Experiment No 2

Implementation of Arithmetic Logic Unit (ALU) in LogiSim

2.1 Objectives:

After completing this experiment, student will be able to:

- Understand the basic functions of an ALU.
- Use different components like MUX, ADDER, SUBTRACTOR and basic Logical Operations in LogiSim.
- Design and Implement 1, 8, 16 and 32 bit ALU in LogiSim.

2.2 Background Theory

An Arithmetic Logic Unit (ALU) is a fundamental component in digital systems, playing a crucial role in performing arithmetic and logical operations. It serves as the computational heart of a microprocessor or a digital circuit, executing mathematical calculations and logical comparisons that are essential for processing data.

2.2.1 Functions of an ALU

2.2.1.1 Addition

The primary arithmetic function of an ALU is addition. It can add binary numbers, which is a fundamental operation in any digital computing system. The ALU takes two binary inputs and produces their sum as the output.

2.2.1.2 Subtraction

Subtraction is closely tied to addition in digital systems. An ALU can perform subtraction by employing a mechanism known as two's complement arithmetic. This allows for efficient addition of negative numbers, and the ALU can effectively subtract one binary number from another.

2.2.1.3 Logical AND Operations

ALUs also perform logical operations, including the AND operation. In the AND operation, each bit of the output is the logical AND of the corresponding bits of the input. It results in a '1' only if both input bits are '1'; otherwise, the output is '0'.

2.2.1.4 Logical OR Operations

Another essential logical operation is the OR operation. The OR operation produces a '1' if at least one of the corresponding input bits is '1'. It results in '0' only when both input bits are '0'.

2.2.1.5 Logical XOR Operations

The XOR operation is a logical operation where the output is '1' if the input bits are different and '0' if they are the same. XOR is frequently used in various applications, including data comparison and error detection.

2.2.2 Importance in Digital Systems

2.2.2.1 Central Processing Unit (CPU)

ALUs are a critical component of a CPU, where they perform the arithmetic and logical operations necessary for executing program instructions. The speed and efficiency of an ALU directly impact the overall performance of the CPU.

2.2.2.2 Data Processing

In digital systems, ALUs are responsible for manipulating data, making them indispensable in applications ranging from basic calculators to complex data processing units in computers and embedded systems.

2.2.2.3 Control Flow

ALUs play a key role in controlling the flow of operations within a digital system. They enable decision-making processes, comparisons, and conditional branching based on the results of arithmetic and logical operations.

2.2.2.4 Mathematical Computations

ALUs are crucial for performing mathematical computations, making them integral to applications such as scientific calculations, simulations, and numerical analysis.

So, the Arithmetic Logic Unit is a fundamental building block of digital systems, providing the computational capabilities necessary for a wide range of applications in the field of electronics and computing. Its ability to perform both arithmetic and logical operations makes it a versatile and indispensable component in the world of digital design and information processing.

2.2.4 1 Bit ALU Design

Designing a 1-bit Arithmetic Logic Unit (ALU) with basic operations like AND, OR, XOR, addition, subtraction, and multiplication involves careful arrangement of logic components. In the following Figure: 2.1, two multiplexers (MUX) play a crucial role in managing the output and carry-out signals. For each operation, the ALU utilizes logic gates such as AND, OR, and XOR to process the input bits. The addition and subtraction operations employ a 1-bit full-adder for the arithmetic computations. To facilitate the selection of the desired operation, a control line is connected to the input of the MUX responsible for generating the output. Another MUX is incorporated to manage the carry-out signal. During addition or subtraction, the carry-out from the full-adder is selected, while for logical operations, the carry-out is set to zero. By implementing this design, the 1-bit ALU effectively performs various operations, and the multiplexers contribute to the flexibility of choosing the appropriate results based on the operation selected.

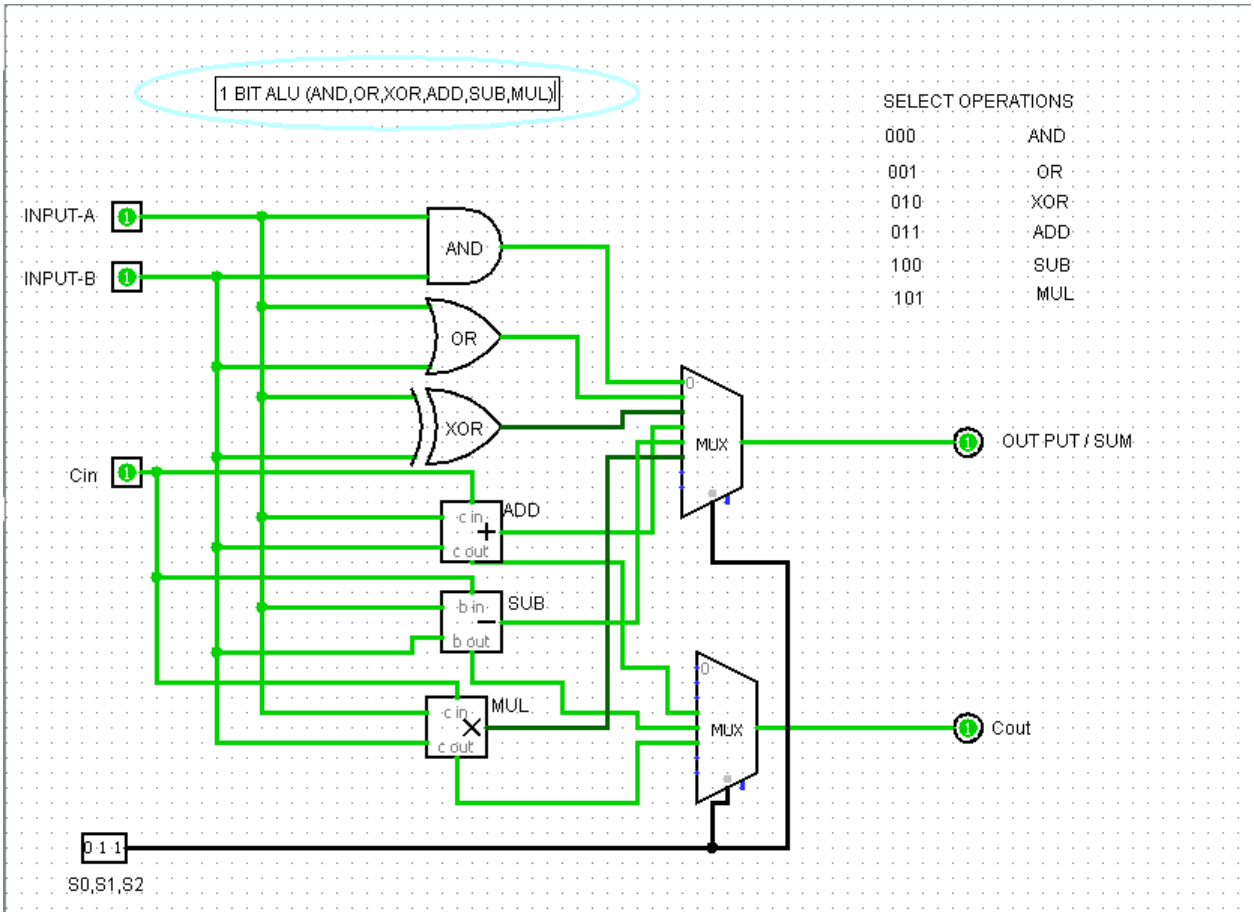


Figure 2.1: 1-Bit ALU Design

2.2.5 8 Bit ALU Design

Just change the input and output bit size to 8 bits and the rest of the circuit will be remain same as shown in Figure: 2.2.

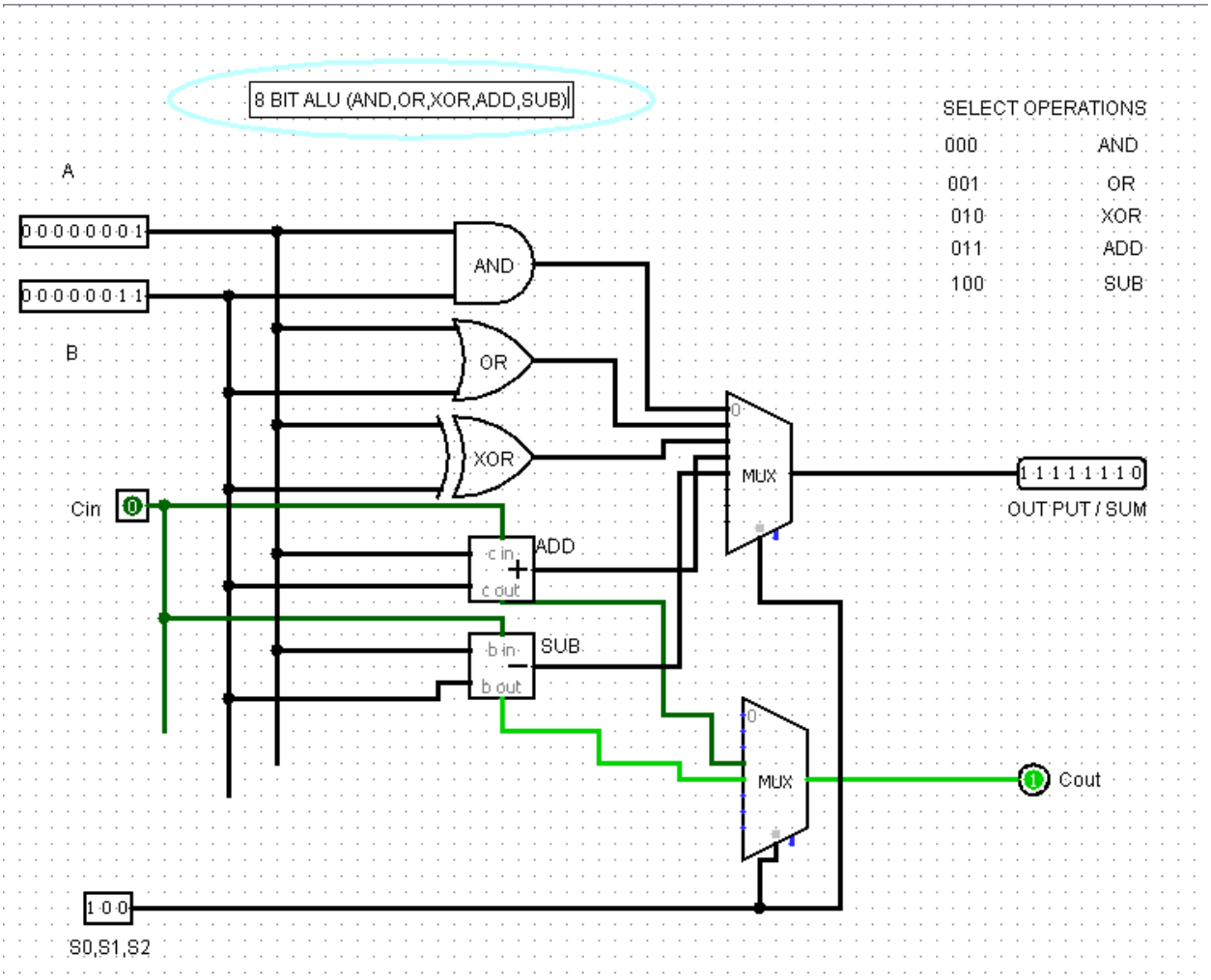


Figure 2.2: 8-Bit ALU Design

2.3 Lab Activities

2.3.1 Task-1: Design 16 Bits ALU in LogiSim having (AND, OR, XOR, ADD and SUB) functions.

2.3.2 Task-2: Design 32 Bits ALU in LogiSim having (AND, OR, NOT, XOR, ADD and SUB) functions.

Lab Exercise and Summary

Summary should cover Introduction, Procedure, Data Analysis and Evaluation.

Student's Signature: _____ **Date: _____**

Cognitive Activity

Q1. You are designing a 4-function ALU (ADD, SUB, AND, OR) selected by a 2-bit control signal. Describe, in words, the components you would use and how the 2-bit control signal decides which result reaches the output. **(5)**

Ans: _____

_____

_____

_____

_____

Q2. For inputs A = 1010 and B = 0011 (4-bit, unsigned), calculate the ALU output for each of: ADD, SUB (A-B, two's complement), AND, and OR. **(5)**

Ans: _____

_____

_____

_____

_____

Obtained Marks	**/10**

Psychomotor Activity 1 — Experimental Setup

S. No	Criteria	Performance	Description	Marks
1	Tool Setup (4)	Level 4	Opens and configures LogiSim and selects the required environment correctly and independently.	4
		Level 3	Configures the required tool with minor errors or assistance.	3
		Level 2	Completes the setup with considerable assistance.	2
		Level 1	Setup is incomplete and requires substantial assistance.	1
2	File/Design Setup (4)	Level 4	Correctly creates/selects the required assembly file, Logisim circuit/design and required components for the Logisim ALU circuit.	4
		Level 3	File/design setup is mostly correct with minor errors or omissions.	3
		Level 2	Setup is partially completed and requires assistance.	2
		Level 1	Major errors or omissions are present in the setup.	1
3	Parameter Setup (2)	Level 2	Correctly defines required data, registers, parameters, components and initial conditions.	2
		Level 1	Most required inputs/components are correctly configured with minor errors.	1
			Total Obtained	/10

If a student is absent:

Criteria	Description	Marks
Absent	Student is absent from the laboratory activity.	0

Psychomotor Activity 2 — Implementation + Results

S. No	Criteria	Performance	Description	Marks
1	**Implementation (4)**	Level 4	Implements the required Logisim ALU circuit correctly and independently.	**4**
		Level 3	Implements the required program/design with minor errors or assistance.	**3**
		Level 2	Partially implements the program/design and requires considerable assistance.	**2**
		Level 1	Implementation is largely incomplete and requires substantial assistance.	**1**
2	**Execution/Simulation (2)**	Level 2	Executes the RISC-V program or simulates the Logisim design correctly and handles basic errors appropriately.	**2**
		Level 1	Executes/simulates the work with minor errors or assistance.	**1**
3	**Results/Output (4)**	Level 4	Obtains correct results and clearly demonstrates the required program output or circuit behavior.	**4**
		Level 3	Obtains mostly correct results with minor errors.	**3**
		Level 2	Obtains partially correct results with noticeable errors or omissions.	**2**
		Level 1	Results are largely incorrect or incomplete.	**1**
			Total Obtained	**/10**

If a student is absent:

Criteria	Description	Marks
Absent	Student is absent from the laboratory activity.	**0**

Affective Activity — Lab Report + Viva Voce

S. No	Criteria	Performance	Description	Marks
1	Lab Report Completeness & Organization (4)	Level 4	Report is complete, well organized and demonstrates full responsibility for the assigned work.	4
		Level 3	Report is complete with minor omissions or organizational issues and demonstrates satisfactory responsibility for the assigned work.	3
		Level 2	Report is partially complete with several omissions and demonstrates limited responsibility for the assigned work.	2
		Level 1	Report has major omissions or poor organization and demonstrates minimal responsibility for the assigned work.	1
2	Code/Design, Results & Conclusion (2)	Level 2	Logisim ALU circuit, results, and conclusion are correctly presented and discussed, demonstrating ownership of the assigned work.	2
		Level 1	Logisim ALU circuit, results, or conclusion are presented with minor errors or omissions.	1
3	Viva Voce (4)	Level 4	Clearly explains the assigned Logisim ALU circuit, working, and results, demonstrating individual responsibility, participation, and effective communication.	4
		Level 3	Explains most of the assigned program/design and results correctly, with minor difficulty, and demonstrates good individual participation.	3
		Level 2	Explains basic aspects of the assigned program/design with some prompting and demonstrates basic participation.	2
		Level 1	Demonstrates limited understanding or involvement and requires substantial prompting to explain the assigned work.	1
			Total Obtained	**/10**

The student has not submitted the report and has not appeared in the Viva Voce.

Criteria	Description	Marks
Lab Report and Results Not Submitted	Student has not submitted the report and results file.	**0**
Absent in Viva Voce	Student is absent from the viva voce.	**0**

Instructor's Signature: _____ **Date:** _____