Project Synopsis: 4-Bit Versatile ALU for Arithmetic and Logical Operations

Problem Statement

We often come across many such components which are common to many digital circuits and are re-used time and again. One such critical component is the **Arithmetic Logic Unit (ALU)**, which is responsible for performing basic operations such as addition, subtraction, multiplication, and comparison. Traditional implementations often require multiple discrete components for each operation, leading to increased hardware complexity, higher power consumption, and inefficient resource utilization.

Furthermore, in educational environments and small-scale applications like eSim-based circuit simulations, there is a lack of modular and easy-to-understand designs that demonstrate the integration of arithmetic and logical functions in a single, compact unit. This creates a gap for learning and implementing such systems effectively.

Proposed Solution

Our 4-bit versatile ALU combines addition, subtraction, multiplication, and comparison, into a single, modular unit. The ALU is designed to handle 4-bit operands and supports the following operations, selectable using a 2-bit operation control signal (`OP[1:0]`):

1. **Addition**: Performs 4-bit addition with overflow detection.
2. **Subtraction**: Performs 4-bit subtraction using 2's complement logic.
3. **Multiplication**: Computes the product of two 4-bit inputs with an 8-bit result.
4. **Comparison**: Determines if one operand is greater than or equal to the other.

Benefits of the Proposed ALU

- **Scalability**: The design can be extended to support larger bit widths or additional operations as needed.
- **Simulation-Ready**: The ALU can be implemented and tested in eSim, demonstrating its compatibility with open-source simulation tools.
- **Practicality**: The inclusion of core arithmetic and logical functions makes this ALU suitable for small-scale embedded systems and educational purposes.
- **User-Friendly**: Simplified operation control via a 2-bit signal makes the design intuitive and easy to simulate.

Reference

https://ieeexplore.ieee.org/document/10140574