12-BIT VERILOG CALCULATOR WITH TRIGONOMETRIC FUNCTIONS

Irra Edralyn L. Manalo [1], Evangeline Rose Q. Montecillo [1], Denmor S. Colinares [1]
Jed Daryl Lousie Lingat [1], Rionel Belen Caldo [2]
[1]*Electronics Engineering Department*
[2] *Electronics and Computer Engineering Department*
Luceum of the Philippines University Laguna (LPU-L)
rionel14_caldo@yahoo.com

ABSTRACT

This paper intends to create a synthesizable Verilog code with sine function, cosine function, logarithm function exponential function, addition function, subtraction function, multiplication function and division function. To choose from different operations an eight by one multiplexer is included in the system. After choosing from different operations the system will ask for a four bit input numbers to be processed and an output of eight bit will be generated, this output will be the input of the multiplexer and depending in the input in the selector an answer will be generated. Since Verilog is purely binary and a sine and cosine of a number may include decimal numbers it is hard to create a verilog code for this kind of functions. The main challenge of this paper is to create a synthesizable Verilog code for sine and cosin function with accurate output. The output of the sin and cosin function will be a 12 bit number 8 bit for the real number and 4 bit for the decimal value.

***Keywords**: Verilog Code, Calculator, ALU, HDL, CORDIC*

INTRODUCTION

Background of the Study

Mathematics plays a very important role in the development of the society. It can be seen as the foundation of technical and scientific knowledge which is vital for the each and everyone's progress [1].

And while the technology advances at full speed. Many calculating devices had existed starting with the abacus, until it was improved into a mechanical device just like a calculator which performs different kinds of operations and functions. And up to this point, that is being used for in everyday life [2].

In this modern time, Calculator is a device used for solving mathematical calculations such as addition, subtraction, multiplication and division. Also, having additional functions such as logarithmic, scientific and trigonometric [3].

CORDIC algorithm, also Coordinate Rotation Digital Computer computes the trigonometric functions by rotating the coordinate system. And its main purpose is to computing transcendental. CORDIC can compute any functions, such as in circular or hyperbolic trig functions, also logarithmic and roots [4].

To keep up with the technology, we respond to it by having a system made up by a Verilog program which can perform the following functions:

- Addition
- Subtraction
- Multiplication
- Division
- Logarithmic
- Exponential
- Trigonometric

Problem Statement

Calculators nowadays feature several functions including arithmetic operations and trigonometric functions. Many programmers

used Visual basic, Java and C++ to code algorithms for calculator.

The proponents attempt to code a calculator that operates addition, subtraction, multiplication, division and some trigonometric functions using Verilog.

Verilog (IEEE 1364) is a Hardware Description Language (HDL). It is intended to be used for verification through simulation.

Objectives of the Study

General Objective

To be able to make a synthesizable Verilog code that can perform different mathematical operations.

Specific Objective

- To determine how accurate the results can be by the use of binary codes compare to the results generated on calculators.
- Perform the operations properly by the given 2-Bit inputs and outputs a 12-Bit Binary code.
- To use CORDIC algorithm to create a synthesizable sin and cosine Verilog code.

METHODOLOGY

Xilinx ISE or Verilog Programming Language

Xilinx, Inc. is an American technology company, primarily a supplier of programmable logic devices. It is known for inventing the field programmable gate array (FPGA) and as the first semiconductor company with a fabless manufacturing model.

Founded in Silicon Valley in 1984, the company is headquartered in San Jose, California, with additional offices in Longmont, Colorado; Dublin, Ireland; Singapore; Hyderabad, India; Beijing, China; Shanghai, China; Brisbane, Australia and Tokyo, Japan.

Major FPGA product families include Virtex (high-performance), Kintex (mid-range) and Artix (low-cost), and the retired Spartan (low-cost) series. Major computer software includes Xilinx ISE and Vivado Design Suite [7].

Proposed System

Using the Xilinx ISE, the proponents aim to create a program that will function as a calculator with sine, cosine, logarithm, exponent, addition, subtraction, division, and multiplication operations. Referring to figure 2.6 the flowchart, the user will be asked to choose between different operations, since we will use an 8x1 multiplexer the user must input a 3 bit binary number from 000 to 111 to choose from different mathematical operations available. 000 and 001is for sine and cosine, 010 is for log, 011 is for exponent, 100 is for addition, 101 is for subtraction, 110 is for division and 111 is for multiplication, after choosing the operation the system will ask to input the desired two 4 bit numbers A and B, this are the inputs to be processed by the mathematical operations, the output is an 8 bit binary number and since the sine and cosine needs 1 input only (A) the other variable will be considered 1 and will be multiplied to the output.

Block Diagram

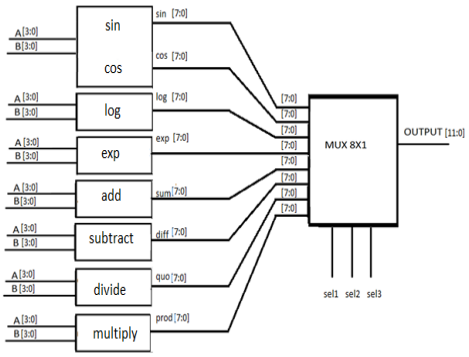


Figure 1 ***System block diagram of verilog calculator***

Calculator Functions:

1. Sine - is the ratio of the length of the side that is opposite that angle to the length of the longest side of the triangle [5].
2. Cosine – same as sine, except that the side used is the adjacent side instead of the opposite side [5].
3. Addition – used for finding the total amount when combined or sum up together.
4. Subtraction – used for finding the difference between two or more inputs.
5. Multiplication – a form of simplified repeated addition.
6. Division – a form of repeated subtraction.
7. Exp – uses the symbol “^”, meaning raised to power [6].
8. Log – specialized way of writing an exponent having base [6].
9. Multiplexer– is a switch designed to output 1 of several inputs in a common output line [8].

IPO Chart

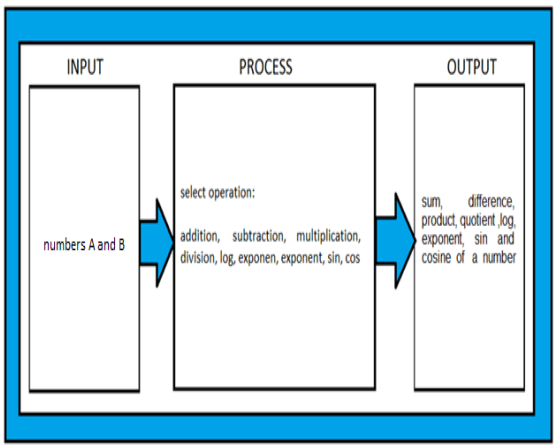


Figure 2 ***Input process output chart of the verilog coded calculator***

Pseudo code

1) Start
2) Choose 3 bit binary number from 000 to 111 to select operation.
3) If the input is 000 the operation will be sine and cosine.
4) If the input is 001 the operation will be cosine and sine
5) If the input is 010 the operation will be logarithm.
6) If the input is 011 the operation will be exponent.
7) If the input is 100 the operation will be addition.
8) If the input is the operation will be subtraction.
9) If the input is 110 the operation will be division.
10) If the input is 111 the operation will be multiplication.
11) Check if the input is from 000 to 111, if not the output is 0.
12) If the input is within the range of available numbers proceed to next step
13) Enter the desired number to be processed by the chosen operation.

14) Output the answer
15) End

2.6 Flowchart

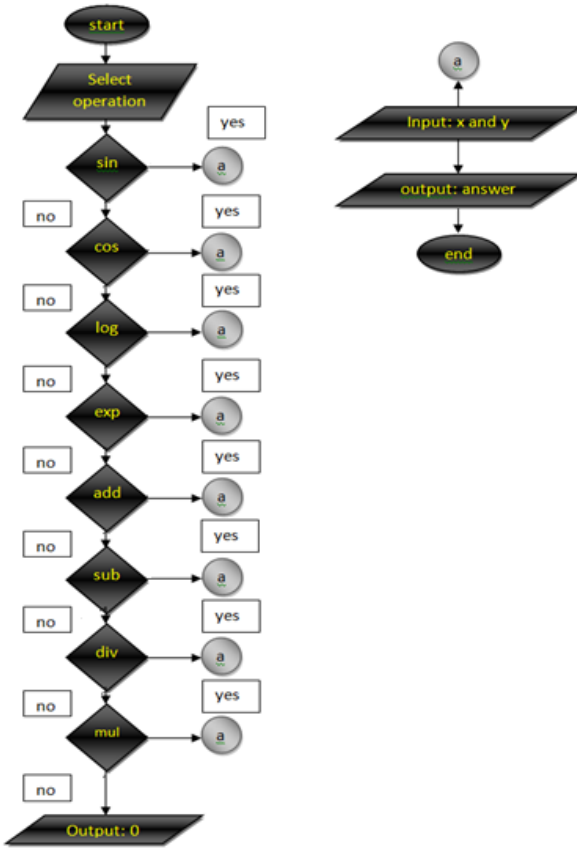


Figure 3 Flowchart of the verilog calculator system

RESULTS AND DISCUSSION

Project Description

The project will feature a mathematical calculator written in verilog code that is designed to perform and verify different operation within a calculator. The calculator is designed only in 12 bit which has 4bit inputs and 8 bit output and specific options for the operations to be performed. This will feature integer numbers that can solve through basic arithmetic functions and also covering up trigonometric functions. And as final, the project will provide the users some of the functionality and ease of use of the scientific calculator.

Properties of the Project

CORDIC Algorithm:

CORDIC (coordinate rotational digital computer) is a technique used for solving sine, cosine, logarithmic tangent and other trigonometric function using only addition subtraction and binary shift method [9].

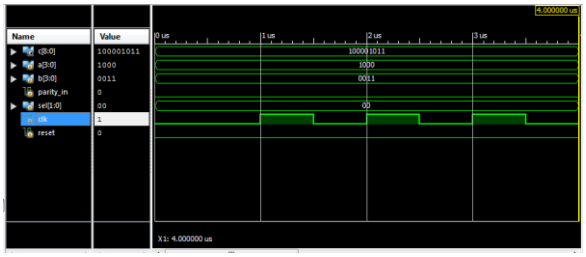
Functions of the System

The system features different functions and operations: sine, cosine, logarithmic, exponential, addition, subtraction, division and multiplication. The user will give two four-bit inputs A and B which the system will process. The eight-bit output of different functions and operations will be the input to the multiplexer. The multiplexer will select, through the selector, one from the eight inputs and will send the selected input into a single line.

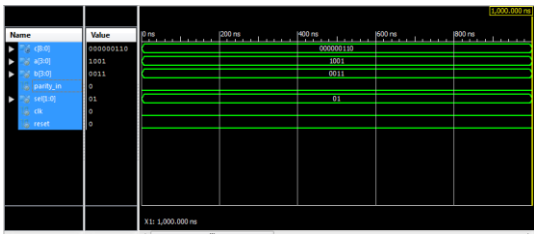
For the accuracy of the output, the proponents decided to use eight-bit for the output of each function and 12-bit for the main output of the system. Verilog can only output whole numbers. It cannot output decimal and fractional numbers therefore the proponents suggested that the first four bits be the whole number and the rest of the bits be the decimal or fractional part.

Tools and Methodologies of the System

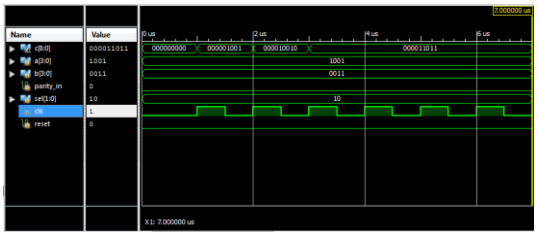
Addition



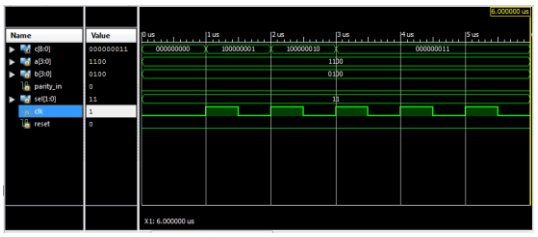
Subtraction



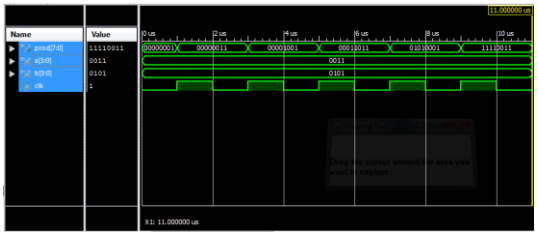
Multiplication



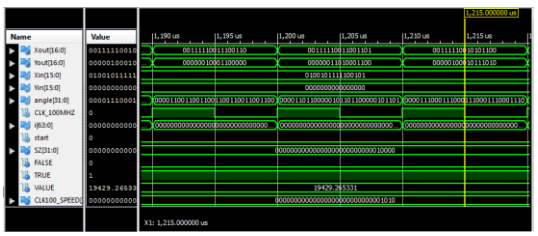
Division



Exponential



Sine and Cosine



CONCLUSION

Using Xilinx ISE Design Suite to create a synthesizable verilog code that can perform different mathematical operations and trigonometric function is very challenging. Verilog is purely binary so using this kind of software to generate outputs of sine and cosine is very hard even with an algorithm to follow. The output is not accurate and the input numbers is limited only.

REFERENCES

[1] Pomerantz, H. (1997). The Role of Calculators in Mathematics Education. Prepared for USI/CPMSA Superintendents Forum Dallas, Texas. December 4, 1997 1-10. Retrieved on 4th Jan 2008 from http://education.ti.com/sites/us downloads/pdf/the role.pdf

[2] Gunstein, L.S., Lipsey, S.J. (Eds.). (2001). Encyclopedia of mathematics education. New York: RoutledgeFalmer

[3] N.Ayers, Calculators and Calculating Devices. Availalbe:http://www.math.wichita.edu/history/topics/calculators.html/

[4] B. Loy, CORDIC (COordinate Rotation DIgital Computer) Simplified Discussion. Availalbe: http://www.genapro.com/cordic.html/

[5] Sine and Cosine: Overview. Availalbe: http://math2.org/math/algebra/functions/sincos/

[6] M. Bourne, (2015) Definitions: Exponential and Logarithmic Functions. [Online]. Available: http://www.intmath.com/exponential-

logarithmic-functions/1-definitions-exp-log-fns.php/

[7] (2015) Xilinx ISE. [Online]. Available: https://en.wikipedia.org/wiki/Xilinx_ISE/

[8] W. Storr (2015) The Multiplexer. [Online]. Available: http://www.electronics-tutorials.ws/combination/comb_2.html/

V. Pieterse and P. E. Black, (2011) "CORDIC", in Dictionary of Algorithms and Data Structures [online]. Available: http://www.nist.gov/dads/HTML/cordic.html/