Digital Logic Design Lab Project Report

Project Title : 6-Bit Arithmetic Logic Unit (ALU)

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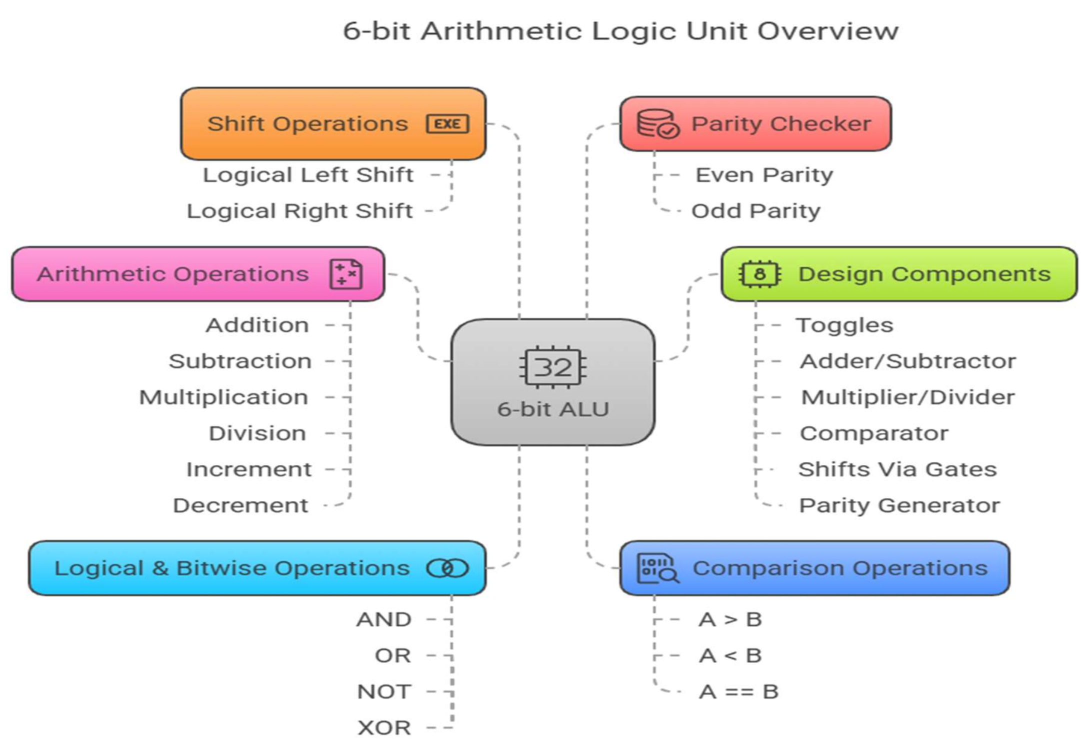


1. Abstract

This project presents the design and implementation of a 6-bit Arithmetic Logic Unit (ALU) capable of performing 16 distinct arithmetic, logical, and shift operations. The A LU was built hierarchically, starting from basic logic gates to functional subcircuits, and final ly integrated into a complete system controlled by 4-bit opcodes. The design demonstrates fu ndamental computer architecture principles and serves as an educational model for understan ding CPU operations.

2. Introduction

2.1 Main Objective :

The primary goal was to **design and implement a functional 6-bit Arithmetic Logic Unit (ALU)** that performs:

1. **Arithmetic operations** (addition, subtraction, multiplication, division)
2. **Logical operations** (AND, OR, NOT, XOR)
3. **Shift operations** (left/right)
4. **Comparison & utility functions** (increment, decrement, parity check)

Key Purpose:

1. Demonstrate how **basic logic gates** combine to form complex computing units.
2. Simulate the **core computational component** of a CPU.
3. Provide hands-on experience in **modular digital circuit design** (from gates → subcircuits → full ALU).

Learning Outcomes:

✓ Understanding of **binary arithmetic & Boolean logic** in hardware

✓ Experience in **hierarchical circuit design**

✓ Practical knowledge of **ALU operation selection & control**

This project serves as a **foundation for computer architecture** and microprocessor design.

2.2 Background:

ALUs are fundamental components of CPUs, handling all arithmetic and logic computations. This project mimics commercial ALU designs at a simplified scale to illustrate:

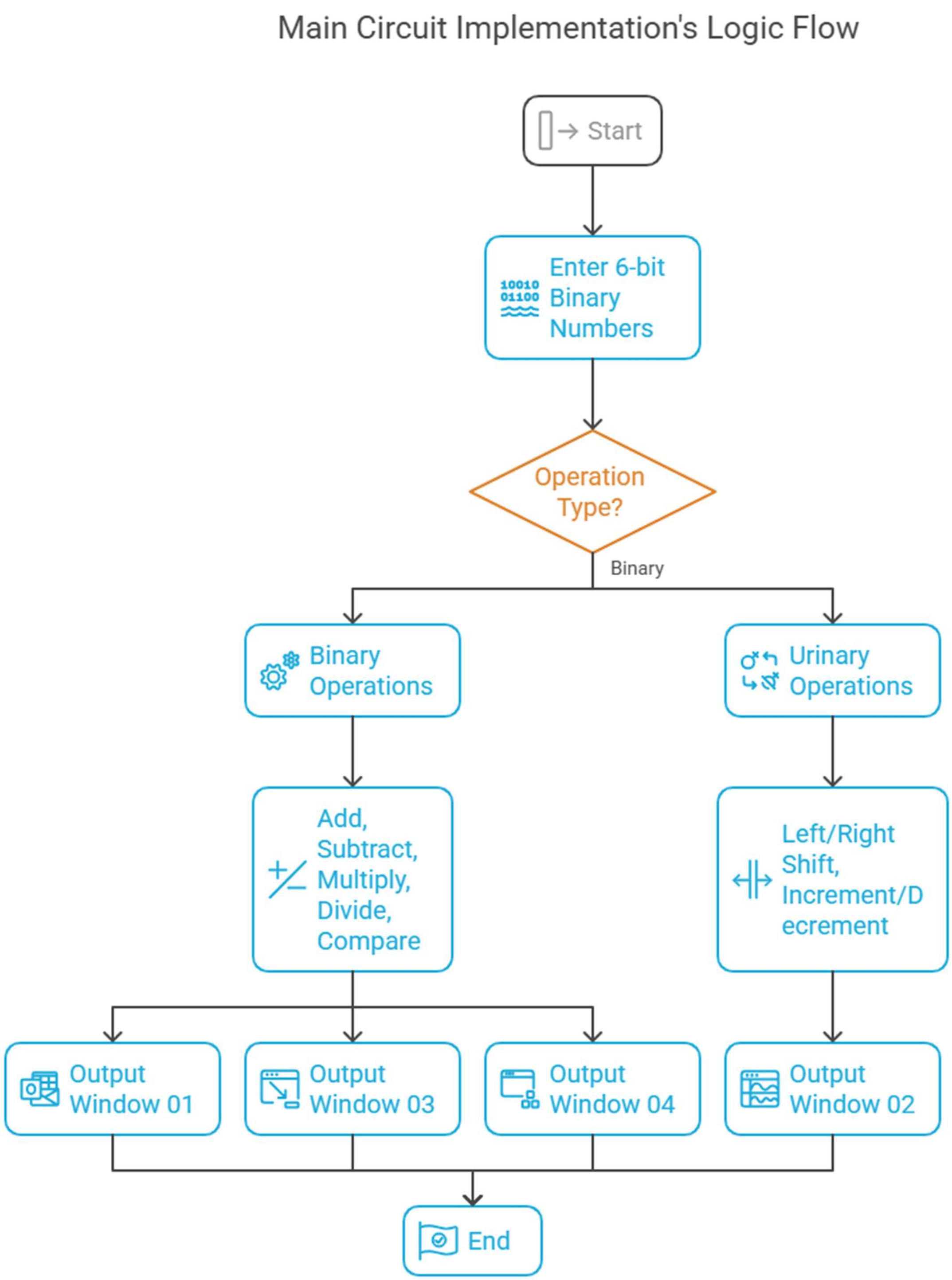
- Binary number representation
- Combinational logic design
- Operation multiplexing

2.3 Tools Used:

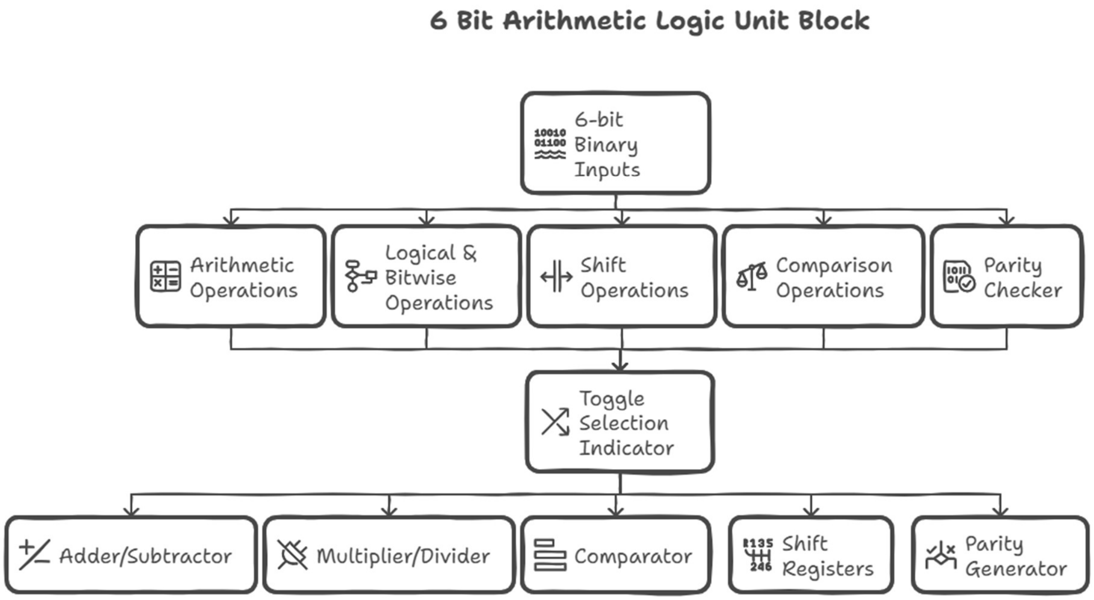
1. Software **Logisim-win** (Version 2.7.1)
2. Components:
   All the Logisim built-in tools are used in development of this ALU, no external components are involved !

3. Design Methodology

3.1 Top-Down Approach :

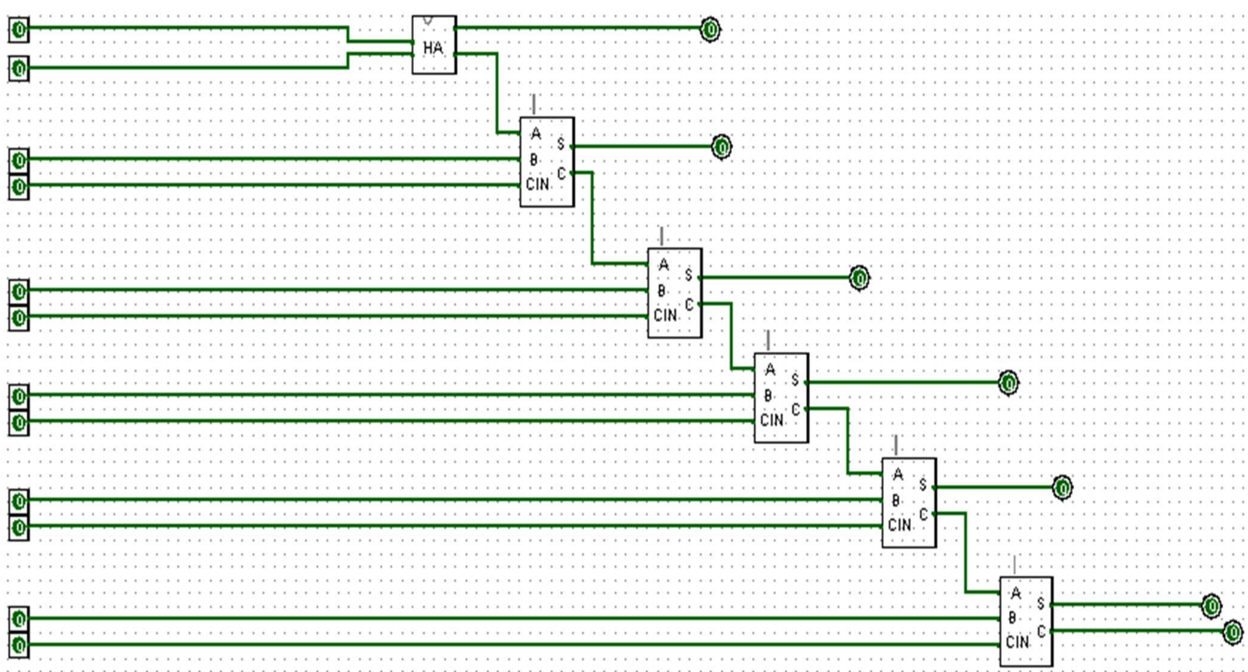


3.2 Core Components:

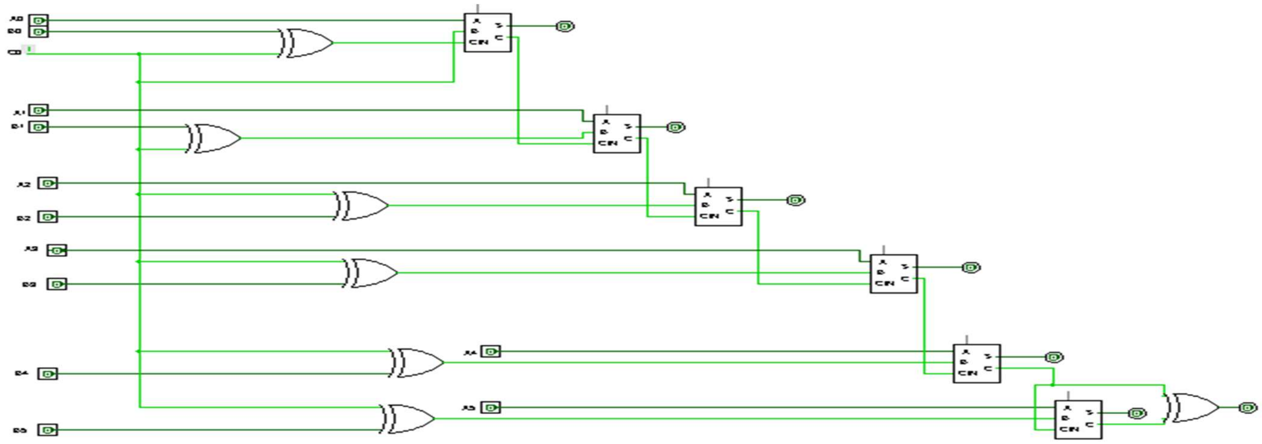


Block Diagram of ALU

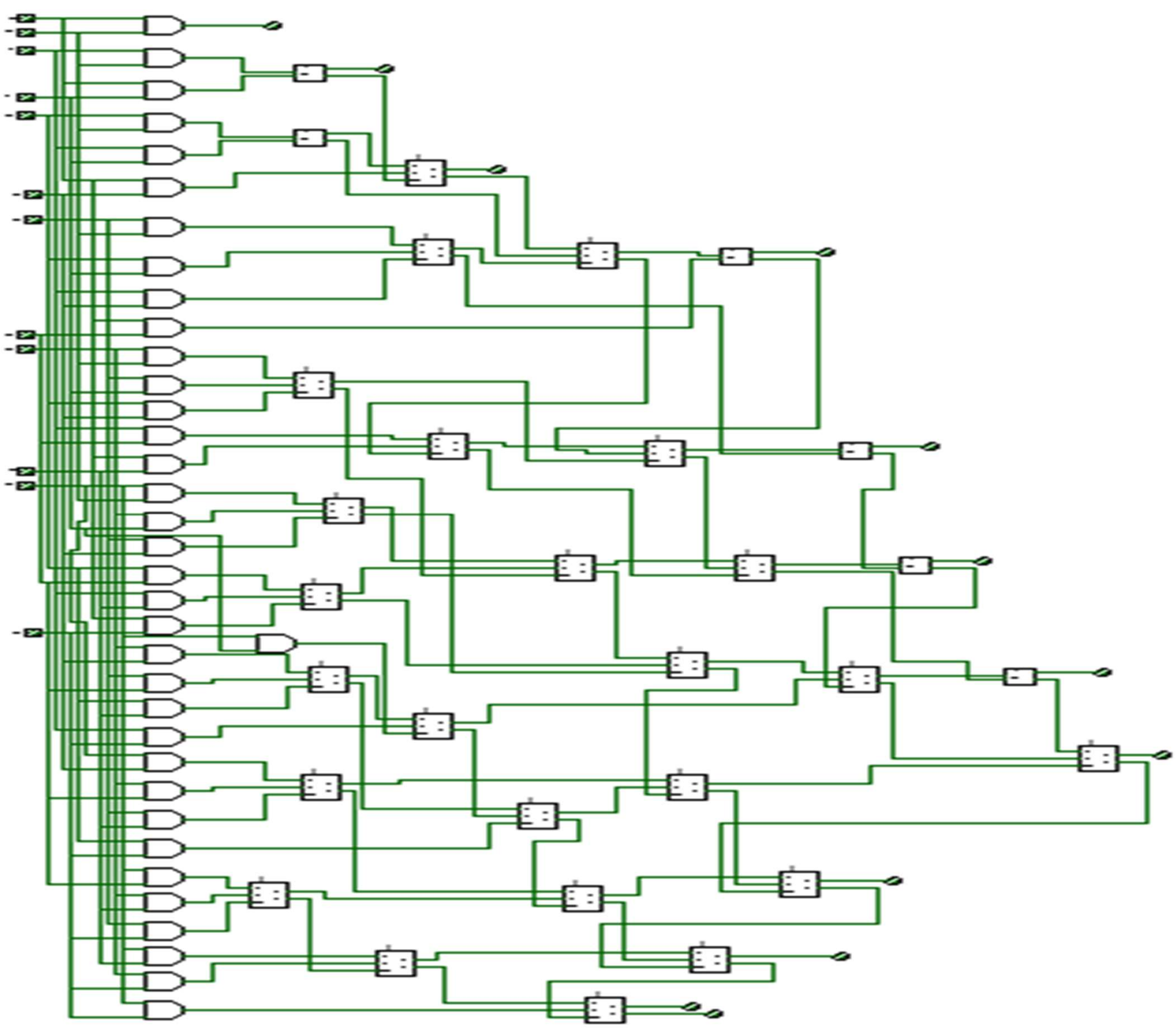
A. Arithmetic Unit



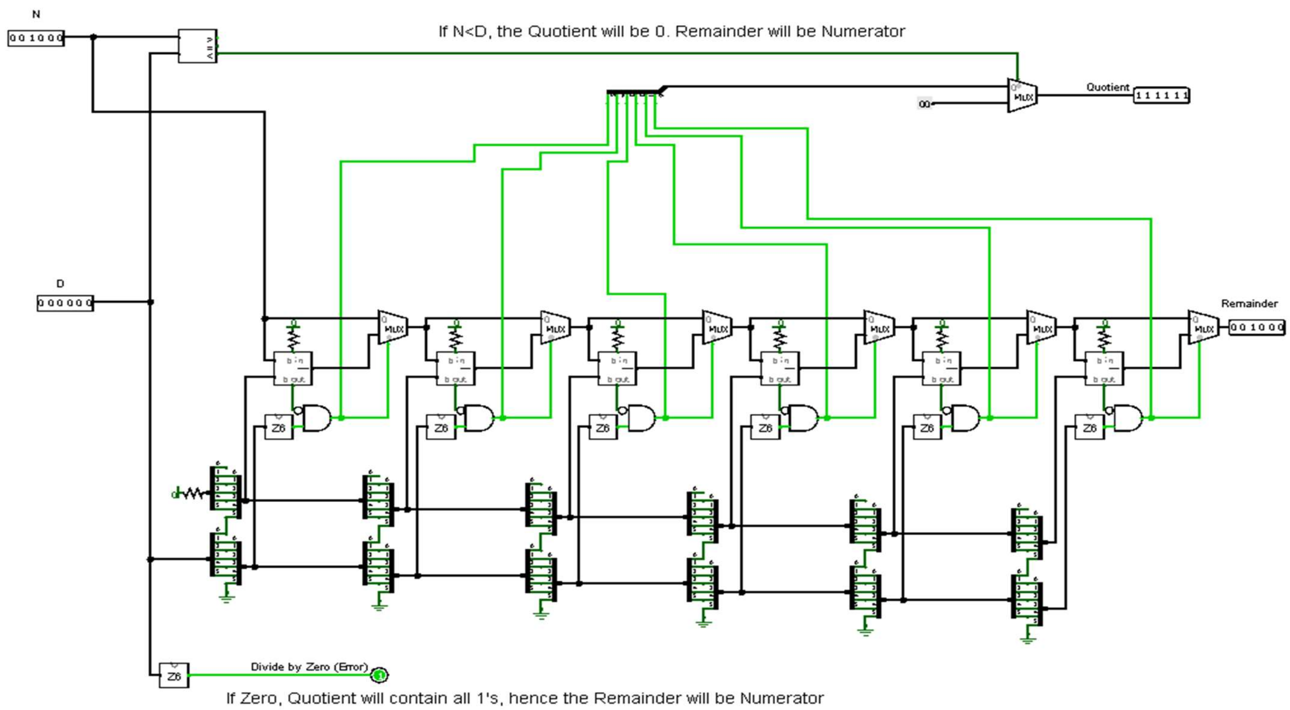
6-Bit Adder using Full Adder as Subcircuit



6-Bit Subtractor using Full Adder as Sub-circuit

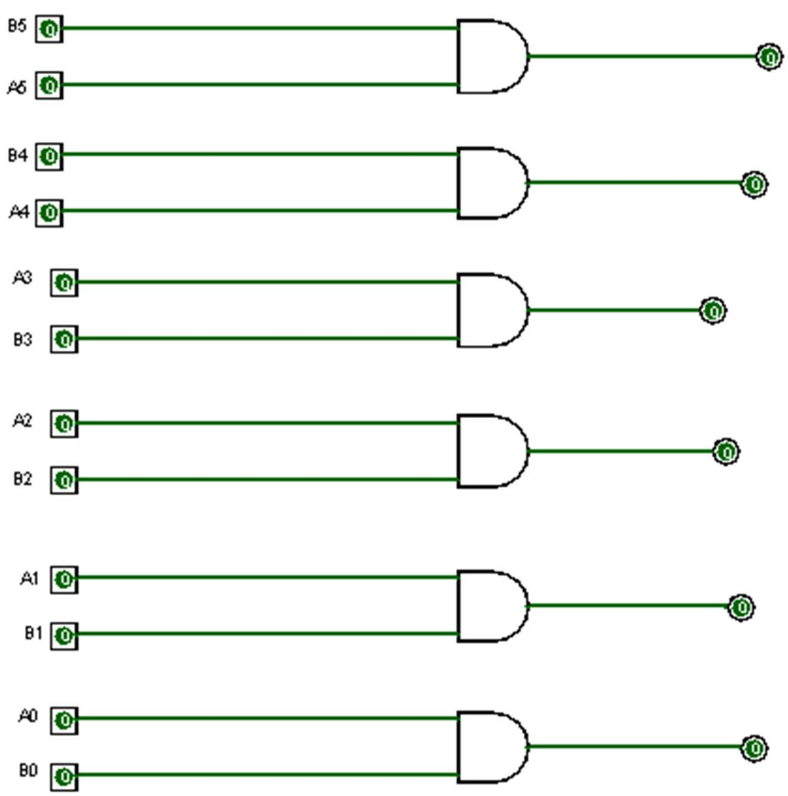


6-Bit Multiplier using Full Adder as Subcircuit

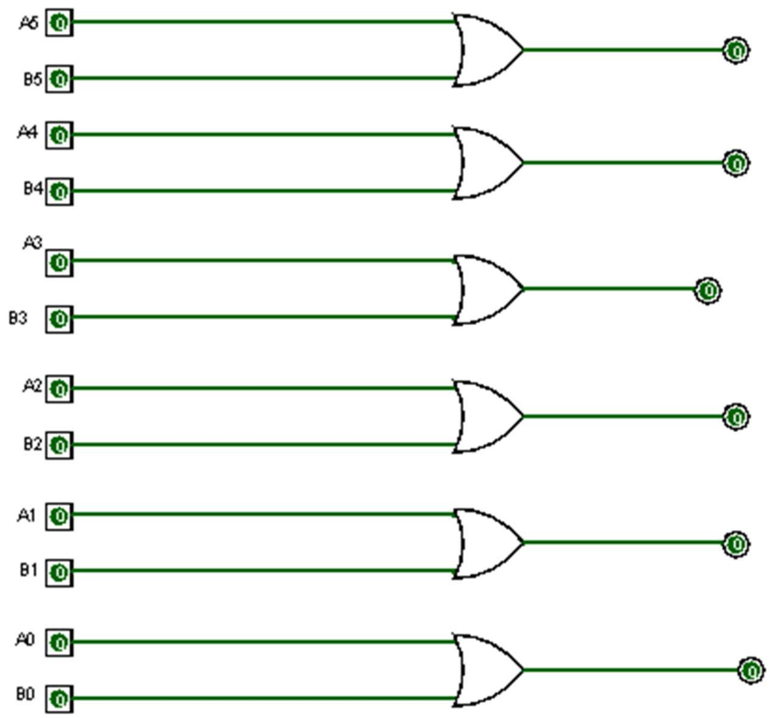


6-Bit Divider using 6-Bit Subtractor as Subcircuit

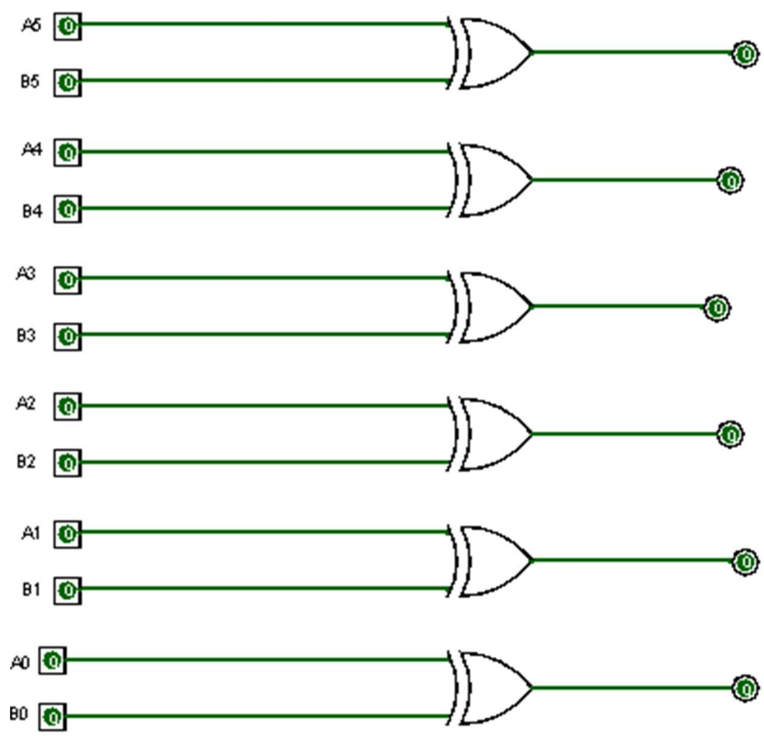
B. Logic Unit : Bitwise operations using gate networks



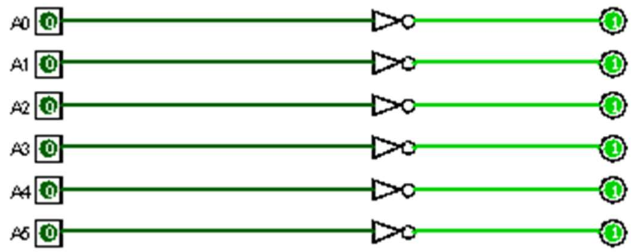
Bitwise AND



Bitwise OR



Bitwise XOR

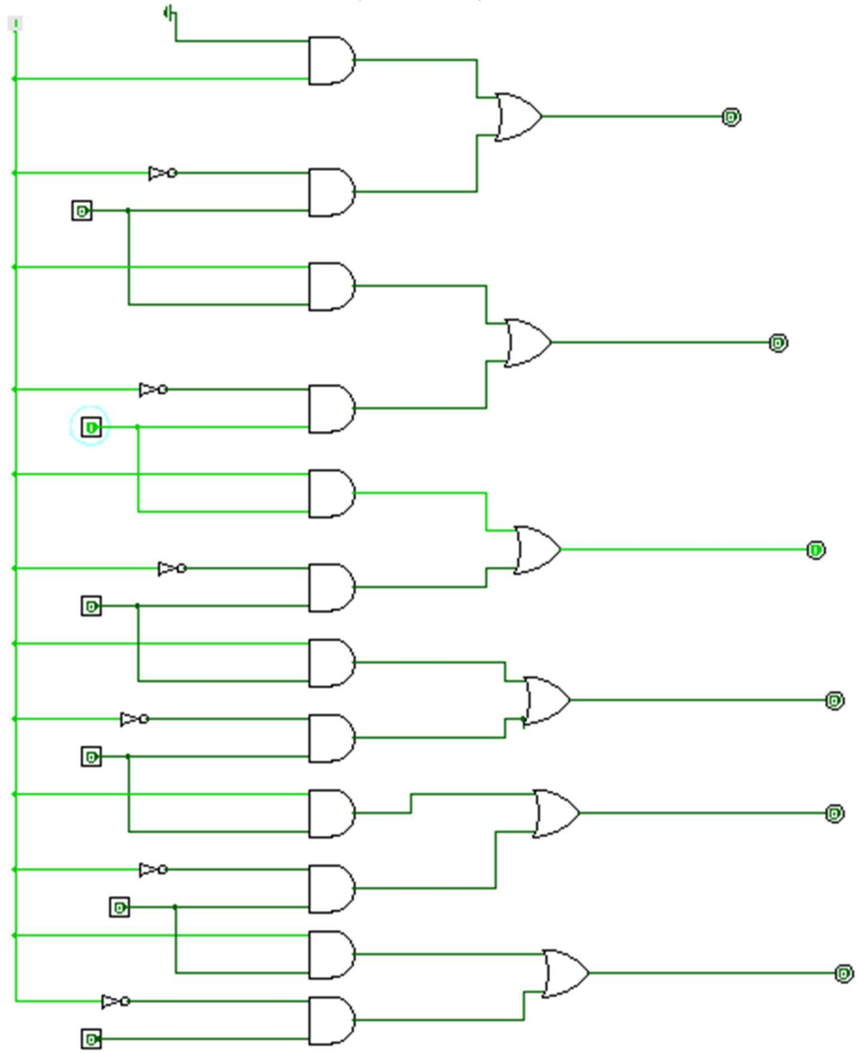


Bitwise NOT

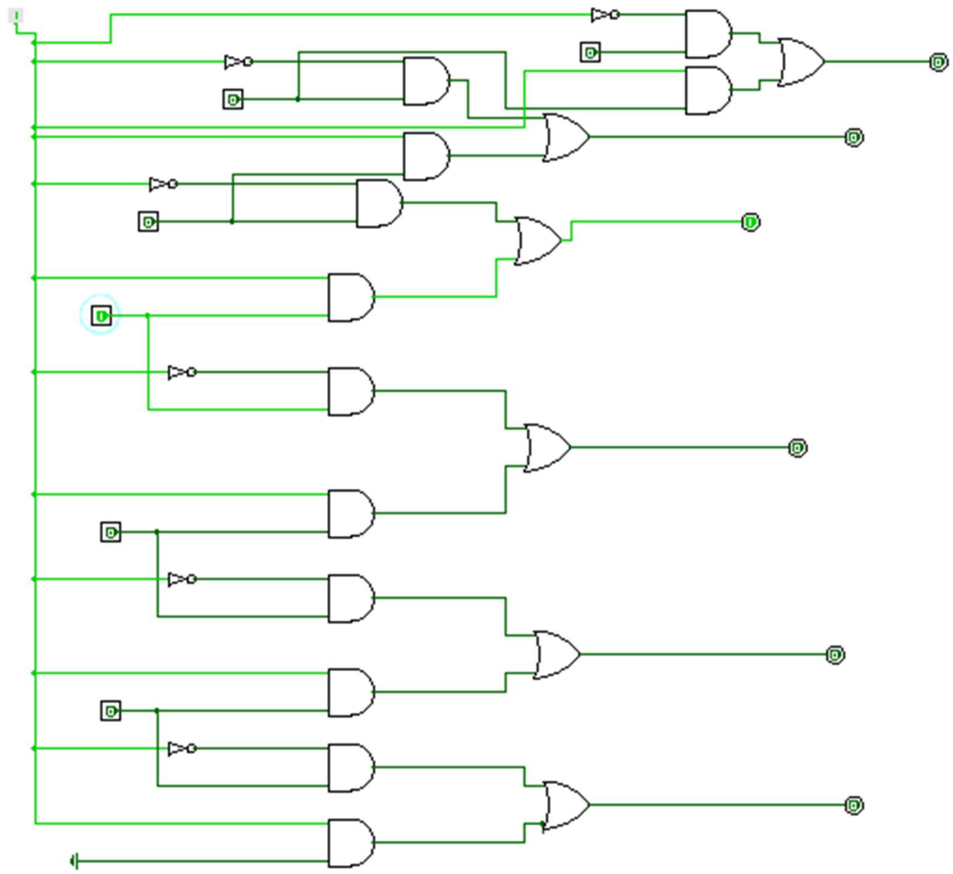
C. Shift Unit:

1. Left Shift:

Bits A[i-n] → RESULT[i] (for `i ≥ n`), else 0.

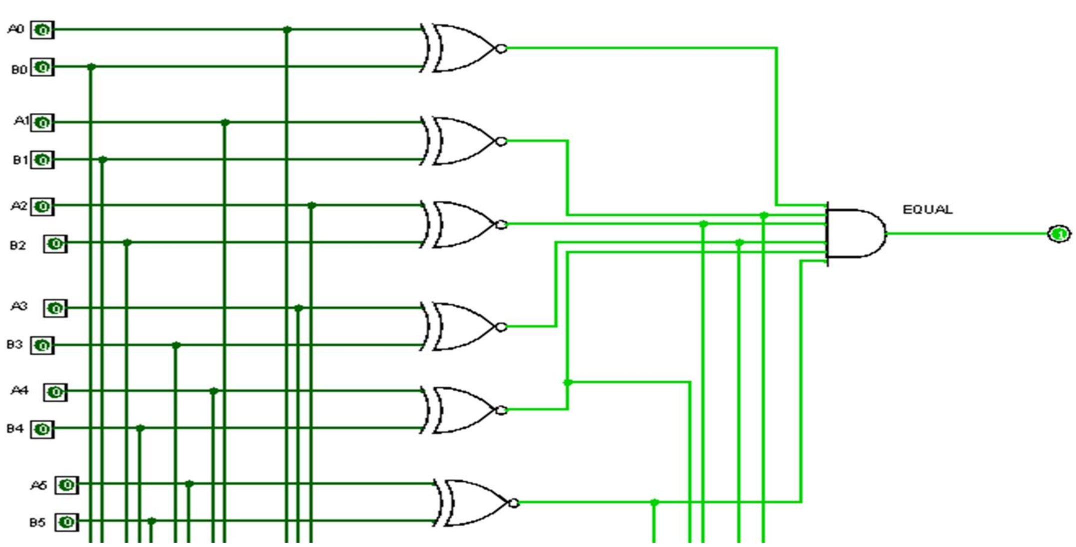


2. **Right Shift:**
   Bits `A[i+n] → RESULT[i]` (for `i ≤ 5-n`), else 0.

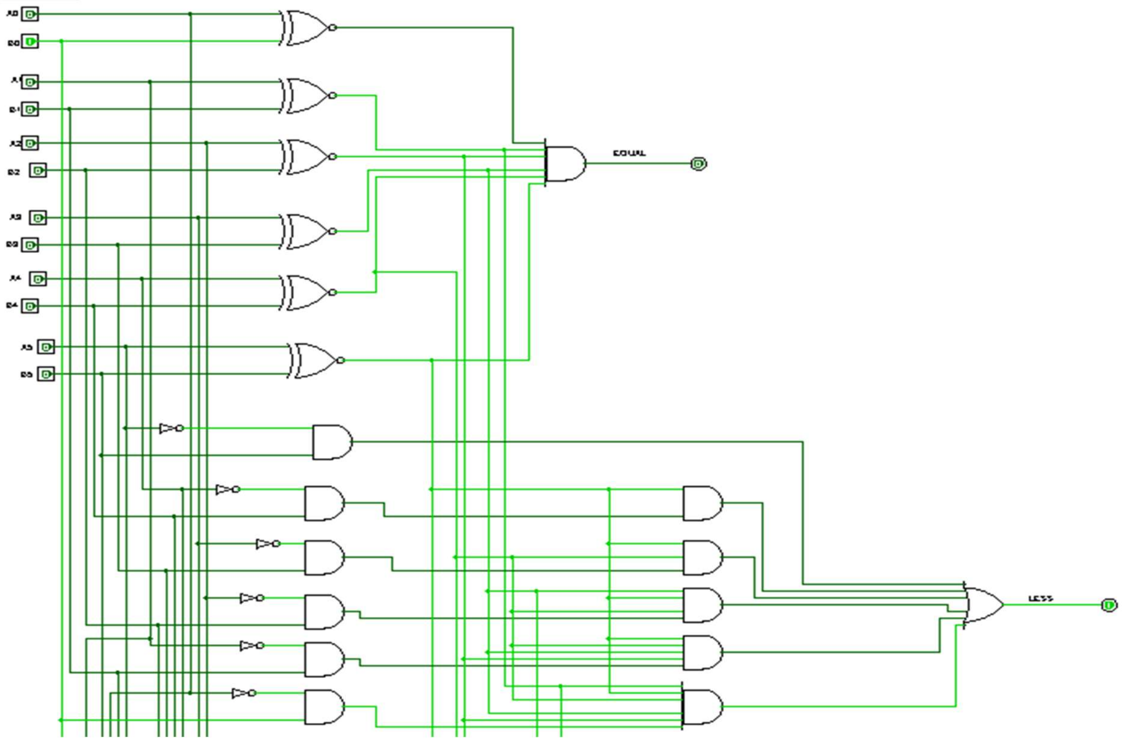


D. Comparison Unit: Compares two 6-bit inputs (`A` and `B`) and outputs:

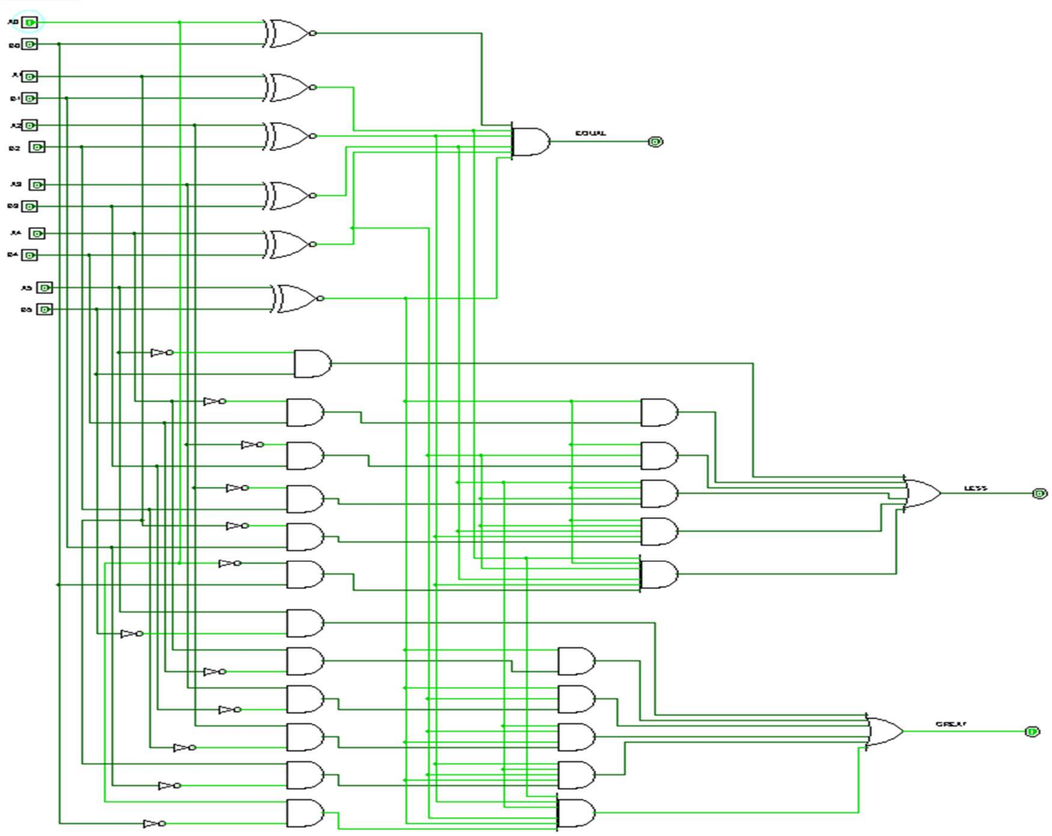
- `A == B`



- A < B

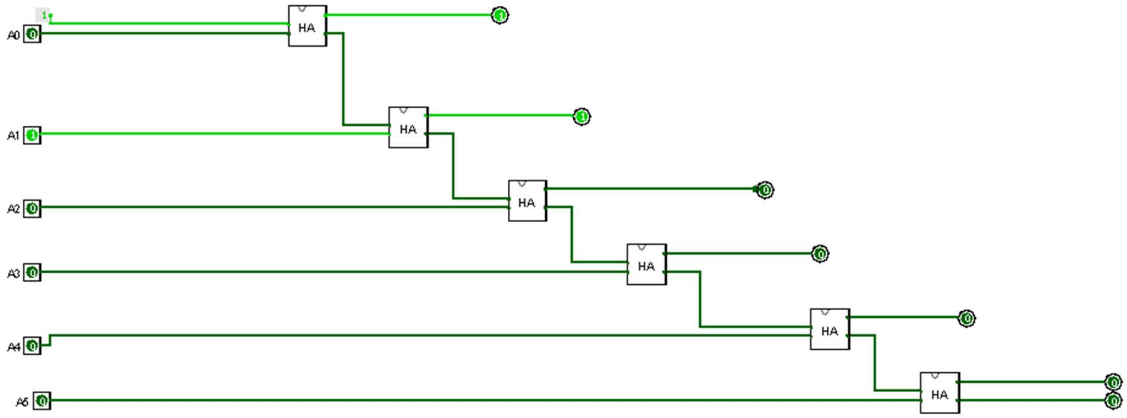


- A > B

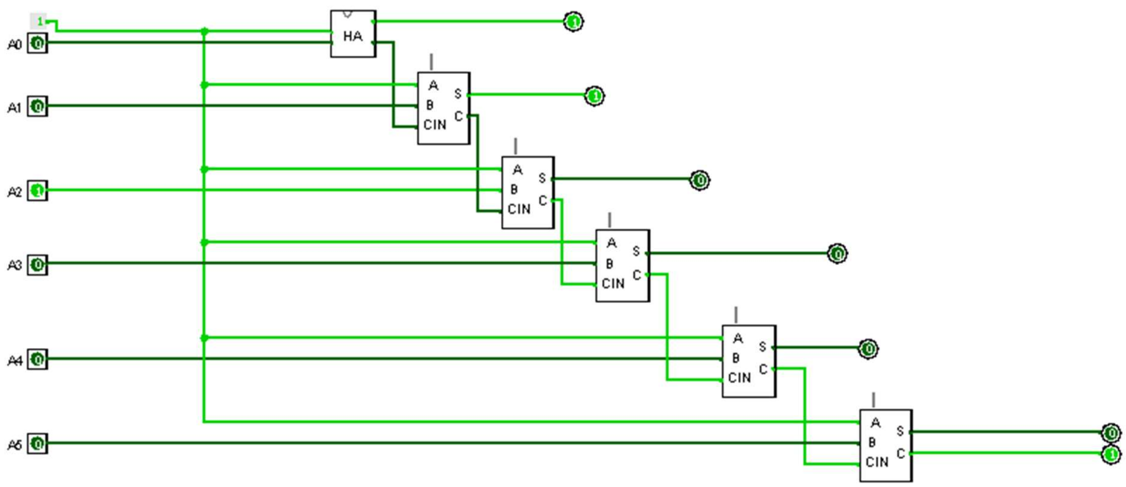


E. Increment/Decrement Unit: Computes `A + 1`(increment) and `A - 1`(decrement)

1. Increment Circuit:

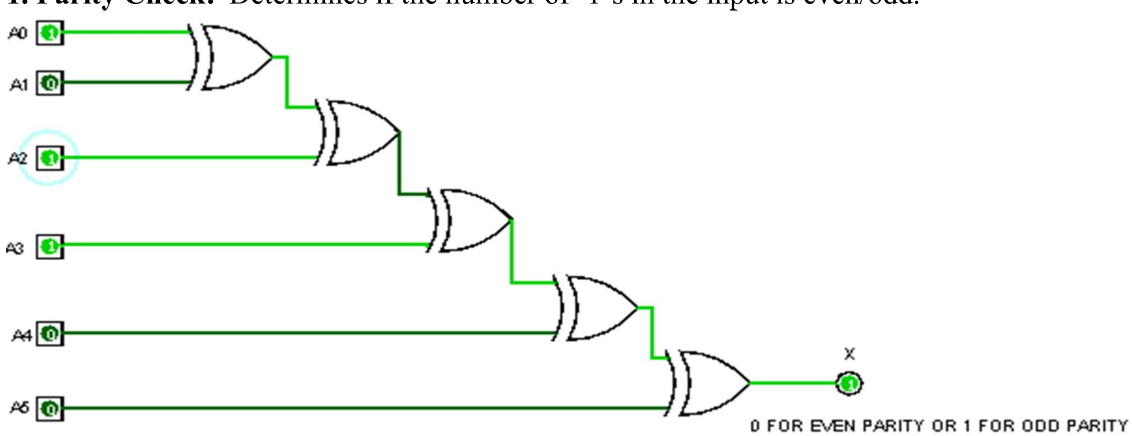


2. Decrement Circuit:

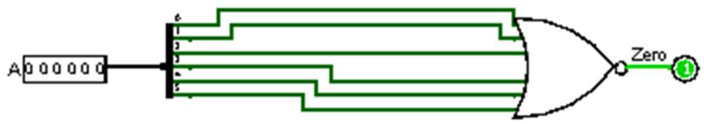


F. Status Flag Unit:

1. Parity Check: Determines if the number of `1`s in the input is even/odd.



2. Zero Detect: Checks if all the input bits are ‘0’.

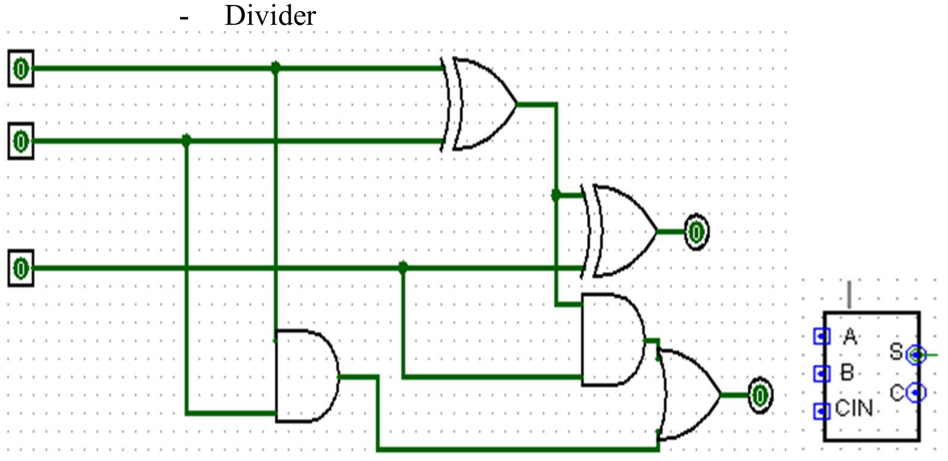


Generously used in 6-Bit Divider Circuit

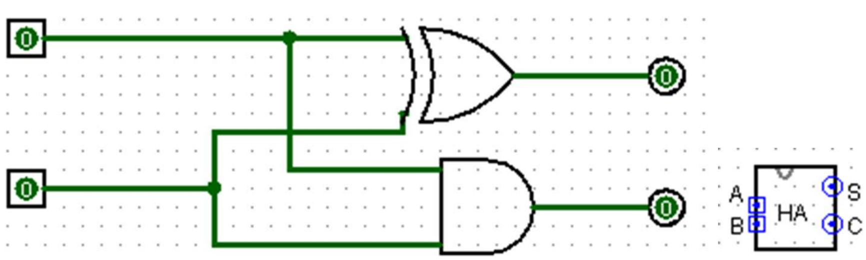
3.3 Gate-Level Building Blocks:

Designed Half Adders and Full Adders using Basic Logic Gates (AND,OR,NOT) and used them in the complex circuit designs like 6-Bit Adder:

- Adder
- Subtractor
- Multiplier
- Divider



Full Adder Circuit

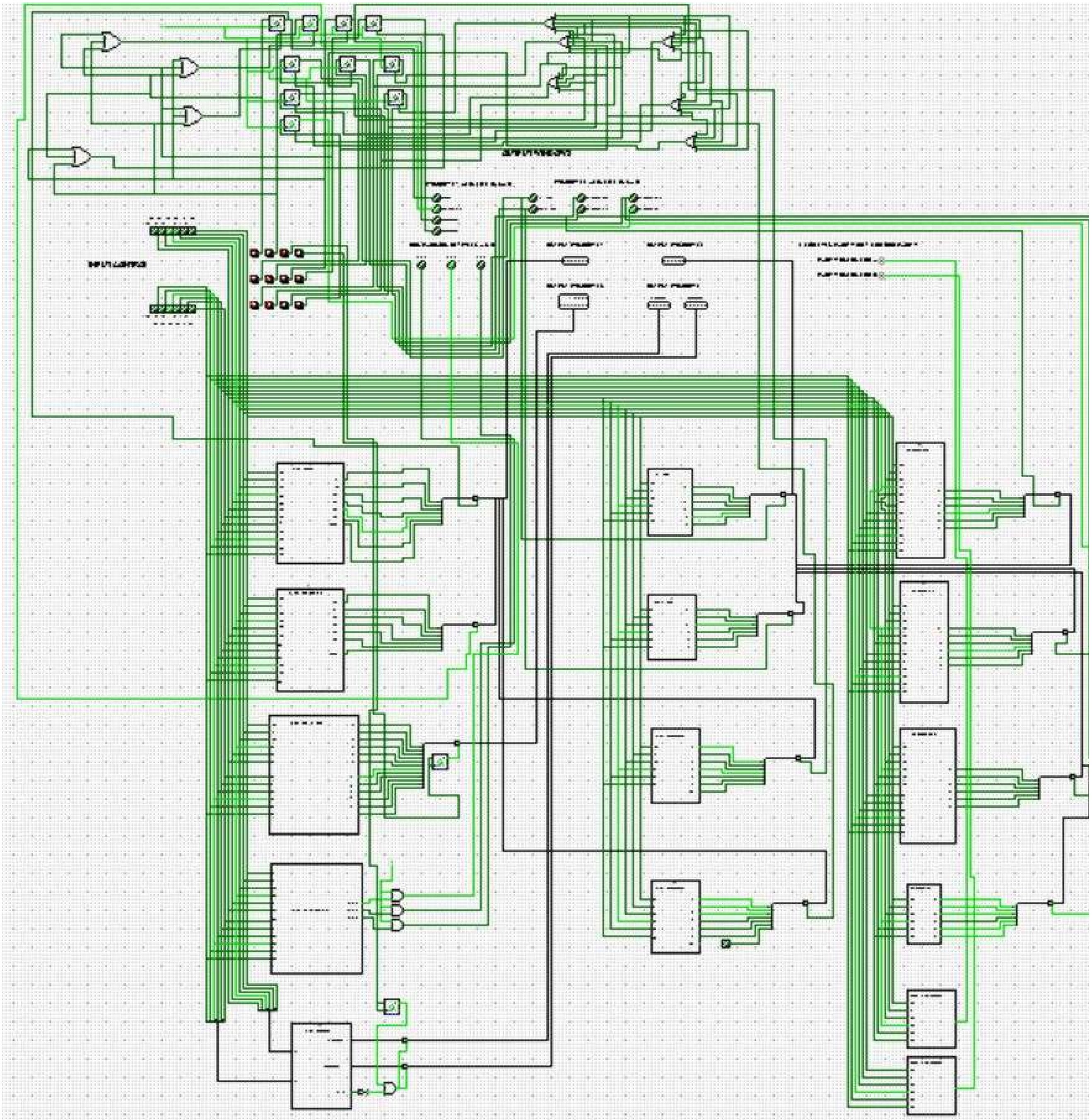


Half Adder Circuit

3.4 Toggle Button Mechanism:

Each operation in the ALU is controlled using a **toggle button**, a press sets it **ON**, and a second press turns it **OFF**. This simplifies user interaction and mimics instruction selection in real CPUs. To guide users, **output indicators** display which operation is active, ensuring clarity when multiple results are visible.

3.4 All in One (Main Circuit) | The Satellite View



The main circuit integrates all submodules, operation decoders, data buses, selectors, and output visualizers—into a unified ALU simulation controlled via Toggle Buttons

"Behold the Beast: A 6-Bit ALU So Powerful, It Defies Screenshots!"

"This circuit is so dense, it has its own gravitational pull."

4. Conclusion: More Than an ALU

What began as logic gates became a journey, a fusion of logic and learning, struggle and satisfaction. Our 6-bit ALU isn't just circuitry; it's a symbol of structured thinking, perseverance, and creative engineering.

Technical Wins
We built a modular, robust system, 16 operations, 120+ gates, countless iterations. Each subcircuit told a story: carry chains, shift registers, comparators, all woven into a functioning digital brain.

The Human Side
We grew in resilience. Simulations failed, yet we tried again. Designs clashed with logic, yet we adapted. Every connection was a decision. Every fix, a step forward.

Looking Ahead
Beyond the bits and operations, we've built a foundation for future systems—and for ourselves as engineers. Thank you to everyone who shared this journey. May every bug bring growth, and every 0 and 1 hold meaning.

***With every bit flipped and every gate conquered, this ALU bows out.
Sayonara, and onward to the next challenge.***