The University of Azad Jammu and Kashmir, Muzaffarabad

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Course Name	Computer Architecture and Logic Design
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Full Adder:

A full adder is a combinational logic circuit that adds three input bits (A, B, and a carry input, Cin) and generates two outputs: a sum (S) and a carry out (Cout).

$$S = \overline{X}\overline{Y}Z + \overline{X}Y\overline{Z} + X\overline{Y}\overline{Z} + XYZ$$
$$= X \oplus Y \oplus Z$$
$$C = XY + XZ + YZ$$

The truth table for a full adder is as follows:

INPUTS			OUTPUTS	
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

Figure 1. Full Adder Truth Table

Logic Expressions

- **Sum** = A ⊕ B ⊕ Cin
- **Cout** = (A · B) + (B · Cin) + (A · Cin)

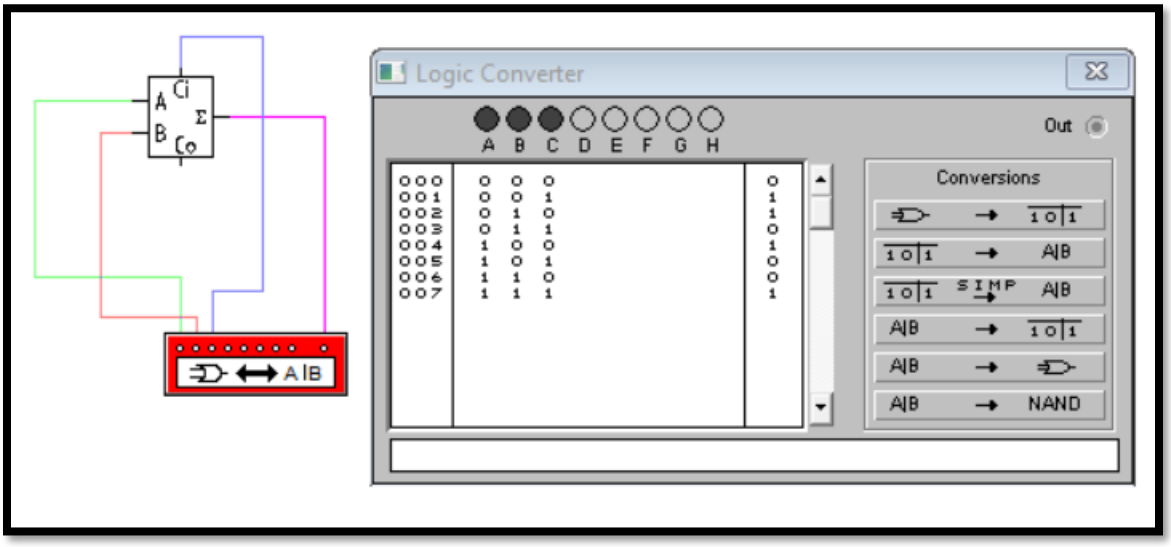
Implementation

- Can be built using two **Half Adders** and one **OR** gate.
- Widely used in multi-bit binary addition by connecting several full adders in series (Ripple Carry Adder).

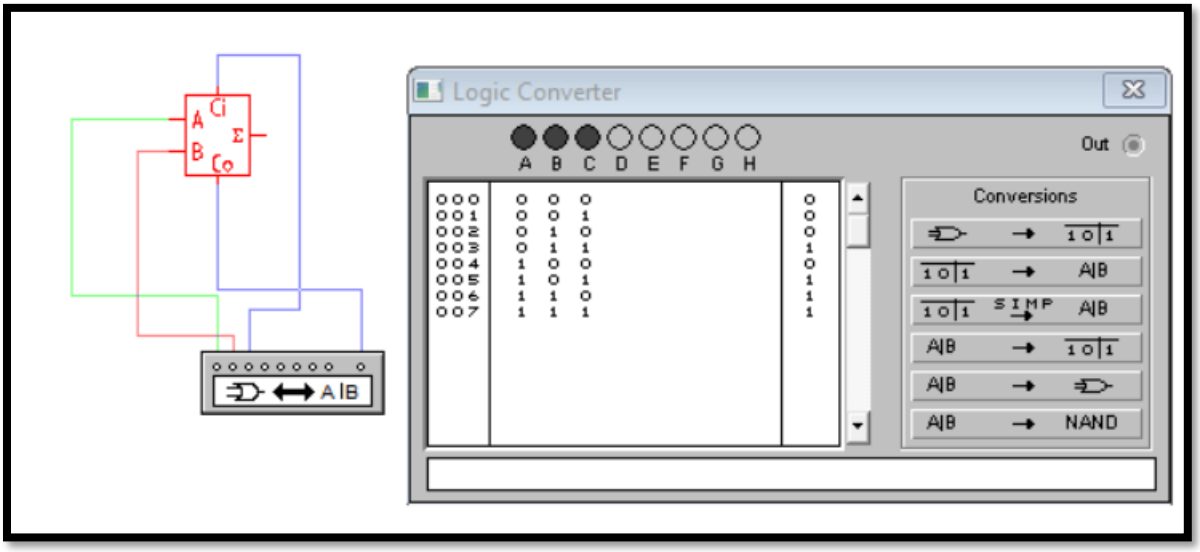
Applications

- Arithmetic Logic Units (ALUs)
- Digital calculators
- Processors and microcontrollers
- Multipliers and digital signal processing

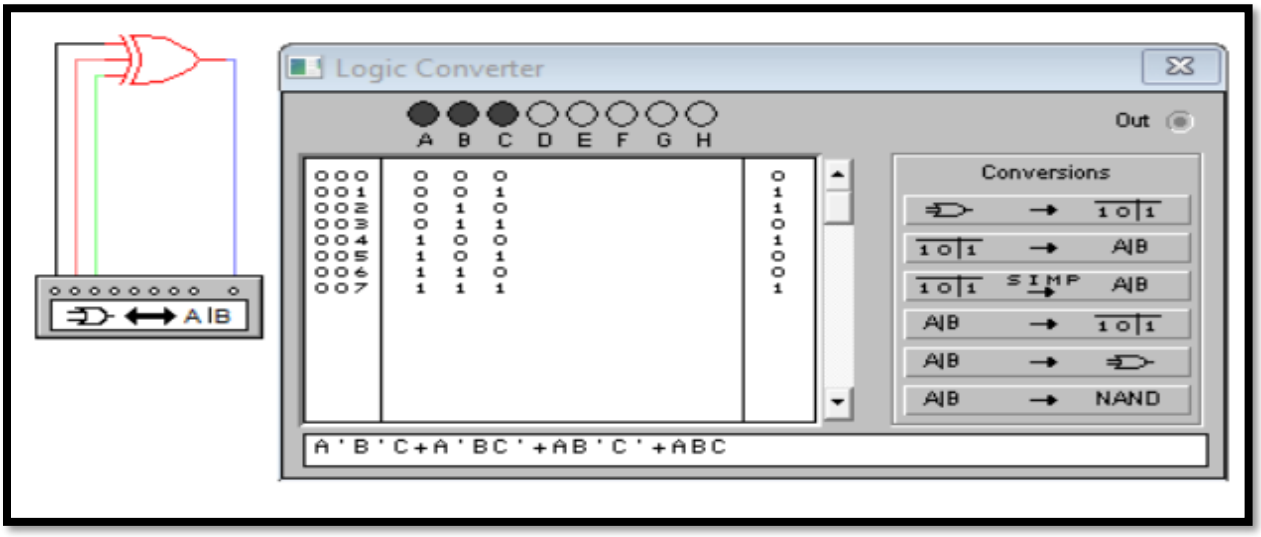
Truth Table (Sum)



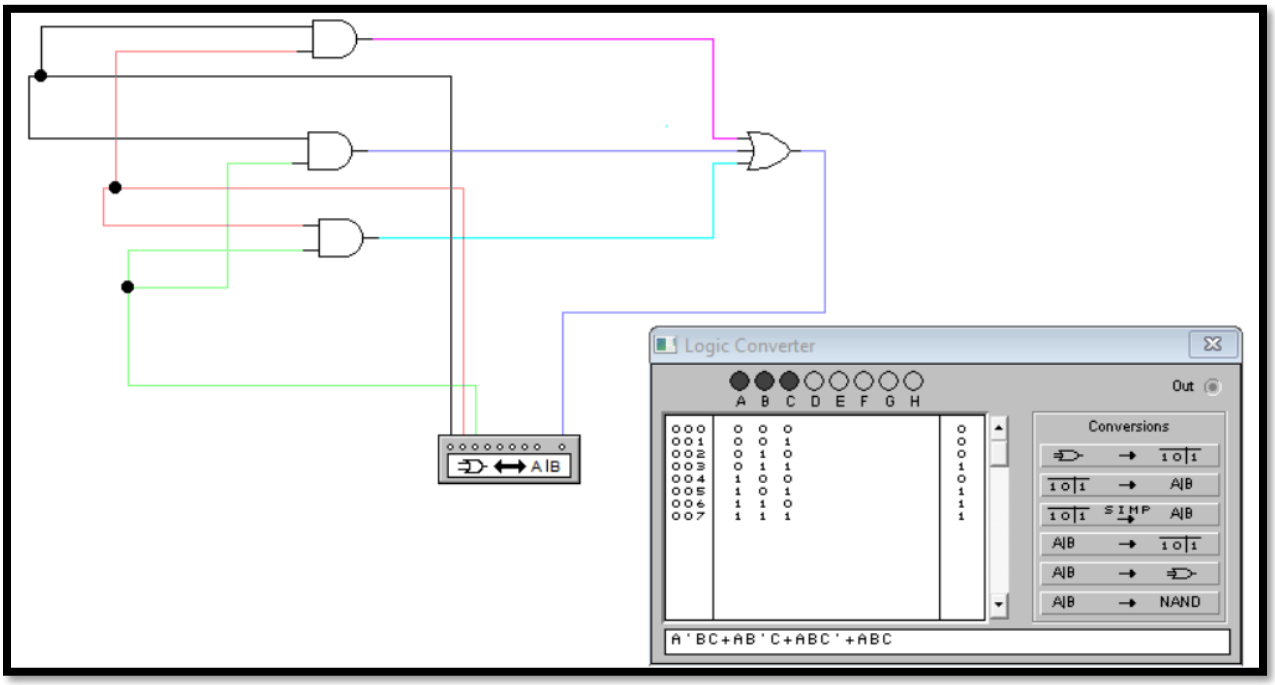
Truth Table (Carry)



Circuit Diagram & Equation (Sum)



Circuit Diagram & Equation (Carry)



1) Half Subtractor

The half-subtractor is a combinational circuit which is used to perform subtraction of two bits. It has two inputs, A (minuend) and B (subtrahend) and two outputs Difference and Borrow. The logic symbol and truth table are shown below.

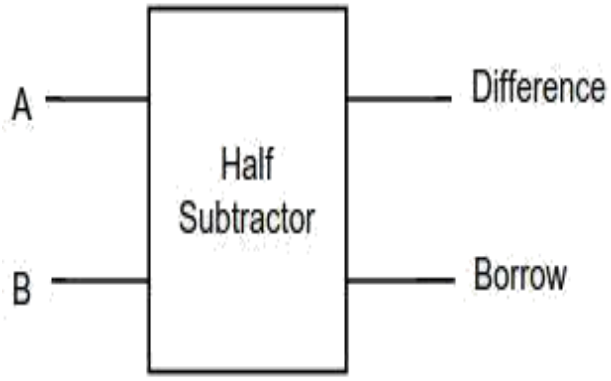


Figure-1: Logic Symbol of Half subtractor

Inputs		Outputs	
A	B	Difference	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Figure-2: Truth Table of Half subtractor

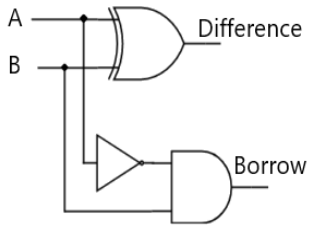


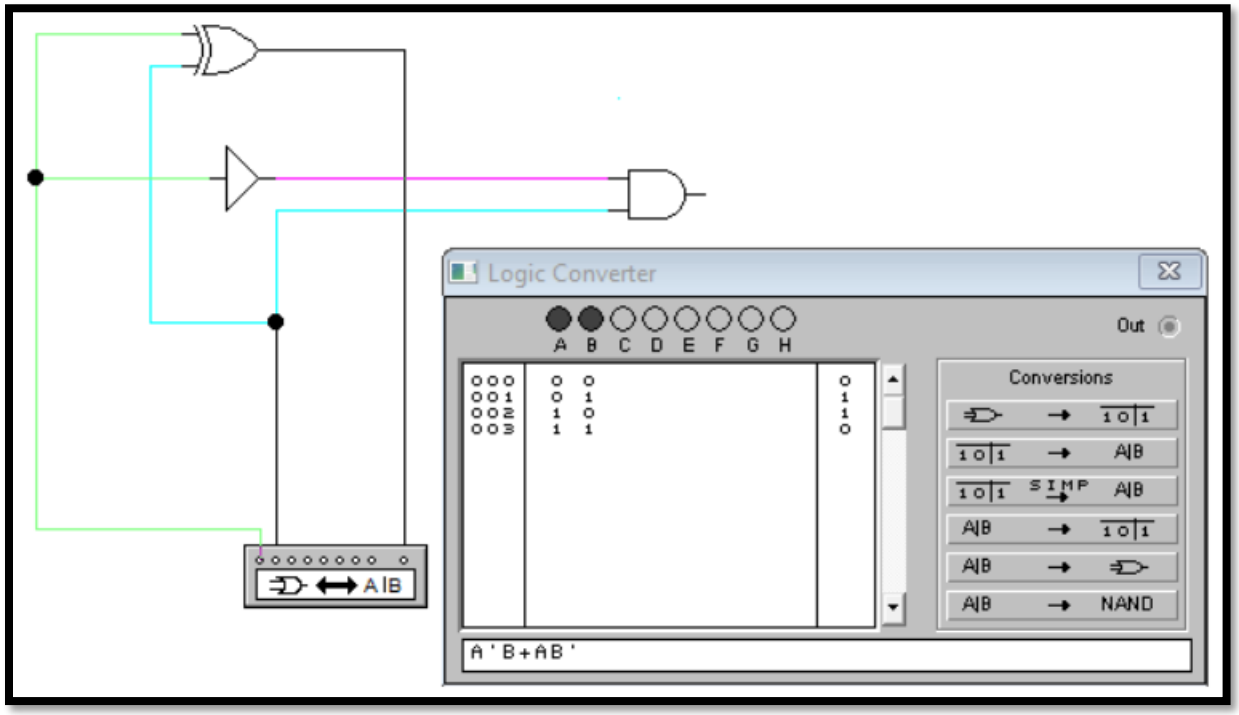
Figure-3: Circuit Diagram of Half subtractor

From the above truth table, we can find the Boolean expression.

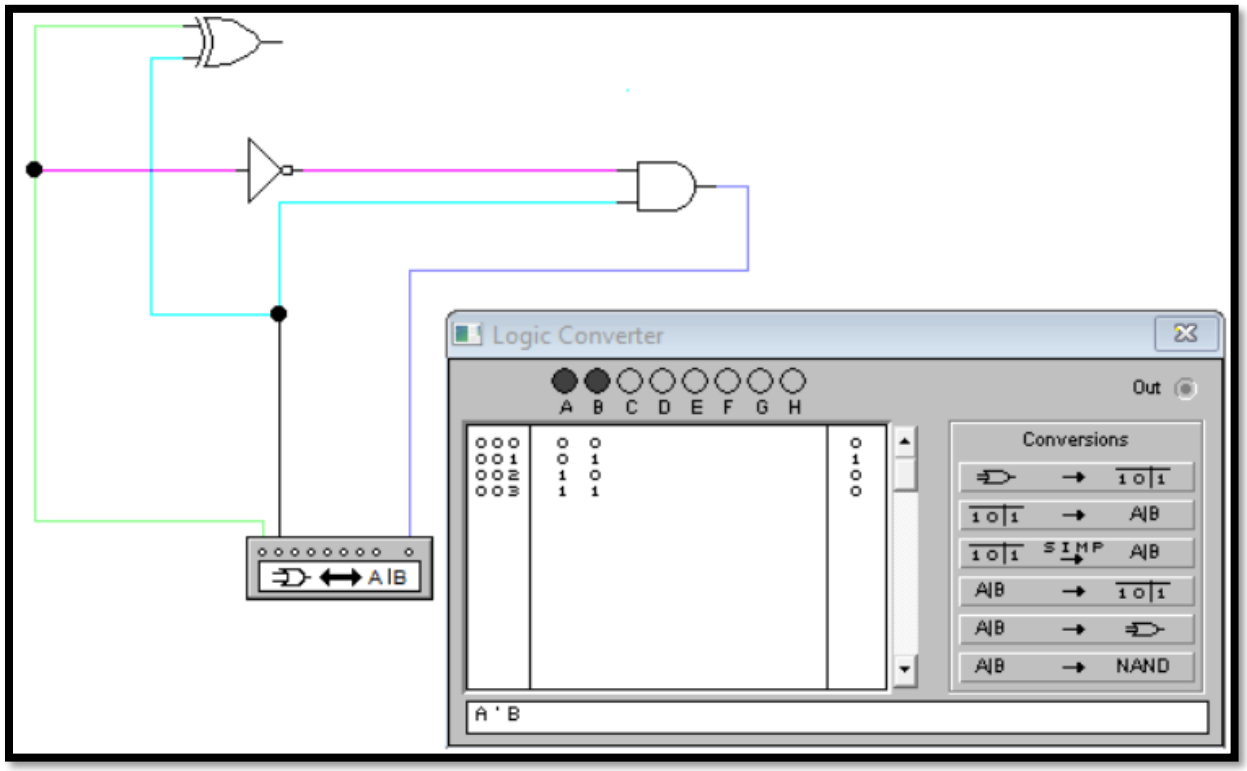
Difference = A ⊕ B
Borrow = A' B

From the equation we can draw the half-subtractor circuit as shown in figure 3.

Truth Table & Equation (Difference)



Truth Table & Equation (Borrow)



2) Full Subtractor

A full subtractor is a combinational circuit that performs subtraction involving three bits, namely A (minuend), B (subtrahend), and Bin (borrow-in) . It accepts three inputs: A (minuend), B (subtrahend) and a Bin (borrow bit) and it produces two outputs: D (difference) and Bout (borrow out). The logic symbol and truth table are shown below.

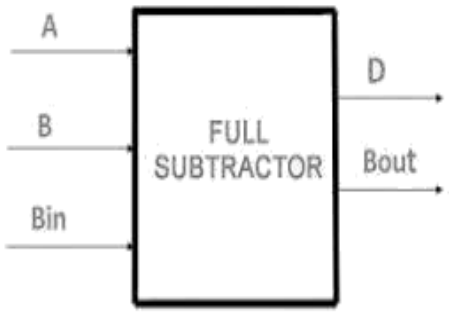


Figure-4: Logic Symbol of Full subtractor

A	B	B_{in}	D	B_{out}
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

Figure-5: Truth Table of Full subtractor

From the above truth table we can find the boolean expression.

D = A ⊕ B ⊕ Bin
Bout = A' Bin + A' B + B Bin

From the equation we can draw the Full-subtractor circuit as shown in the figure 6.

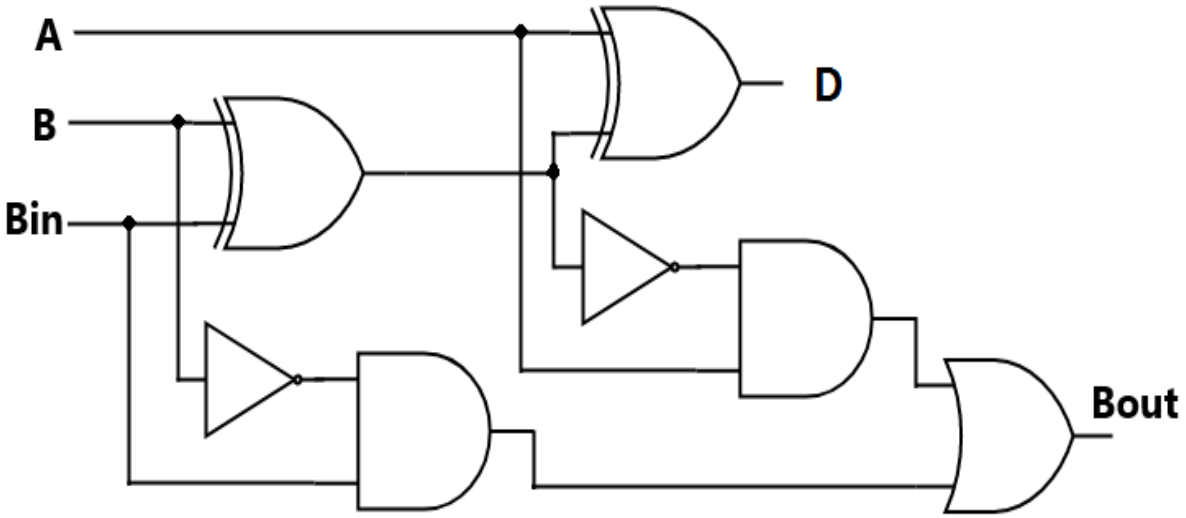
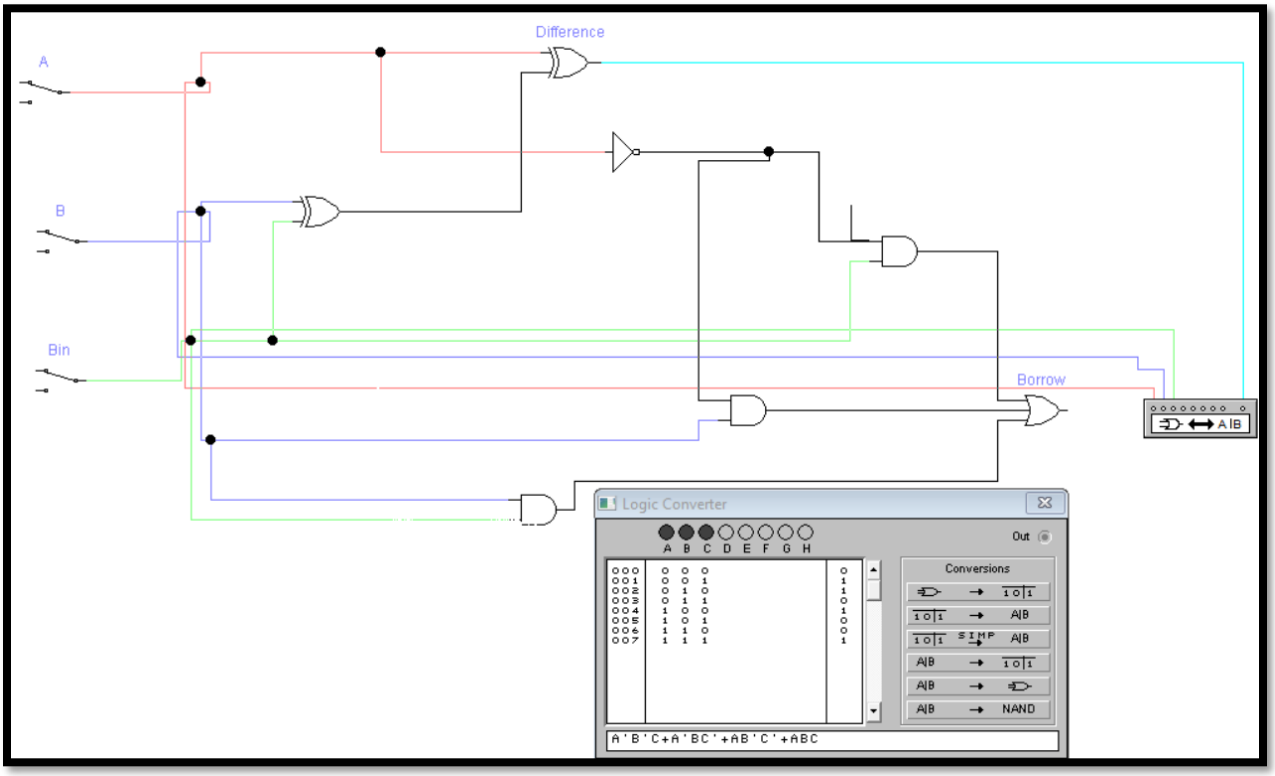


Figure-6: Circuit Diagram of Full subtractor.

Circuit Diagram & Equation (Difference)



Circuit Diagram & Equation (Borrow)