Delay Optimization in CORDIC Waveform Generator

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Abstract: ***CORDIC is an acronym for Coordinate Rotation Digital Computer. It is a class of shift and adds algorithms for rotating vectors in a plane, which is usually used for the calculation of trigonometric functions, multiplication, division and conversion between binary and mixed radix number systems of DSP applications, such as Fourier Transform. A fast and energy-efficient CORDIC for the calculation of elementary function is always needed in electronics systems i.e. DSP processors, image processing and arithmetic units in microprocessors. On VLSI implementation level, the area also becomes quite important as more area means more system cost. The three parameters i.e. power, speed and area are always traded off. For DSP processors area and speed are the main ones. But sometimes, increasing the speed also increases the power consumption, so there is an upper bound of speed for a given power budget. Since elementary functions calculation dominates the execution time of most DSP algorithms, so there is need for high speed CORDIC algorithm. In this thesis, a very high speed CORDIC algorithm is implemented for fast calculations and generation of trigonometric functions for generation of waveform VHDL is used to implement a technology-independent design.***

Keywords: CORDIC, DDS

I. INTRODUCTION

CORDIC is an introduced by Jack E. Volder to describe the Coordinate Rotation Digital Computer algorithm which he developed in 1959. It was used for the real time navigation system at that time and was further extended by Walther in the year 1971. It is used for the fast calculation of elementary functions like multiplication, division, trigonometric functions, logarithmic function, and various conversions like conversion of rectangular to polar coordinate and vice-versa. Although CORDIC may not be the fastest technique to perform these operations, it is attractive due to the simplicity of its hardware implementation, since the same iterative algorithm could be used for all these applications using the basic shift-add operations CORDIC algorithm can be applied in two modes (ex. rotation and vectoring) and three types (ex. linear, circular and hyperbolic mode). The algorithm is very attractive for hardware implementation because it uses only elementary shift-and-add operations to perform the vector rotation. so its power dissipation is very less and it is also very compact. It is frequently used in an array of processing elements on VLSI chips.

1.1 CORDIC PRINCIPLE

It is based on vector rotation operation. Each rotation can be realized with shift and add arithmetic operations. Vector rotation from vector v to v' through an angle give the x=cosine component and y=sine component. Rotation of any vector gives the equations .The CORDIC gives sine and cosine function easily as compared to traditional method like tailor series and look up table method.

In tailor series method the long mathematical formulae are given for evaluation of the sine , cosine and other trigonometric functions like hyperbolic functions. For hardware implementation of tailor series expansion of different trigonometric function more hardware required. Due to this reason for getting trigonometric function using tailor series is not an efficient. Also lookup table method has drawback of requirement of larger lookup table for getting resolution of output.

1.2 CORDIC OPERATION

CORDIC perform using the adds and shift operation to getting a function like trigonometric and hyperbolic for waveform generation. Doing this the hardware implementation required adder and shifter which has less area and power consumption. The minimum possible permissible shifts in the CORDIC iteration have been termed as basic shift, which is equal to the number of right shifts in the first CORDIC iteration. Below fig shows the adds and shift operation of CORDIC which gives simple operation for getting the desired output.

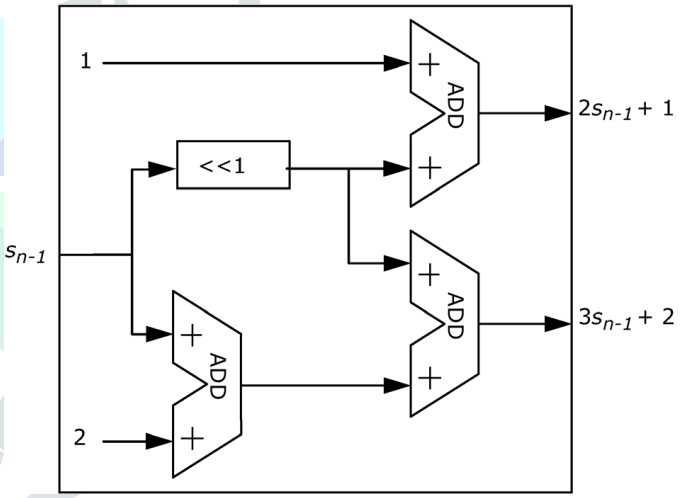

Fig 1- Adds and shift operation in CORDIC

II. DIRECT DIGITAL SYTHESIZER

In this section, we propose a new technique for generating arbitrary waveforms using the CORDIC processor. In the proposed design, the phase of hyperbolic DDS function generator is randomly modulated using a linear feedback shift register (LFSR). In the next subsection, we discuss the design of hyperbolic DDS based on the proposed CORDIC processor, following which the architecture of proposed AWG is described. The proposed DDS can be used to generate hyperbolic, exponential and other arbitrary waveforms. For generating sinusoidal waveforms, the output of circular CORDIC processor replaces the hyperbolic CORDIC processor in the proposed DDS. The direct digital synthesizer is having three main block counter, lookup table and proposed CORDIC processor. Here the three bit counter is made using T-flip- flop. The basic direct digital synthesizer is shown in figure below. The second block is lookup table which store the phase angle which is increment by counter. Third block is proposed CORDIC processor which give output function by adds and shift operation.

Direct digital synthesizer (DDS) is valuable technique used for waveform generation. It is preferred in modern communication due to its advantage of fine frequency resolution, low phase noise . Very fast frequency changes make a DDS more effective than PLL.

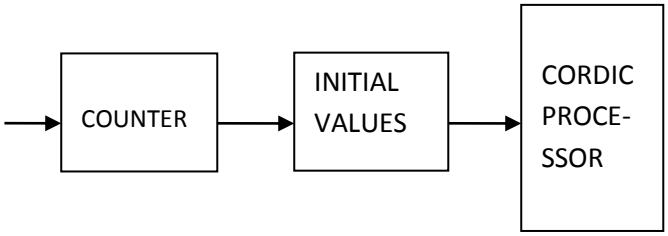

Fig 2- Direct Digital Synthesizer

2.1 COUNTER

Here we required up-down counter to design direct digital synthesizer. The counter is design using T - flip flop which is efficient than counter using D - flip flop. The delay generated in T-flip flop counter is less than D-flip flop counter. So that we use T-flip flop counter for further design of DDS.

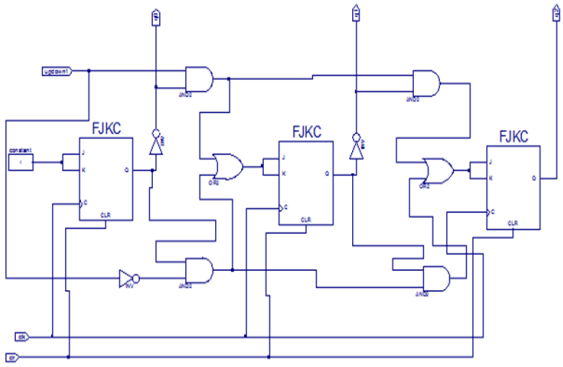

Fig 3- up-down counter

2.2 CORDIC ALGORITHM

In this paper we implement the CORDIC algorithm using only add operation. For generating the trigonometric function using CORDIC algorithm we implement circle equation only using the add operation. Below fig 4 show the DDS unit using CORDIC algorithm for waveform generation. Here we implement circle equation for that we required two multiplier.

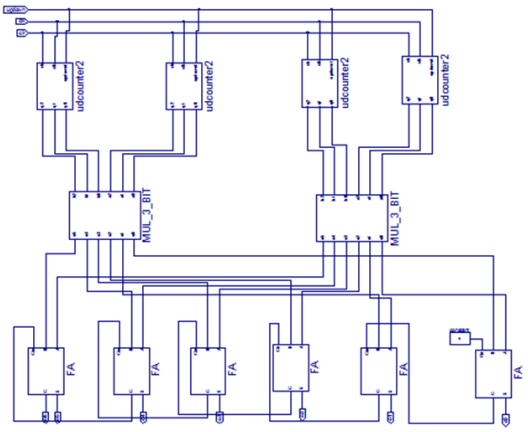

Fig 4- Direct digital synthesizer

2.2.1 MULTIPLIER

Multiplier for implement the CORDIC algorithm used only add operation. It is used half and full adder for multiplication. Below fig 5 shows that 3-bit multiplier using half adder and full adder. We required two multiplier for implement circle equation for getting trigonometric function.

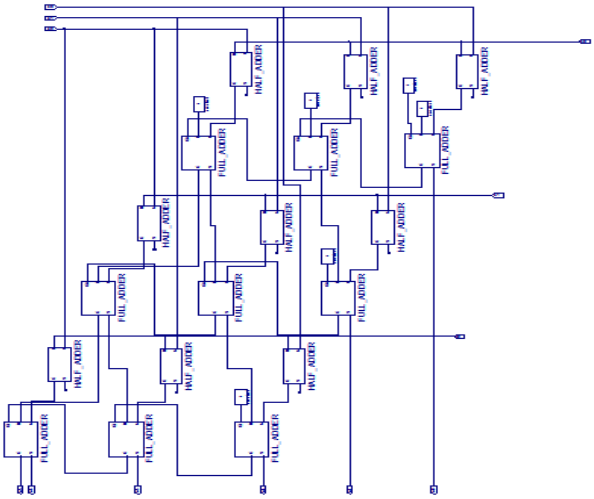

Fig 5- 3 bit multiplier

III.WAVEFORM GERNERATION

The performance of CORDIC waveform generator is depends on counter and CORDIC processor. For getting the different trigonometric function the different counter action is used as per required waveform. In this paper sine, cosine, exponential and hyperbolic waveform is generated.

IV. OUTPUT

We use Xilinx software tool in VHDL schematic to implement the design on Spartan 6 device.

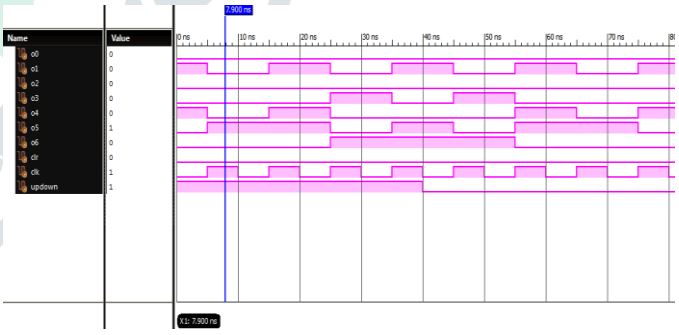

Fig 6- sine wave output

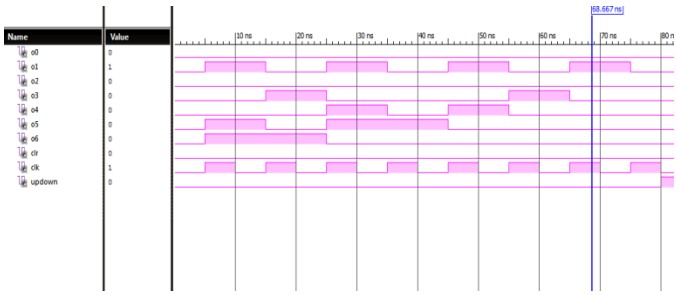

Fig 7- cosine wave output

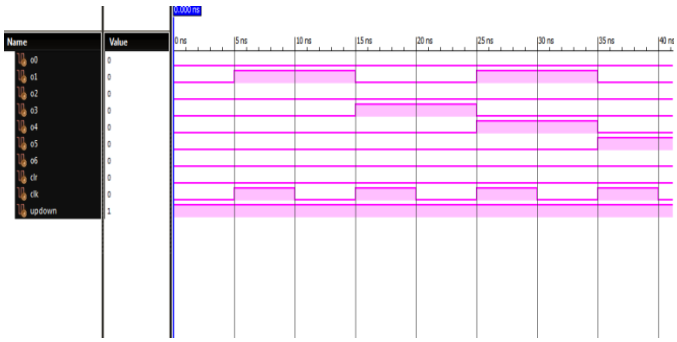

Fig 7- exponential wave output

Fig 7- cosh wave output

V. RESULT ANALYSIS AND COMPARISON

Parameter	Refered CORDIC	Proposed CORDIC
Delay(ns)	140	77.850
FLIP-FLOP	375	8
Gate count	14448	1019

VI. CONCLUSION

The fast CORDIC algorithm is used in this paper for fast waveform generation. The key feature in this CORDIC algorithm is that it uses less number of flip-flop and gate so that the complexity of CORDIC algorithm is reduced and it perform fast and efficient operation.

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