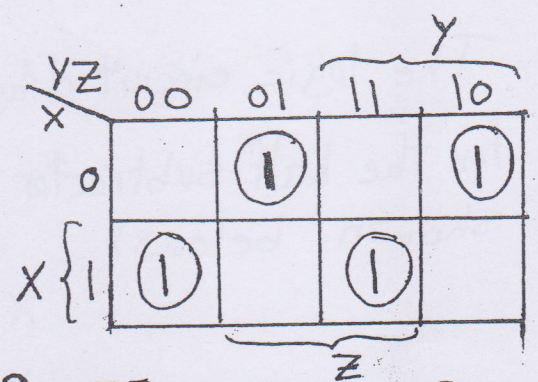
Full Adder (FA)

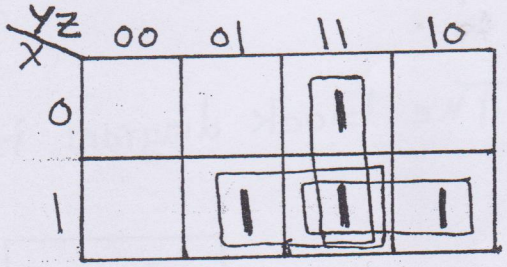
A full-adder is a combinational circuit that forms the arithmetic sum of three bits. It consists of three inputs and two outputs. Two of the inputs variables, denoted by x and y, represent the two significant bits to be added. The third input, z, represents the carry from the previous lower significant position. Two outputs are necessary because the arithmetic sum of three binary digits ranges in value from 0 to 3, and binary 2 or 3 needs two digits. The two outputs are designated by the symbols S for sum and C for carry.

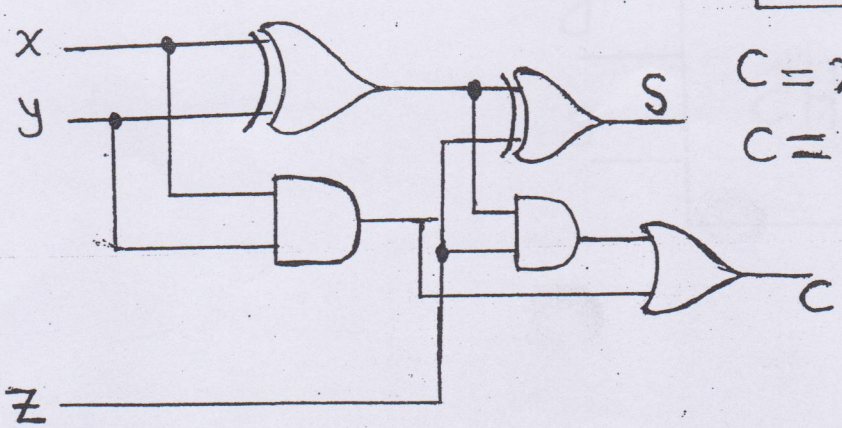
x	y	z	C	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1



$$S = \bar{x}\bar{y}z + \bar{x}y\bar{z} + x\bar{y}\bar{z} + xyz$$

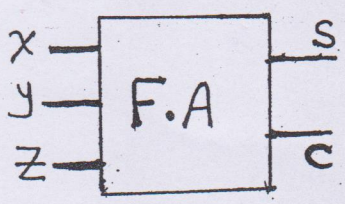
$$S = x \oplus y \oplus z$$





$$C = xy + xz + yz$$

$$C = z(x \oplus y) + xy$$



Half Subtractor (HS)

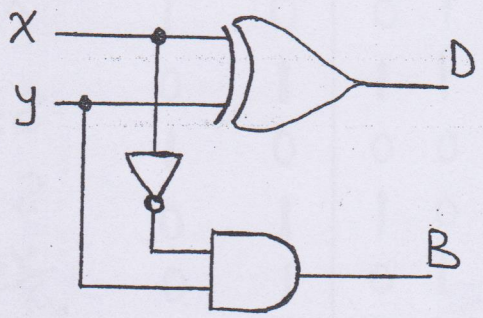
It is used to subtract two binary digits only as show in the following truth table.

Where D is the difference between x and y ($D = x - y$), and B is the Borrow bit from the next significant bit in the number x.

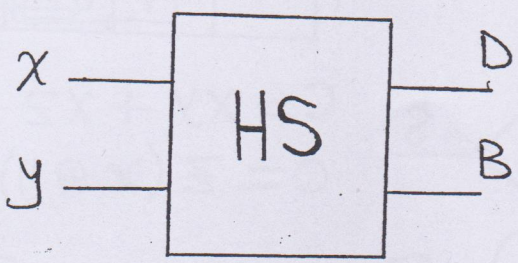
x	y	D	B
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

$$D = \bar{x}y + x\bar{y}$$
$$D = x \oplus y$$
$$B = \bar{x}y$$

The logic circuit diagram for the half subtractor is shown below:



The block diagram is shown below



Full Subtractor (FS)

This circuit is used to subtract three binary digits, the subtract operation is ordered as $(x-y-z)$.

$$D = \bar{x}\bar{y}z + \bar{x}y\bar{z} + x\bar{y}\bar{z} + xyz$$

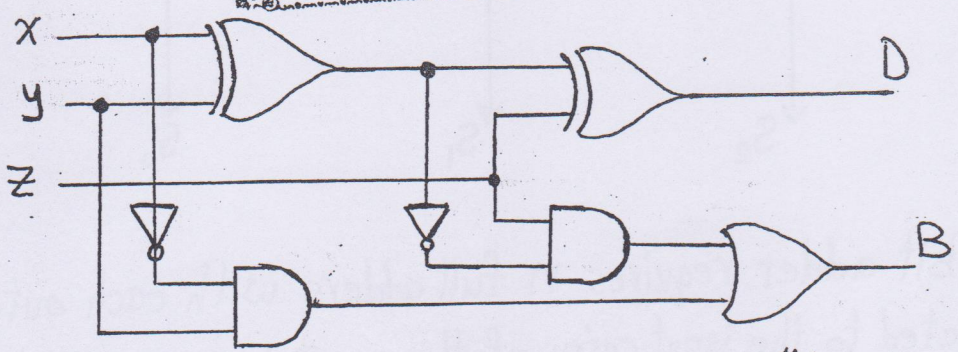
$$D = \bar{x}(\bar{y}z + y\bar{z}) + x(\bar{y}\bar{z} + yz)$$

$$D = x \oplus y \oplus z$$

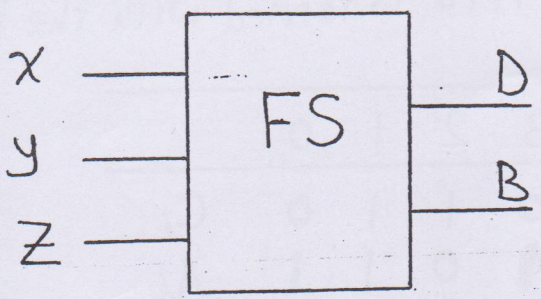
$$B = \bar{x}\bar{y}z + \bar{x}y\bar{z} + \bar{x}yz + xyz$$

$$B = \bar{x}y + \overline{(x \oplus y)}\, z$$

x	y	z	D	B
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



"Logic Circuit"



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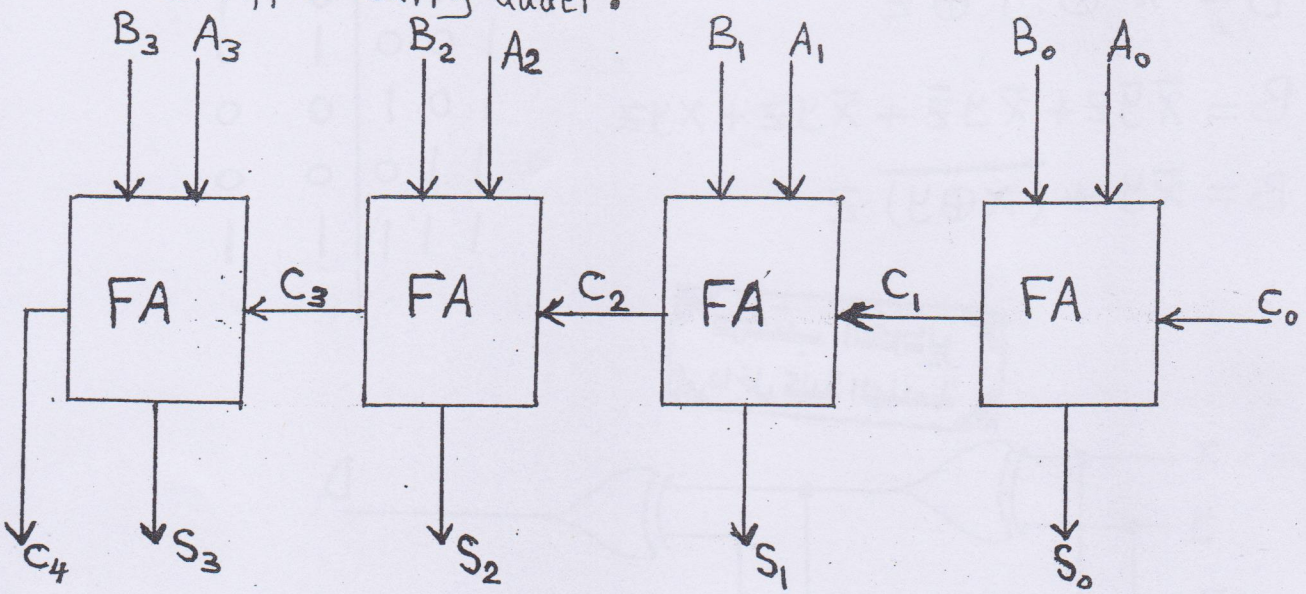
"block Diagram"

Binary Adder

A binary adder is a digital circuit that produces the arithmetic sum of two binary numbers. It can be constructed with full adders connected in cascade, with the output carry from each full adder connected to the input carry of the next full adder in the chain. This figure below shows the interconnection of four full adder (FA) circuits to provide a 4-bit binary ripple carry adder.

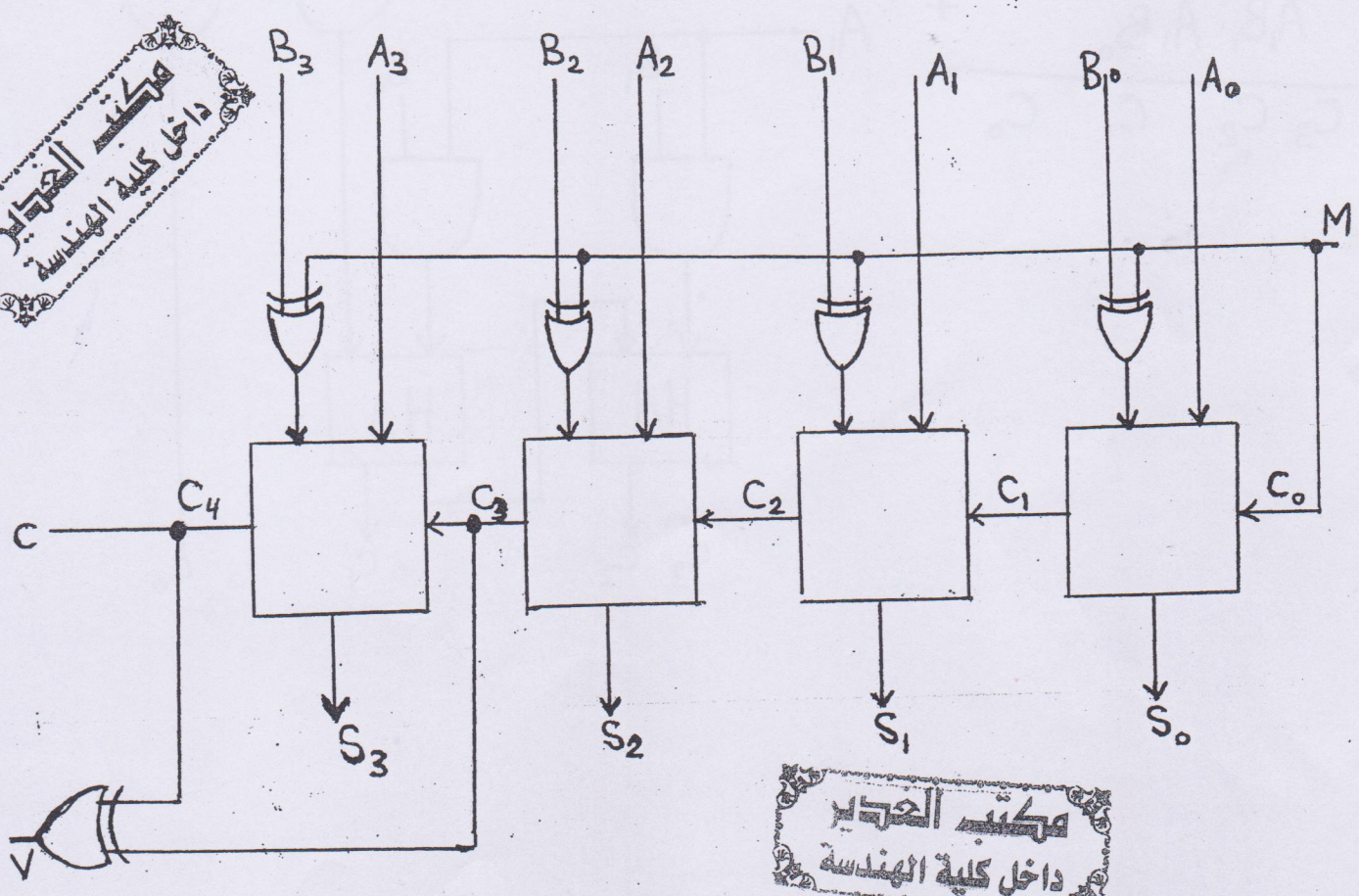


An n-bit adder requires n full adders with each output carry connected to the input carry of the next higher-order full adder. Consider the two binary numbers, $A = 1011$ and $B = 0011$. Their sum $S = 1110$ is formed with the four-bit as follows:

Subscript i:	3	2	1	0	
Input carry	0	1	1	0	C_i
Augend	1	0	1	1	A_i
Addend	0	0	1	1	B_i
Sum	1	1	1	0	S_i
output carry	0	0	1	1	C_{i+1}

4-Bit Adder-Subtractor

A 4-bit adder-subtractor circuit is show below. The mode input M controls the operation. When M=0, the circuit is an adder, and when M=1, the circuit becomes a subtractor. Each exclusive-OR gate receives input M and one of the inputs of B. When M=0, we have $B \oplus 0 = B$. The full adders receive the value of B, the input carry is 0, and the circuit performs A plus B. When M=1, we have $B \oplus 1 = \bar{B}$ and $C_0 = 1$. The B inputs are all complemented and a 1 is added through the input carry. The circuit performs the operation A plus the 2's complement of B. (The exclusive-OR with output V is for detecting an overflow.)



Binary Multiplier

Multiplication of binary numbers is performed in the same way as in decimal numbers. The multiplicand is multiplied by each bit of the multiplier starting from the least significant bit. Each such multiplication forms a partial product. Successive partial products are shifted one position to the left. The final product is obtained from the sum of the partial products.

The multiplication of two 2-bit numbers is shown in the following figure:

$$
\begin{array}{rr}
 & B_1\ B_0 \\
\times & A_1\ A_0 \\
\hline
 & A_0B_1\ A_0B_0 \\
+ & A_1B_1\ A_1B_0 \\
\hline
 & C_3\ C_2\ C_1\ C_0
\end{array}
$$