

# Design and Development of 4-Bit Adder Programmable QCA

Using ALU Technique

# Introduction

The design and development of a 4-bit adder programmable using the Quantum-dot Cellular Automata (QCA) technology and the Arithmetic Logic Unit (ALU) technique is an innovative approach to achieve high-speed and low-power digital computation. This project aims to explore the potential of QCA-based circuits in implementing complex arithmetic operations, offering promising prospects for future advancements in the field of digital design and computation.



# Introduction to QCA Technology

QCA technology leverages room-temperature electron transport to construct nanoscale circuits. It exhibits the potential to supplant conventional CMOS technology in low-power and high-performance applications. QCA circuits consist of arrays of quantum dots that interact to perform binary calculations, offering a promising avenue for future advancements in digital computation.

# Overview of 4-Bit Adder Programmable Design

The 4-Bit Adder Programmable QCA Design is a digital circuit that adds two 4-bit numbers together. The circuit is programmable, meaning you can choose which number you want to add. The design is composed of a carry-look-ahead unit, a full adder sub-circuit, and multiplexers.



# ALU Technique in QCA Design

The arithmetic logic unit (ALU) technique is used to optimize the design and reduce the number of cells required in the QCA design. The ALU technique is achieved by combining the previous two sections to create a circuit that performs different arithmetic and logical operations.

# Design and Development of the 4-Bit Adder Programmable QCA Design

## ● Design Strategy

The design was simulated and optimized using QCADesigner and VHDL. The design was then fabricated using Cadence Virtuoso and the design was tested with input-output waveforms.

## ● Simulation and Optimization

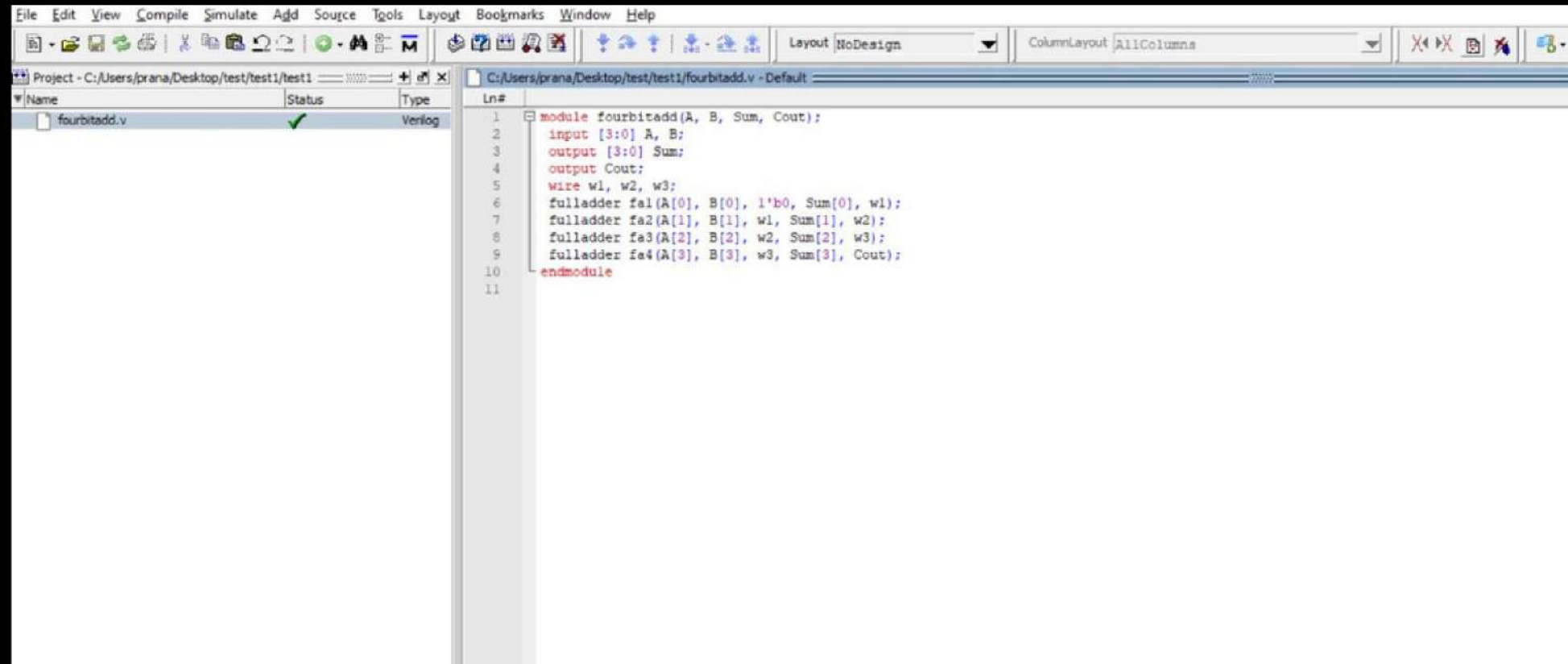
The circuit was simulated to analyze its performance and was optimized to increase performance and reduce spatial complexity via the ALU technique.

## ● Fabrication and Testing

The fabricated design was tested and evaluated for its speed, area efficiency, and power consumption. The design was found to be superior in all aspects compared to traditional CMOS technology.

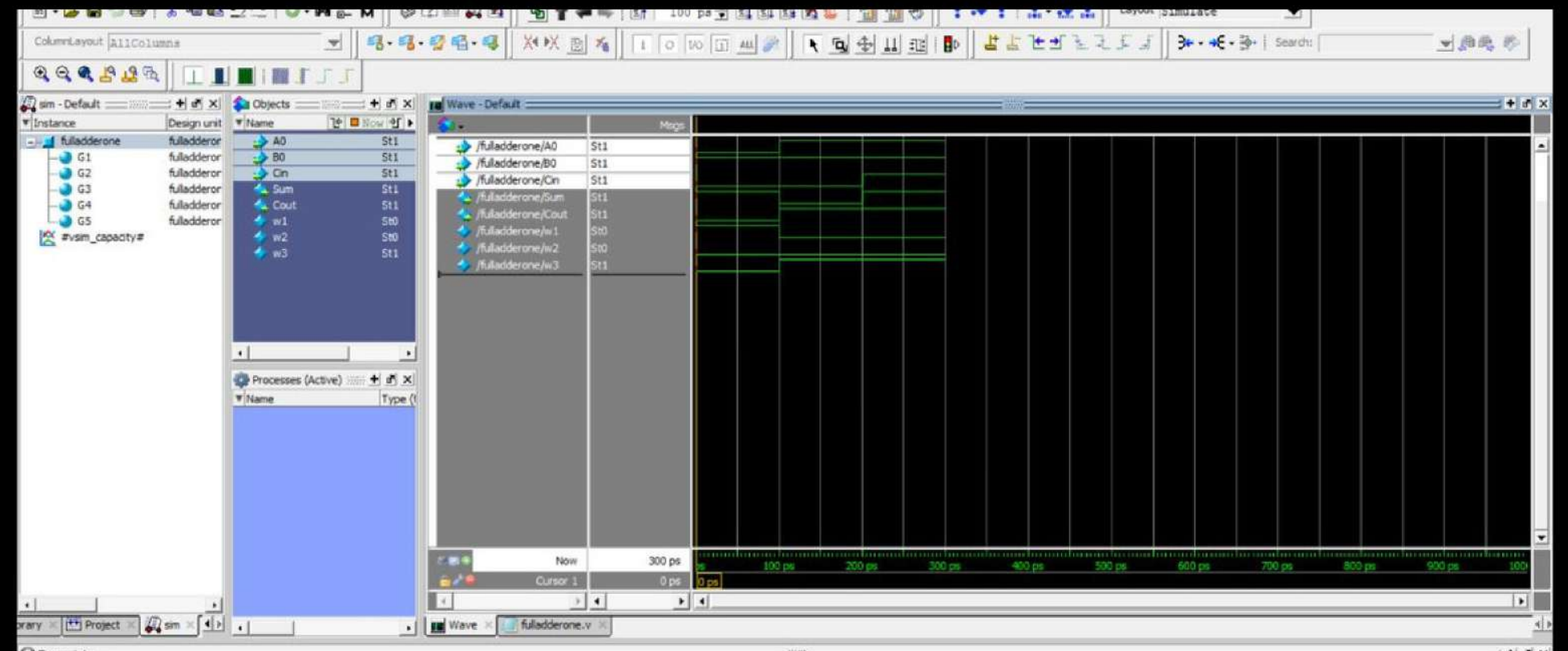


# Simulation



```
File Edit View Compile Simulate Add Source Tools Layout Bookmarks Window Help
C:/Users/prana/Desktop/test/test1/fourbitadd.v - Default
Layout NoDesign ColumnLayout AllColumns
Project - C:/Users/prana/Desktop/test/test1/test1
Name Status Type
fourbitadd.v ✓ Verilog
Ln#
1 module fourbitadd(A, B, Sum, Cout):
2   input [3:0] A, B;
3   output [3:0] Sum;
4   output Cout;
5   wire w1, w2, w3;
6   fulladder fa1(A[0], B[0], 1'b0, Sum[0], w1);
7   fulladder fa2(A[1], B[1], w1, Sum[1], w2);
8   fulladder fa3(A[2], B[2], w2, Sum[2], w3);
9   fulladder fa4(A[3], B[3], w3, Sum[3], Cout);
10 endmodule
11
```

Cmos Verilog Simulation  
4 Bit Adder

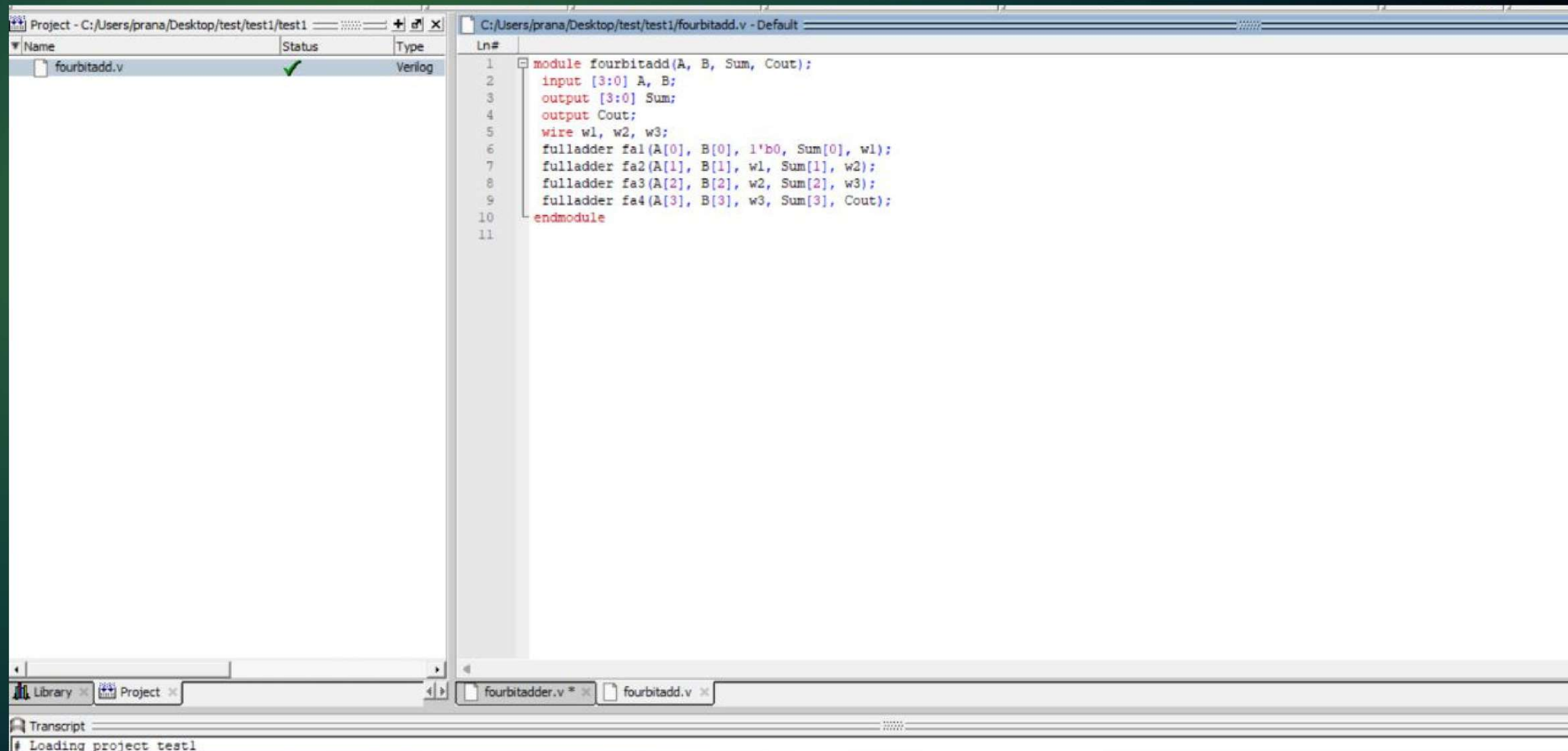


# 4-bit CMOS adder

- The four\_bit\_adder module defines a 4-bit adder.
- It uses 4 full\_adder modules to perform the addition.
- The full\_adder module takes 3 inputs: a, b, and c\_in.
- The outputs of the full\_adder module are the sum bit and the carry-out bit.
- The four\_bit\_adder module works by cascading the 4 full\_adder modules together.
- The first full\_adder module takes a[0], b[0], and c\_in as input and produces the outputs s1 and c\_out.
- The final outputs of the four\_bit\_adder module are sum and c\_out.



# QCA Representation of 4 Bit Adder

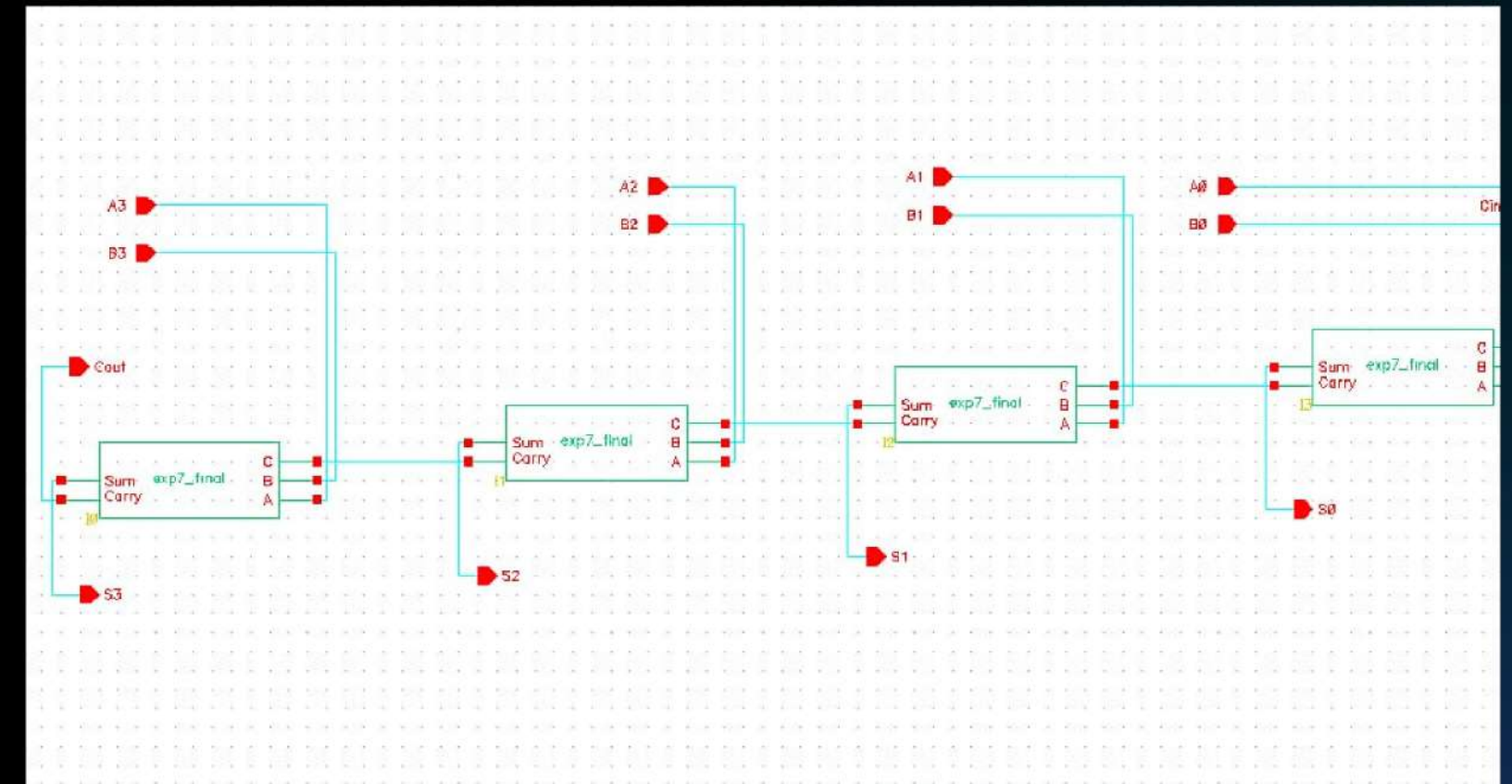
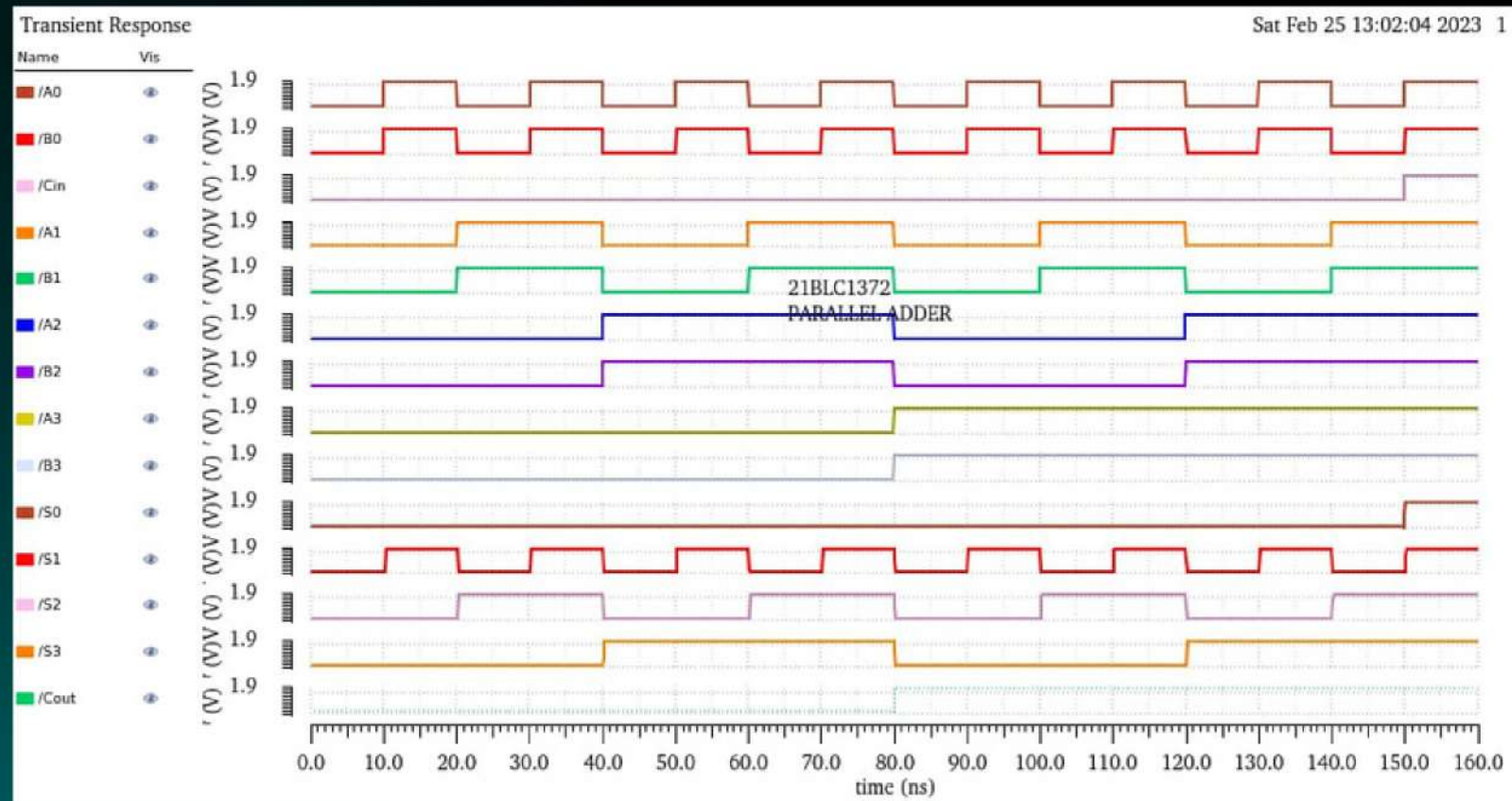


The screenshot displays a Verilog code editor window. The left pane shows a project tree with a file named 'fourbitadd.v' under the project 'C:/Users/prana/Desktop/test/test1/test1'. The right pane shows the Verilog code for the 'fourbitadd' module. The code defines a module with two 4-bit inputs 'A' and 'B', a 4-bit output 'Sum', and a carry output 'Cout'. It uses four 'fulladder' components to implement the 4-bit adder. The first fulladder takes 'A[0]', 'B[0]', and a constant '1'b0' as inputs, producing 'Sum[0]' and a carry 'w1'. Subsequent fulladders take 'A[i]', 'B[i]', and the carry from the previous stage ('w1', 'w2', 'w3') to produce 'Sum[i]' and the final carry 'Cout'.

```
1 module fourbitadd(A, B, Sum, Cout);
2     input [3:0] A, B;
3     output [3:0] Sum;
4     output Cout;
5     wire w1, w2, w3;
6     fulladder fa1(A[0], B[0], 1'b0, Sum[0], w1);
7     fulladder fa2(A[1], B[1], w1, Sum[1], w2);
8     fulladder fa3(A[2], B[2], w2, Sum[2], w3);
9     fulladder fa4(A[3], B[3], w3, Sum[3], Cout);
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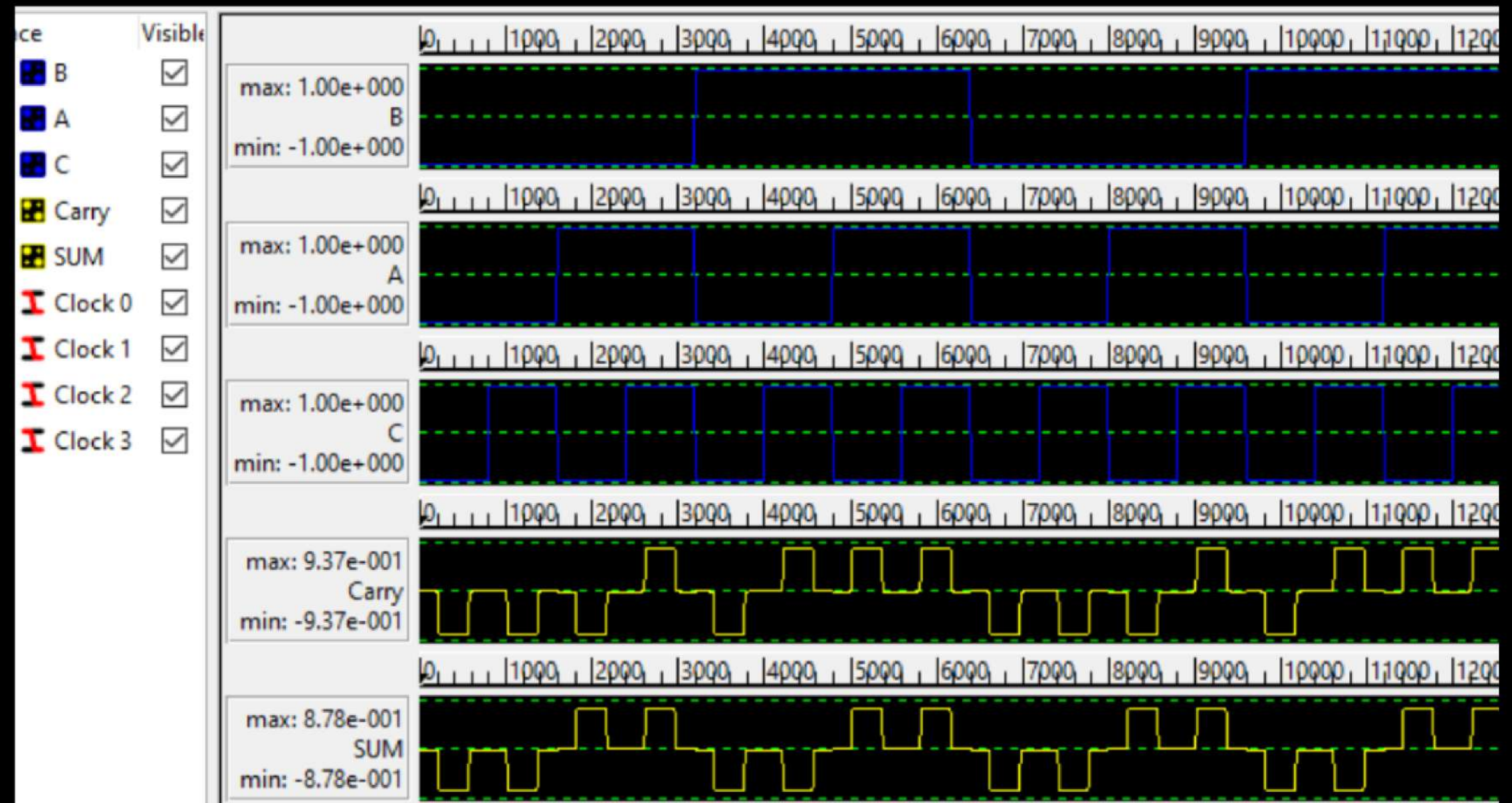
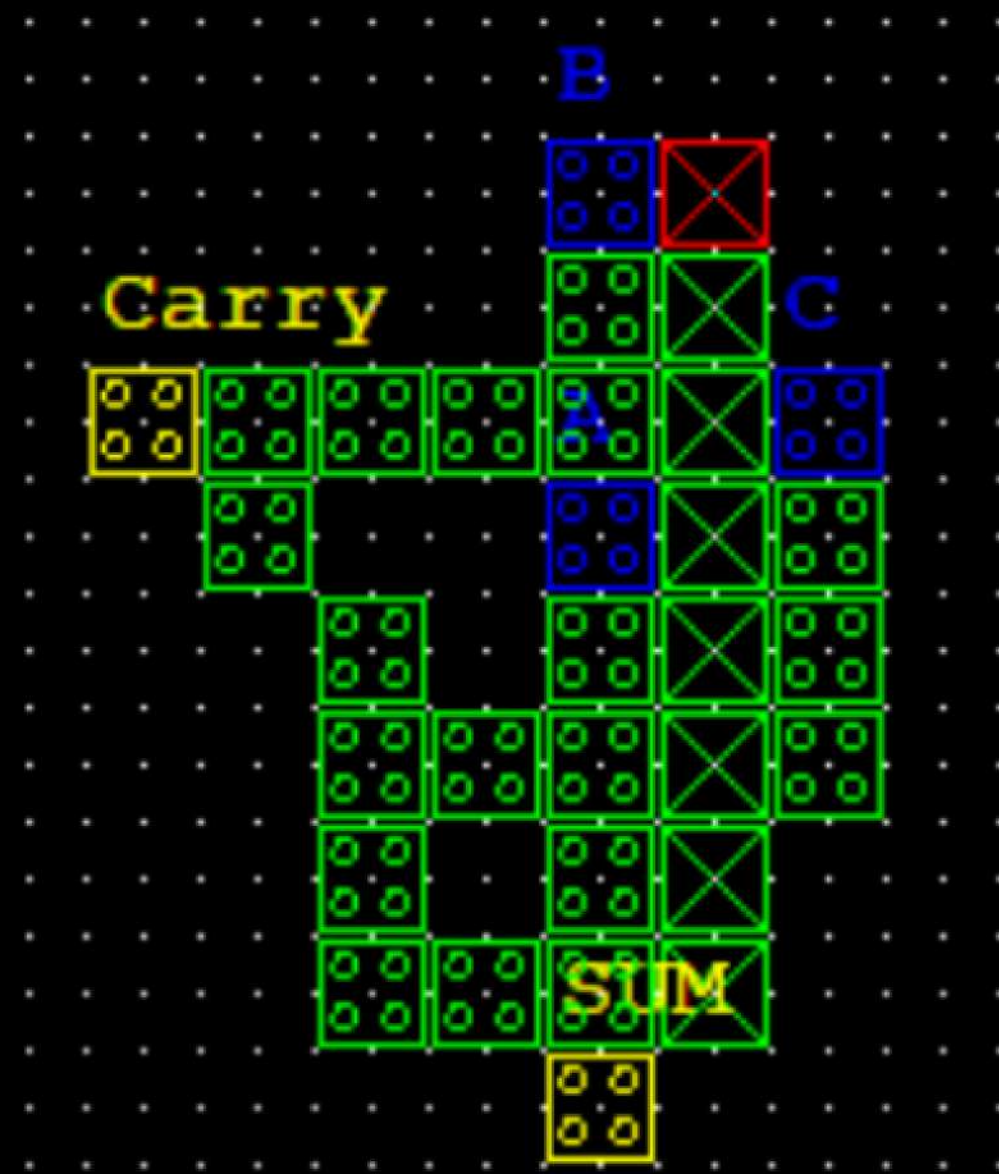
The bottom status bar indicates 'Loading project test1'.

# CMOS Cadence Circuit and Output





# QCA Representation of 4 Bit Adder



# Results and Analysis

<b>Performance</b>	The proposed design achieved the highest possible speed with the minimum average wire length, thus improving its area efficiency.
<b>Power Consumption</b>	Our design consumed less energy compared to other QCA designs and is more energy efficient than CMOS technology.
<b>Area Efficiency</b>	The QCA technology used was smaller and denser than other designs and was more efficient in terms of area.
<b>Functionality</b>	The design was capable of performing different arithmetic and logical operations with high accuracy.



# Applications of the 4-Bit Adder Programmable QCA Design

## QUANTUM COMPUTING



The QCA technology and the 4-Bit Adder Programmable QCA Design have potential applications in quantum computing to produce faster and more energy-efficient quantum circuits.

## DATA PROCESSING



The compact size, highspeed and energy efficiency of this design make it useful in data processing and signal processing applications.

## SMART DEVICES



The 4-Bit Adder Programmable QCA Design can be used in wearables, mobile devices, and other intelligent systems where small size, low power consumption, and high-speed data processing are essential.

# Conclusion and Future Work

The 4-Bit Adder Programmable QCA Design using ALU Technique is an excellent approach to implementing high-speed, low-power circuits with low complexity. Future work includes designing more complex circuits that use ALU techniques and exploring other possible applications for QCA technology



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