

# 4-Bit Arithmetic Logic Unit

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A **4-bit adder-subtractor** is a combinational circuit that performs both **addition and subtraction** while the arithmetic logic unit also performs **logical operations** such as **AND**, **OR** and **XOR** on 4-bit binary numbers. It combines a 4-bit binary adder with additional logic to handle the subtraction operation by using the concept of the 2's complement. In Digital Circuits, A **Binary Adder-Subtractor** is can do both the addition and subtraction of binary numbers in one circuit itself. The operation is performed depending on the binary value the control signal holds. It is one of the components of the ALU (Arithmetic Logic Unit).

## Components

### 1. 4-bit Binary Adder:

- A 4-bit adder takes two 4-bit binary numbers (**A** and **B**) and produces their sum along with a carry-out bit.
- It has four full adders cascaded to handle each bit and the carry from the previous bit.

### 2. XOR Gates:

- XOR gates are used to conditionally invert the bits of one operand (**B**) during subtraction.

### 3. Mode Control Input (M):

- A single-bit control signal that determines whether the circuit performs addition (**M = 0**) or subtraction (**M = 1**).

### 4. Carry-In/Input Logic:

- The carry-in for the least significant bit (LSB) is set to **0** for addition and **1** for subtraction. For subtraction, this implements the 2's complement operation.

## Functional Description

Operation Table

A (4 bits)	B (4 bits)	op (1 bit)	Operation	R (4 bits)	C_out (1 bit)
A (binary)	B (binary)	0	Addition (A + B)	Sum (4-bit)	Carry (overflow)
A (binary)	B (binary)	1	Subtraction (A - B)	Difference (4-bit)	Borrow (overflow)

### Addition (Control = 0)

- The 4-bit binary numbers AAAA and BBBB are added.
- If the sum exceeds 4 bits (i.e., it requires a 5th bit), C\_out will be set to 1.

### Subtraction (Control = 1)

- The 4-bit binary number BBBB is complemented (using 2's complement method) and added to AAAA.
- $B' = \text{NOT}(B) + 1$  (2's complement of B)
- The 4-bit result is stored in R, and if a borrow occurs, C\_out will be set to 1

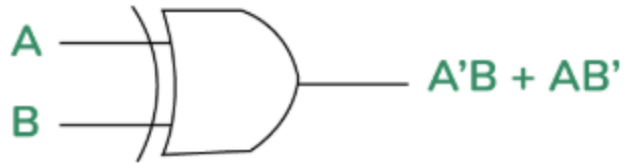
### XOR gate operation

- \* If one input is high it produce invert of the other input.
- \* If one input is low it produce same of the other input.

### 2's complement

- \* It represent a positive number as it is and negative number by its corresponding 2s-complement so we can use the same circuit to perform addition and subtraction.

## XOR Gate



Truth Table

A (Input 1)	B (Input 2)	$X = A'B + AB'$
0	0	0
0	1	1
1	0	1
1	1	0

### 2's complement

\* It represent a positive number as it is and negative number by its corresponding 2s-compleme so we can use the same circuit to perform addition and subtraction.

### Internal Design

#### 1. Full Adders

- The ALU has 4 **1-bit Full Adders** connected serially.
- Each bit position ( $A_0, A_1, A_2, A_3$ ) and ( $B_0, B_1, B_2, B_3$ ) are processed one by one.

#### 2. Operation Control

- The operation selector (**op**) determines if addition or subtraction is to be performed.
- To perform subtraction, BBBB is XOR-ed with **op** to invert the bits of BBBB when  $op=1$ , and a **1** is added to achieve 2's complement subtraction.
- For addition, the bits of BBBB remain unchanged.
- **$B' = B \text{ XOR } op$**  (this acts like a NOT gate on BBB when  $op=1$ ).

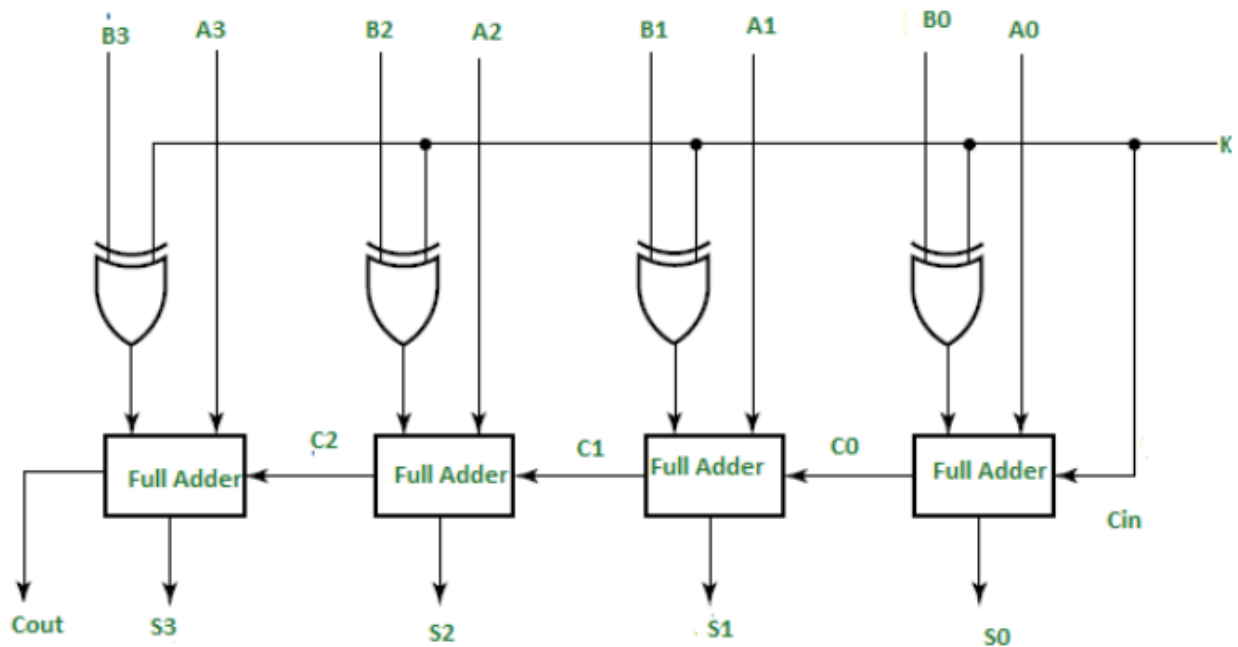
### 3. Carry/Borrow Handling

- The carry out (**C\_out**) is set when overflow occurs in addition or borrow occurs in subtraction.

## Circuit Design

Logic Circuit Design for the 4-bit ALU includes:

1. XOR gates to modify BBB based on the operation ( $B' = B \text{ XOR control}$ ).
2. Full Adders using and,or and ex-or gates to compute the sum of AAAA and  $B'B'B'B'$ .
3. Switches to select between addition and subtraction.
4. Overflow/Borrow Detection is done via C\_out from the last stage.
5. 7 segment Display to show the inputs and outputs.



## Logical Operations

The 4-bit ALU (Arithmetic Logic Unit) is a combinational circuit designed to perform bitwise logical operations on two 4-bit inputs. This ALU supports the following operations:

- **AND**
- **OR**
- **XOR**

The ALU uses a 2-bit control signal to select the desired operation. The output is a 4-bit result, along with a carry or overflow indicator

The circuit functionality of a 1 bit ALU is shown here, depending upon the control signal  $S$ , and  $S_0$  the circuit operates as follows:

for Control signal  $S_1 = 0$ ,  $S_0 = 0$ , the output is  $A$  And  $B$ ,

for Control signal  $S_1 = 0$ ,  $S_0 = 1$ , the output is  $A$  Or  $B$ ,

for Control signal  $S_1 = 1$ ,  $S_0 = 0$ , the output is  $A$  Xor  $B$ ,

for Control signal  $S_1 = 1$ ,  $S_0 = 1$ , the output is  $A$  Add/Subtract  $B$ .

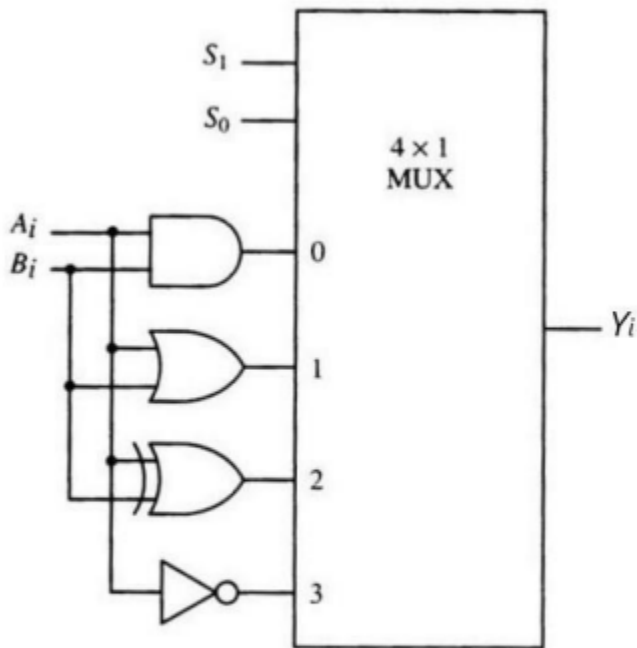


Figure of 1-bit ALU using 4:1 MUX

## **Advantages**

1. Combines two operations in a single circuit, saving hardware resources.
2. Efficient for small-scale binary arithmetic operations.

## **Applications**

1. Arithmetic Logic Units (ALUs) in microprocessors.
2. Digital signal processing.
3. Basic computational tasks in embedded systems.

## **Git-Hub Repository Link**

<https://github.com/nishitanya/Electronics-Project>