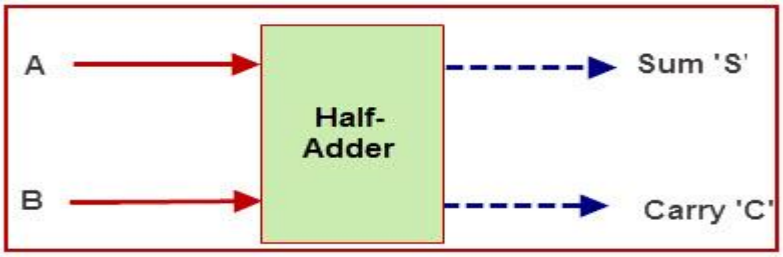
An adder is a digital logic circuit in electronics that implements addition of numbers. In many computers and other types of processors, adders are used to calculate addresses, similar operations and table indices in the ALU and also in other parts of the processors.

Types of adder: i) Half adder
ii) Full adder

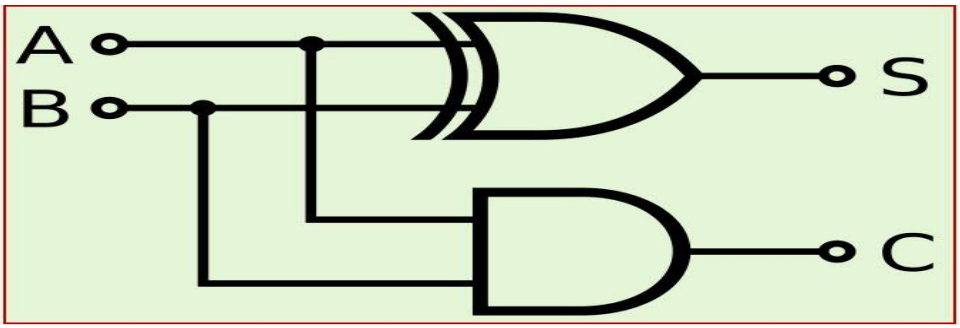
i) Half adder

Half adder is a combinational logic circuit with two inputs and two outputs. The half adder circuit is designed to add two single bit binary number A and B. It is the basic building block for addition of two **single** bit numbers. The half adder adds two binary digits called as augend and addend and produces two outputs as sum and carry; XOR is applied to both inputs to produce sum and AND gate is applied to both inputs to produce carry.

Block diagram:



Circuit:



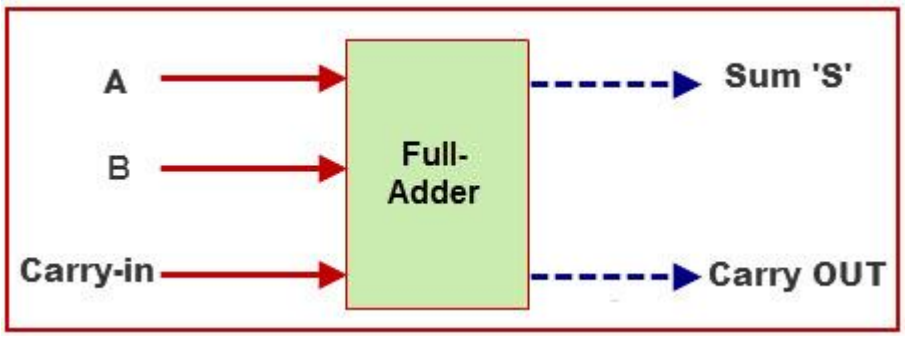
Truth Table:

INPUTS		OUTPUTS	
A	B	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

ii) Full Adder:

Full adder is developed to overcome the drawback of Half Adder circuit. It can add two one-bit numbers A and B, and carry c. The full adder is a three input and two output combinational circuit.

Block Diagram:

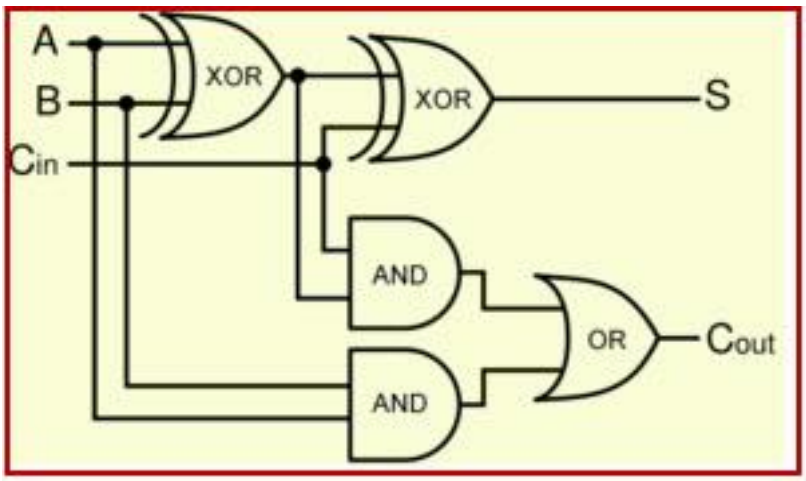


Truth Table:

INPUTS			OUTPUT	
A	B	C-IN	C-OUT	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

With the truth-table, the full adder logic can be implemented. We can see that the output S is an XOR between the input A and the half-adder, SUM output with B and C-IN inputs. We take C-OUT will only be true if any of the two inputs out of the three are HIGH.

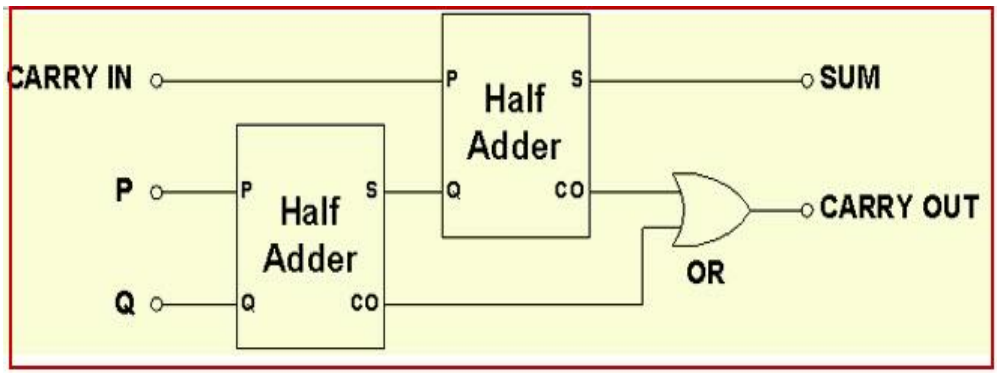
Circuit:



So, we can implement a full adder circuit with the help of two half adder circuits. At first, half adder will be used to add A and B to produce a partial Sum and a second half adder logic can be used to add C-IN to the Sum produced by the first half adder to get the final S output.

Full adder by using half adder

We can implement a full adder circuit with the help of two half adder circuits. At first, half adder will be used to add A and B to produce a partial Sum and a second half adder logic can be used to add C-IN to the Sum produced by the first half adder to get the final S output. If any of the half adder logic produces a carry, there will be an output carry. So, COUT will be an OR function of the half-adder Carry outputs. Take a look at the implementation of the full adder circuit shown below.



Subtractor

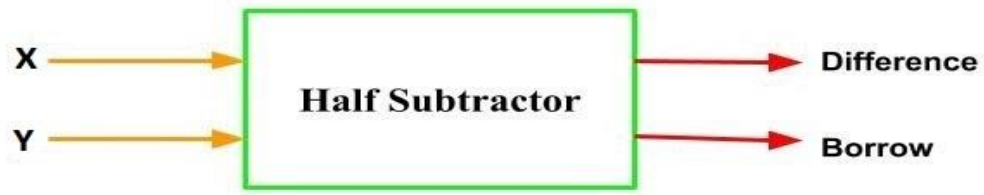
Subtraction is an arithmetical function where one digit is subtracted from another digit to attain equal quantity. The digit from which another digit is to be subtracted is known as minuend. Similarly, the number which is subtracted from the minuend is known as a subtrahend.

Types: i) Half Subtractor
ii) Full Subtractor

i) Half Subtractor

Half subtractor is used to subtract two single bit digits. It includes two inputs as well as two outputs. The inputs are X, Y whereas the outputs are difference (D) and borrow (B).

Block diagram



Truth Table

Input		Output	
X	**Y**	**D**	**B**
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

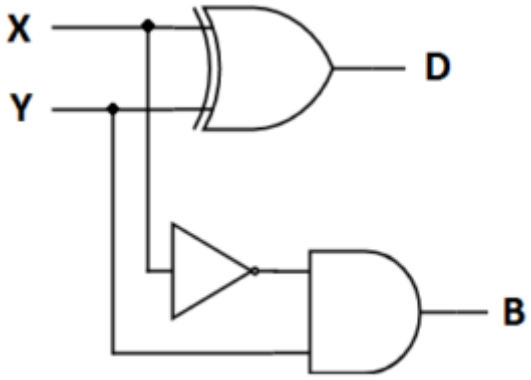
The half subtractor boolean expressions are :

$D = (X'Y+XY') = X \oplus Y$

$B = X'Y$

Circuit Diagram:

From the Boolean expression it is clear that to generate difference Ex-OR is used and to generate borrow AND gate is used.



ii) <u>Full Subtractor</u>

When there is a situation where the minuend and subtrahend number contains more significant bit, then the **borrow** bit which is obtained from the subtraction of 2-bit binary digits is subtracted from the next higher order pair of bits. In such situation, the subtraction involves the operation of 3 bits. Such situation of subtraction can't handle by a simple half subtractor. So, combining two half subtractor we can form another combinational circuit which can perform this type of operation. This circuit is known as the full subtractor.

So we can define full subtractor as a combinational circuit which takes three inputs and produces two outputs **difference** and **borrow**. There are three input variables X, Y and Z which refers to the term **minuend, subtrahend** and **borrow** bit respectively. The two outputs **difference** and **borrow** are named as D and B respectively.

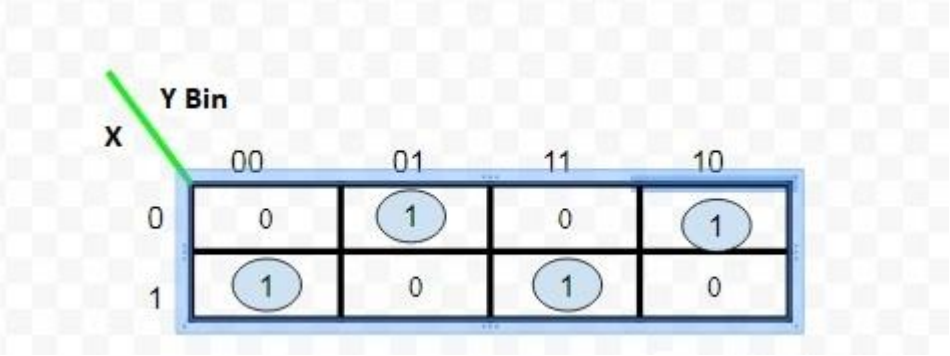
Block Diagram

Truth Table

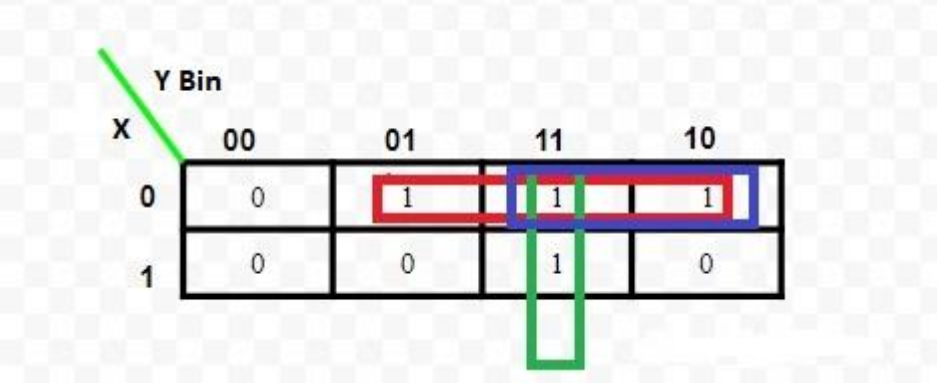
Input			Output	
X	**Y**	**Bin**	**D**	**Bout**
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Full Subtractor K-Map

The simplification of the K-map for the difference and borrow is shown below.



The simplification of the K-map for the difference and borrow is shown below.



The full subtractor expression for Difference is,

$$\mathbf{D = X'Y'Bin + XY'Bin' + X'YBin' + XYBin}$$

The full-subtractor expression for Borrow is,

$$\mathbf{Bout = X'Bin + X'Y + YBin}$$

Circuit Diagram:

From the Boolean expression the full subtractor circuit is drawn as: