Survey of Optimization of NCO for Digital Communication Systems

Ronak P.Mistry[1] *Shruti Oza*[2]

PG Student, E.C. Department,

KIT&RC, Kalol, Gujarat, India
ronakmistry88@gmail.com

Associate Professor, E.C. department

KIT&RC, Kalol, Gujarat, India
swajan_2004@yahoo.co.in

Abstract

We will develop Optimized Numerically controlled Oscillator for digital communication systems. In order to achieve this goal, several steps need to be followed. The first step is to find the different structure of NCO, and choose a traditional NCO structure. After defining the NCO structure, optimized NCO by algorithm and different technique. There are a large number of algorithms and methods in the signal processing literature. Therefore, the state of art algorithms and different methods should be analyzed and compared. Based on different algorithms and methods, different power consumptions, area and speed of the NCO will be achieved. So their ASIC suitability should be analyzed and the effort should be focused on the choosing algorithms and architectures and optimization. Furthermore, the improvement space should be analyzed and the architecture should be further optimized.

The proposed CORDIC based algorithm can significantly reduce the die size.

Keywords: DDS (direct digital synthesizer), FPGA, CORDIC, SFDR.

1. Introduction

A numerically controlled oscillator (NCO) is a digital signal generator which creates a synchronous (i.e. clocked), discrete-time, discrete-valued representation of a waveform, usually sinusoidal. NCOs are often used in conjunction with a digital-to-analog converter (DAC) at the output to create a direct digital synthesizer (DDS).[10]

Numerically controlled oscillators offer several advantages over other types of oscillators in terms of agility, accuracy, stability and reliability. NCOs are used in many communications systems including digital up/down converters used in 3G wireless and software radio systems, digital PLLs, radar systems, drivers for optical or acoustic transmissions and multilevel FSK/PSK modulators or demodulators.

A numerically controlled oscillator (NCO) is an electronic system for synthesizing a range of frequencies from a fixed time base. Unlike a phase-locked loop-based analog frequency synthesizer, it is capable of synthesizing a very wide range of precise frequency ratios. Numerically Controlled Oscillators (NCO), also called Direct Digital Synthesizers (DDS), is a powerful technique used in the generation of radio frequency signals for use in a variety of applications from radio receivers to signals generators and many more. A conventional numerically controlled oscillator (NCO) uses time domain amplitude samples to generate a sinusoidal waveform whose frequency is controlled by a digital control word in the period of a single clock cycle. An NCO's output frequency can change instantly without the acquisition and lock time delays associated with conventional phase locked loop (PLL) synthesizers. The NCO's output frequency is controlled by an input count/integer value. The architecture inside an NCO core basically contains a phase accumulator and a phase-to-amplitude converter (PAC). Most PACs use two or more lookup tables and some associated logic to provide the phase-to-amplitude conversion. For saw-tooth wave generation we uses the logic of a counter and for the generation of Sine / Cosine wave we use Rom (which stores the values of Sine and Cos). Depending on the input count that we send to this block, they will pick values from the ROM, which in turn is our Sine / Cosine wave. In our project we have done coding for the above mentioned logic to generate a saw tooth as well as a sine wave.[10]

As the method of realizing a NCO by the sine lookup table costs a mass of logic resources, with the developing of digital communication technology, the demand for cheaper NCO becomes more and more urgent. The scheme proposed in this research uses CORDIC (Coordinate Rotation Digital Computer) algorithm to calculate sine and cosine values at real time, which can saves a lot of resources and reduces the system cost, so it makes NCO become more popular in communication systems.[10]

CORDIC is a well-known algorithm that uses simple adders and shifters to evaluate various elementary functions. Thus, CORDIC is suitable for the design of high performance chips by VLSI technology.

2. Theory of NCO

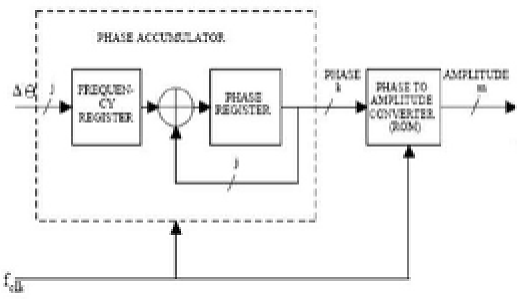

Figure 2.1: Traditional NCO

The typical NCO shown in fig 2.1 having two components: the phase accumulator, and sine-cosine lookup table[1].

Based on the input frequency, the NCO's phase accumulator produces values that address a sine-cosine lookup table. The Sine/Cosine Lookup block produces the actual complex sinusoidal signal[1].

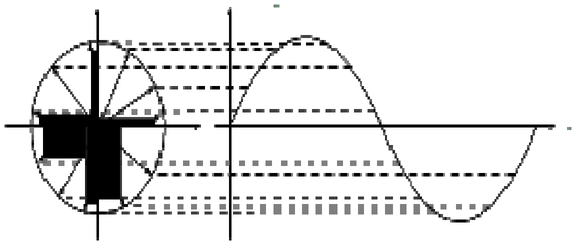

Figure 2.2: Phasor diagram of NCO

Numerically Controlled Oscillators (NCO) is extensively used in the generation of sinusoidal waveforms in digital signal processing. **A** numerically controlled oscillator is a system that produces a digital approximation to **a** sine or cosine wave relative to a change in its input. The conventional approach to implement these oscillators is to use look up tables (LUT) for generating the waveforms. We implemented a NCO with the same p as discussed in section 2 above as an input. In this case, the required frequency (f) of the sine or cosine signal generated depends on the input beta p, which **is** represented as 8 bit 2's complement[2].

$$-1 \le \beta < 1$$

$$f_{req} = \frac{\Delta\beta . f_s}{2\pi}, \text{ where } 2\pi = 2^n$$

3. CORDIC Algorithm

The Coordinate Rotation Digital Computer (CORDIC) was invented in 1959 by Volder . Its concept has been further developed to include calculation of the exponential, logarithm, forward and inverse circular and hyperbolic functions, ratios and square roots .It has been applied in the field of Direct Digital Frequency Synthesiser (DDFS), Orthogonal Frequency Division Multiplexing (OFDM),
Fast Fourier Transform (FFT).[11]

It is an iterative fixed-point technique that achieves approximately one more bit of accuracy under each step of iteration. In spite of merely linear convergence, the inner loop just consists of arithmetic operation of shifts and adds.It is competitive with (and even outperforms)floating-point techniques with quadratic convergence, for the accuracy typically required for 2-dimensional raster graphics. [1]

The algorithm, credited to , shown in Figure 2.3, is derived from the general rotation transform:

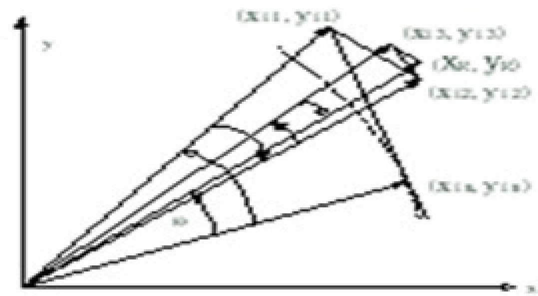

Figure 2.3: Phasor diagram of NCO on Cartesian Scale[1]

The generalized CORDIC algorithm is able to perform the calculation of elementary functions, such as *, / , sin, cos, tan, sinh, cosh, tanh, ln, exp, and square root simply by a
Series of different coordinate systems, which could be circular, linear, and hyperbolic.

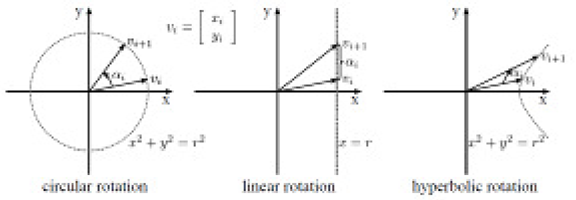

Figure2.4: Vector rotation in different coordinate system

Figure 2.4 illustrates how vector rotation is performed in these three coordinate systems. Since the rotations are realized with just shift-and-add (or shift-and-subtract) operations, the CORDIC can be implemented iteratively without the involvement of multipliers. Such a feature makes the CORDIC a preferable choice for hardware logic implementation. The mathematic expression of the vector rotation at the i-th iteration is given by

$$\begin{aligned} x_{i+1} &= x_i - m\sigma_i 2^{-S_{m,i}} y_i, \\ y_{i+1} &= y_i + \sigma_i 2^{-S_{m,i}} x_i, \\ z_{i+1} &= z_i - \sigma_i \alpha_{m,i}, \end{aligned}$$

Where σ_i represents the rotation direction (clockwise and counter-clockwise for -1 and +1, respectively), m decides the choice of the coordinate systems (circular, linear, and hyperbolic for m = 1; 0;-1 respectively), S_m,i is a non decreasing integer shift sequence, and $ά_m$,i denotes the elementary rotation angle and could be obtained through

$$\alpha_{m,i} = \frac{1}{\sqrt{m}} \tan^{-1}\left(\sqrt{m}\, 2^{-S_{m,i}}\right).$$

The generalized CORDIC algorithm supports two operational modes, rotation and vectoring, and each of them has different iteration goal. In the rotation mode the CORDIC treats z0 as system input and its goal is to make z as close as possible to 0 through iterations.

On the contrary, the vectoring mode treats x_0 and y_0 as system input and its iteration goal is to get y to 0 instead. Depending on the operational mode, the direction σ_i is determined by

$$\sigma_i = \begin{cases} \text{sign}(z_i) & \text{if rotation mode} \\ -\text{sign}(y_i) & \text{if vectoring mode} \end{cases}$$

].

4. Simulation Results:

4.1 VHDL RTL View [9]:

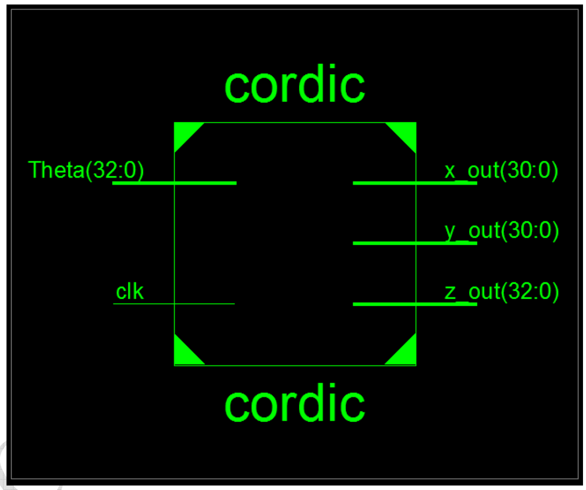

Figure 4.1: RTL logic of CORDIC algorithm (XILINX)

4.2 MATLAB Simulink Results[7]:

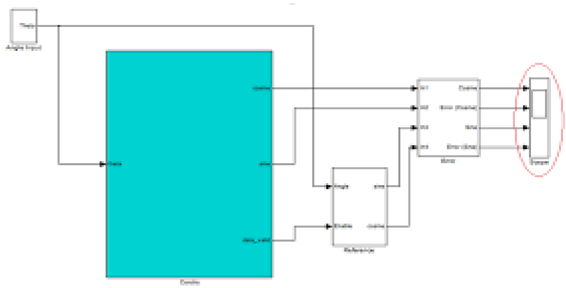

Figure 4.2: General Block-diagram of CORDIC algorithm

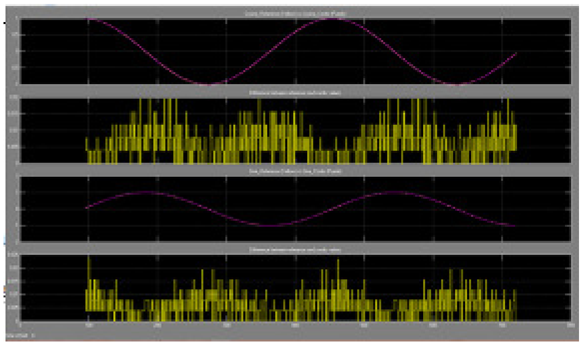

Figure 4.3: CORDIC algorithm simulink based sine/cosine function

4. CONCLUSION

Different algorithms and iteration method for numerically controlled oscillator(NCO) are available in literature it can be said that there is no unique NCO algorithm, archicture and method, NCO is used in all types of digital communication for modulation and demodulation purpose. Due to Small silicon area, High throughput, Short processing time and Reduced power consumption CORDIC based architecture is well suited and It is reduced the complexity of circuit.

Here, resulting CORDIC based sine/cosine function with low spur in signal.

REFERENCES

[1] Shuhua Hu, Hui Li, Jiaqing Huang ,"An Optimal Algorithm for Designing NCO Circuit In Mobile Communication Systems",International Conference on Communications and Mobile Computing, p.p 372-376,2009.

[2] Sameer Kadam, Dhinesh Susidaran, Amjud Awuwdeh, Louis Johnson, Michael Soderstrand,"Comparision of various Numerically Controlled Oscillators"Oklahoma state university,p.p 200-203,2002

[3] Guoping Wang, Dalian,"An FPGA-based Spur-Reduced Numerically Controlled Oscillator", International Conference on System Science and Engineering,p.p 187-192 2012,

[4] ShubhadaDeo, Sreeraj Menon, Saritha Nallathambhi and Michael A. Sodershand."Improved Numerically-Controlled Digital Sinusoidal Oscillator",IEEE, p.p 211-214,2002

[5] M Saber,Y.jitsumatsu&M.T.A.khan,"A Simple Design to Mitigate Problems of Conventional Digital Phase Locked Loop",An international journal(SPIJ),vol 6,issue 2,p.p 65-77,2012

[6] JunmingYe, Guangxiang Zhou, Haiyan Liu,"Design and Research of Improved Digital Phase-Locked Loop Based on FPGA", International Workshop on Information and Electronics Engineering,Procedia Engineering 29 p.p547 – 552,2012.

[7] MATLAB Toolbox.

[8] Grezegorz popek,marian kampik"Low-spur Numerically controlled approximation"Silesian university of technology,
p.p 30-33,2009

[9]XILINX 13.2 Toolbox.

[10] http://www.circuitstoday.com/pll-operating-principle

[11] Sung, T.-Y., Hsin, H.-C, "Design and simulation of reusable IP CORDIC core for special-purpose processors",
Computers & Digital Techniques, IET Volume: 1 Issue: 5 Sept. 2007 Page(s): 581-589