

Binary Adder-Subtractor

A Binary Adder-Subtractor is a special type of circuit that is used to perform both operations, i.e., Addition and Subtraction. The operation which is going to be used depends on the values contained by the control signal. In Arithmetic Logical Unit, it is one of the most important components.

To work with Binary Adder-Subtractor, it is required that we have knowledge of the **XOR gate**, Full-Adder, Binary Addition, and subtraction.

For example, we will take two 4-bit binary numbers 'X' and 'Y' for the operation with digits.

$X_0 X_1 X_2 X_3$ for	X
$Y_0 Y_1 Y_2 Y_3$ for Y	

The Binary Adder-Subtractor is a combination of 4 Full-Adder, which is able to perform the addition and subtraction of 4-bit binary numbers. The control line determines whether the operation being performed is either subtraction or addition. This determination is done by the binary values 0 and 1, which is hold by K.

In the above diagram, the control lines of the first Full-Adder is directly coming as its input(input carry C_0). The X_0 is the least significant bit of A, which is directly inputted in the Full-Adder. The result produced by performing the XOR operation of Y_0 and K is the third input of the Binary Adder-Subtractor. The sum/difference(S_0) and carry(C_0) are the two outputs produced from the First Full-adder.

When the value of K is set to true or 1, the $Y_0 \oplus K$ produce the complement of Y_0 as the output. So the operation would be $X+Y_0'$, which is the 2's complement subtraction of X and Y. It means when the value of K is 1; the subtraction operation is performed by the binary Adder-Subtractor.

In the same way, when the value of K is set to 0, the $Y_0 \oplus K$ produce Y_0 as the output. So the operation would be $X+Y_0$, which is the binary addition of X and Y. It means when the value of K is 0; the addition operation is performed by the binary Adder-Subtractor.

The carry/borrow C_0 is treated as the carry/borrow input for the second Full-Adder. The sum/difference S_0 defines the least significant bit of the sum/difference of numbers X and Y . Just like X_0 , the X_1 , X_2 , and X_3 are fed directly to the 2nd, 3rd, and 4th Full-Adder as an input. The outputs after performing the XOR operation of Y_1 , Y_2 , and Y_3 inputs with K are the third inputs for 2nd, 3rd, and 4th Full-Adder. The carry C_1 , C_2 are passed as the input to the Full-Adder. C_{out} is the output carry of the sum/difference. To form the final result, the S_1 , S_2 , S_3 are recorded with s_0 . We will use n number of Full-Adder to design the n -bit binary Adder-Subtractor.

Example:

We assume that we have two 3 bit numbers, i.e., $X=100$ and $Y=011$, and feed them in Full-Adder as an input.

$$X_0 = 0 \quad X_1 = 0 \quad X_2 = 1$$

$$Y_0 = 1 \quad Y_1 = 1 \quad \& \quad Y_2 = 0$$

For $K=0$:

$$Y_0 \oplus K = Y_0 \text{ and } C_{in} = K = 0$$

So, from first Full-Adder

$$S_0 = X_0 + Y_0 + C_{in}$$

$$S_0 = 0 + 1 + 0$$

$$S_0 = 1$$

$$C_0 = 0$$

Similarly,

$$S_1 = X_1 + Y_1 + C_0$$

$$S_1 = 0 + 1 + 0$$

$$S_1 = 1 \text{ and } C_1 = 0$$

Similarly,

$$S_2 = X_2 + Y_2 + C_1$$

$$S_2 = 1 + 0 + 0$$

$$S_2 = 1 \text{ and } C_2 = 0$$

Thus,

$$X = 100 = 4$$

$$Y = 011 = 3$$

$$\text{Sum} = 0111 = 7$$

For $K=1$

$$Y_0 \oplus K = Y_0' \text{ and } C_{in} = k = 1$$

So,

$$S_0 = X_0 + Y_0' + C_{in}$$

$$S_0 = 0 + 0 + 1$$

$$S_0 = 1 \text{ and } C_0 = 0$$

Similarly,

$$S_1 = X_1 + Y_1' + C_0$$

$$S_1 = 0 + 0 + 0$$

$$S_1 = 0 \text{ and } C_1 = 0$$

Similarly,

$$S_2 = X_2 + Y_2' + C_1$$

$$S_2 = 1 + 1 + 0$$

$$S_2 = 0 \text{ and } C_2 = 0$$

Thus,

$$X = 010 = 4$$

$$Y = 011 = 3$$

$$\text{Difference} = 001 = 1$$