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Implementation of CORDIC Based Sine & Cosine Generator in VHDL

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Abstract: *The current research in the design of high speed VLSI architectures for real-time digital signal processing (DSP) algorithms has been directed by the advances in the VLSI technology, which have provided the designers with significant impetus for porting algorithm into architecture. Many of the algorithms used in DSP and matrix arithmetic require elementary functions such as trigonometric, inverse trigonometric, logarithm, exponential, multiplication, and division functions and one such algorithm is CORDIC. Often trigonometric functions are used in embedded applications. Examples of this include motion control, filtering and waveform synthesis. For waveforms with few output points per cycle (for example one output point per degree) a lookup table will often suffice, and indeed this method is optimal in that it offers a reasonable compromise between speed and the need to use the microcontroller's memory efficiently. The CORDIC computing technique—a highly efficient method to compute elementary functions sine and cosine values of the given angle using CORDIC algorithm.*

Keywords: *CORDIC, Sine, Cosine, VHDL, FPGA*

1. Introduction

The CORDIC algorithm is a well-known and widely studied iterative technique for calculating many basic arithmetic operations and elementary functions. CORDIC works by rotating the coordinate system through constant angles until the angle is reduces to zero. These functions frequently used in applications expressed in terms of basic plane rotations. Today's most of processors are designed using this iterative technique because of its hardware-efficient solutions and this is a iterative solutions for trigonometric and other transcendental functions that use only shifts and adds to perform. Its current application is in the field of digital signal processing, image processing, filtering, matrix algebra, etc. The trigonometric functions are based on vector rotations while other functions such as square root are implemented using an incremental expression of the desired function. The trigonometric algorithm is called CORDIC, An acronym for Co-ordinate Rotational Digital Computer. The CORDIC algorithm generally produces one additional bit of accuracy for each iteration.

CORDIC is an entire-transfer computer and contains a special arithmetic unit consisting of three shift registers, three adder-sub tractors, and special interconnections, the CORDIC arithmetic unit can be used to solve either set of the following equations:

$$Y' = K(Y \cos \lambda + X \sin \lambda)$$

$$X' = K(X \cos \lambda + Y \sin \lambda)$$

Where, K is a constant. The trigonometric CORDIC algorithms were originally developed as a digital solution for real-time navigation problems.

CORDIC process is fast but implements the algorithm in the hardware and requires a long program and energy. Usage of FPGA needs a large knowledge in hardware description language VHDL or VERILOG. Sometimes, there are cores that implement an algorithm as CORDIC core; this core can generate a several algorithms like sin and cos, sinh and cosh, square root.

The CORDIC algorithm can be implemented in hardware using three approaches: a sequential approach - the structure is unfolded in time, a parallel approach – the structure is unfolded in space or a combination of the two. These three approaches and the resulting structures are also referred to in the literature as iterative, cascaded and cascaded fusion, respectively. A sequential CORDIC design performs one iteration per clock cycle and consists of three n-bit adders/sub tractors, two sign extending shifters, a look-up table (LUT) for the step angle constants and a finite state machine. A parallel CORDIC design is similar to an array multiplier structure consisting of rows of adders/subtractors, with hardwired shifts and constants. Parallel CORDIC can be implemented in the form of purely combinational arrays or can be pipelined depending on the size of the design and the requested data rate. A combined CORDIC design is based on a sequential structure where the logic for several successive iterations is cascaded and is executed within one clock cycle [1].The number of “fused” successive iteration stages determines the order of a combined CORDIC design. Figure 1 summarizes the structures used in hardware implementation of the CORDIC algorithm.

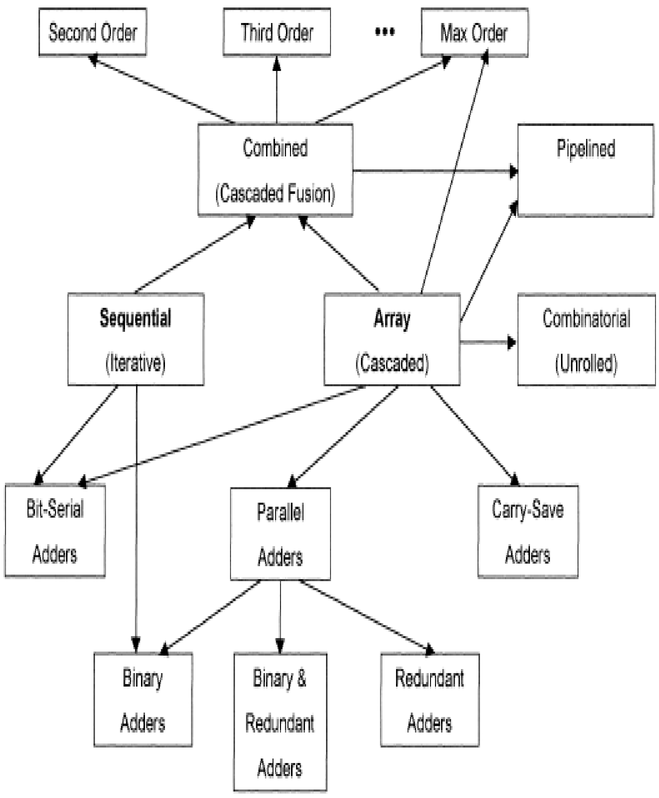
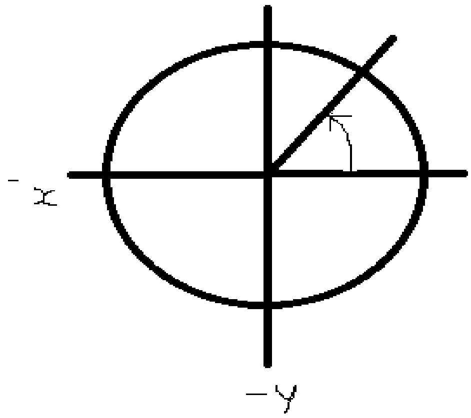


Figure1. *CORDIC Architecture*

1.1. Mathematical Basis of the algorithm

Vector rotation is the first step to obtain the trigonometric functions. It can also be used for polar to rectangular and rectangular to polar conversions, for vector magnitude, and as a building block in certain transforms such as the DFT and DCT. The aim of the Algorithm is to compute the Sine and Cosine of a given angle, which we will call Θ (Theta). Suppose that we have a point on a unit circle.



As discussed above, when the angle is in the arctangent base, this extra element is not needed. The CORDIC rotator is normally operated in one of two modes, i.e., the rotation mode and the vectoring mode.

2. METHODOLOGY

Theoretical design of sine and cosine generator based on CORDIC algorithm

Design of pipelined architecture of sine and cosine architecture in VHDL

Simulation and Synthesis of circuit

Verification using test benches

Comparison of obtained results with available literature

Modification if required to improve results

3. IMPLEMENTATION AND RESULTS

In this paper, the FPGA implementation for calculating the sine and cosine values of given angle using CORDIC algorithm is presented. The module was implemented by using Xilinx ISE Design Suite 9.2i and VHDL. The Model Sim simulator was used to verify the functionalities of the module and this module was described in VHDL and synthesized using the Xilinx ISE Design Suite.

4. CONCLUSION

Most of the applications either in wireless communication or in digital signal processing are based on microprocessors, these processors are costs efficient and offer extreme flexibility but yet are not suited for some of these applications. CORDIC algorithm based architecture are may be used in above applications we have successfully simulated an CORDIC algorithm for calculating the Sine and Cosine of an angle, on Model Sim simulator using the VHDL language. Our System can be implemented on Xilinx Spartan 3 XC3S50 using ISE Design Suite 9.2i and VHDL language. The design is more efficient and consumes less resource and is less time intensive.

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