

# CORDIC Background (2B)

---

- FPGA Architecture
-

Copyright (c) 2010, 2011 Young W. Lim.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

Please send corrections (or suggestions) to [youngwlim@hotmail.com](mailto:youngwlim@hotmail.com).

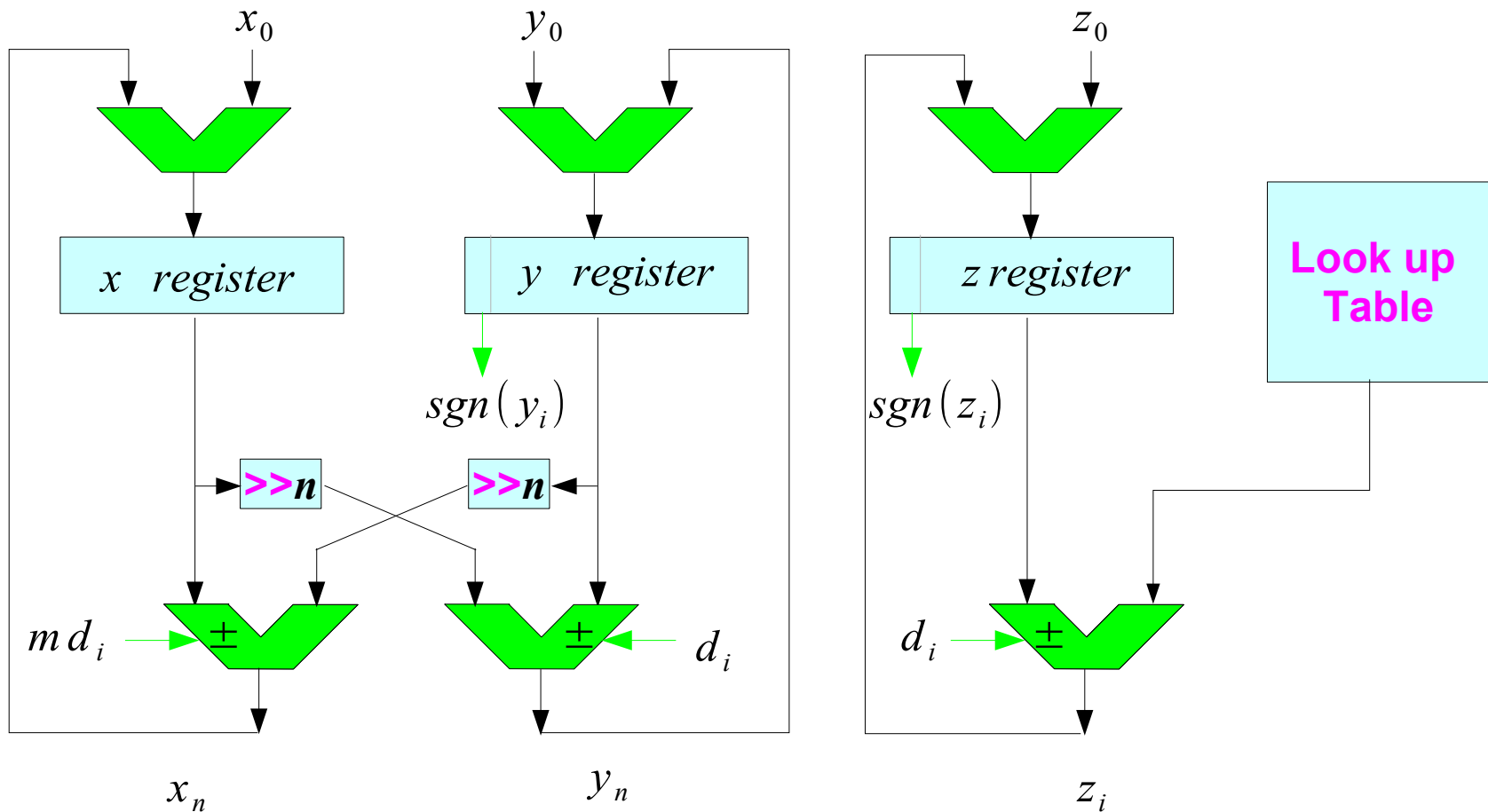
This document was produced by using OpenOffice and Octave.

# CORDIC Background

---

1.A survey of CORDIC algorithms for FPGAs, Ray Andraka,  
[www.andraka.com/cordic.htm](http://www.andraka.com/cordic.htm)

# Bit-Parallel Iterative CORDIC Structure



# Vector Rotation (2)

Decision Function  $d_i$

In rotation mode

$$\begin{aligned}x_{i+1} &= x_i - y_i \cdot d_i \cdot 2^{-i} \\y_{i+1} &= y_i + x_i \cdot d_i \cdot 2^{-i} \\z_{i+1} &= z_i - d_i \cdot \tan^{-1}(2^{-i})\end{aligned}$$

$$\begin{aligned}d_i &= -1 \quad \text{if } z_i < 0 \\d_i &= +1 \quad \text{otherwise}\end{aligned}$$

sign of  $z$  register

In vectoring mode

$$\begin{aligned}x_{i+1} &= x_i - y_i \cdot d_i \cdot 2^{-i} \\y_{i+1} &= y_i + x_i \cdot d_i \cdot 2^{-i} \\z_{i+1} &= z_i - d_i \cdot \tan^{-1}(2^{-i})\end{aligned}$$

$$\begin{aligned}d_i &= +1 \quad \text{if } y_i < 0 \\d_i &= -1 \quad \text{otherwise}\end{aligned}$$

sign of  $y$  register

# Unified CORDIC Iteration Eq

---

N iteration (clock cycles)

Variable Shifters

Adder- Subtractors

the amount of shift

the address of ROM LUT

the proper elementary angle

to z add/ subtractor

Bit-parallel variable shifter

Not good for FPGA

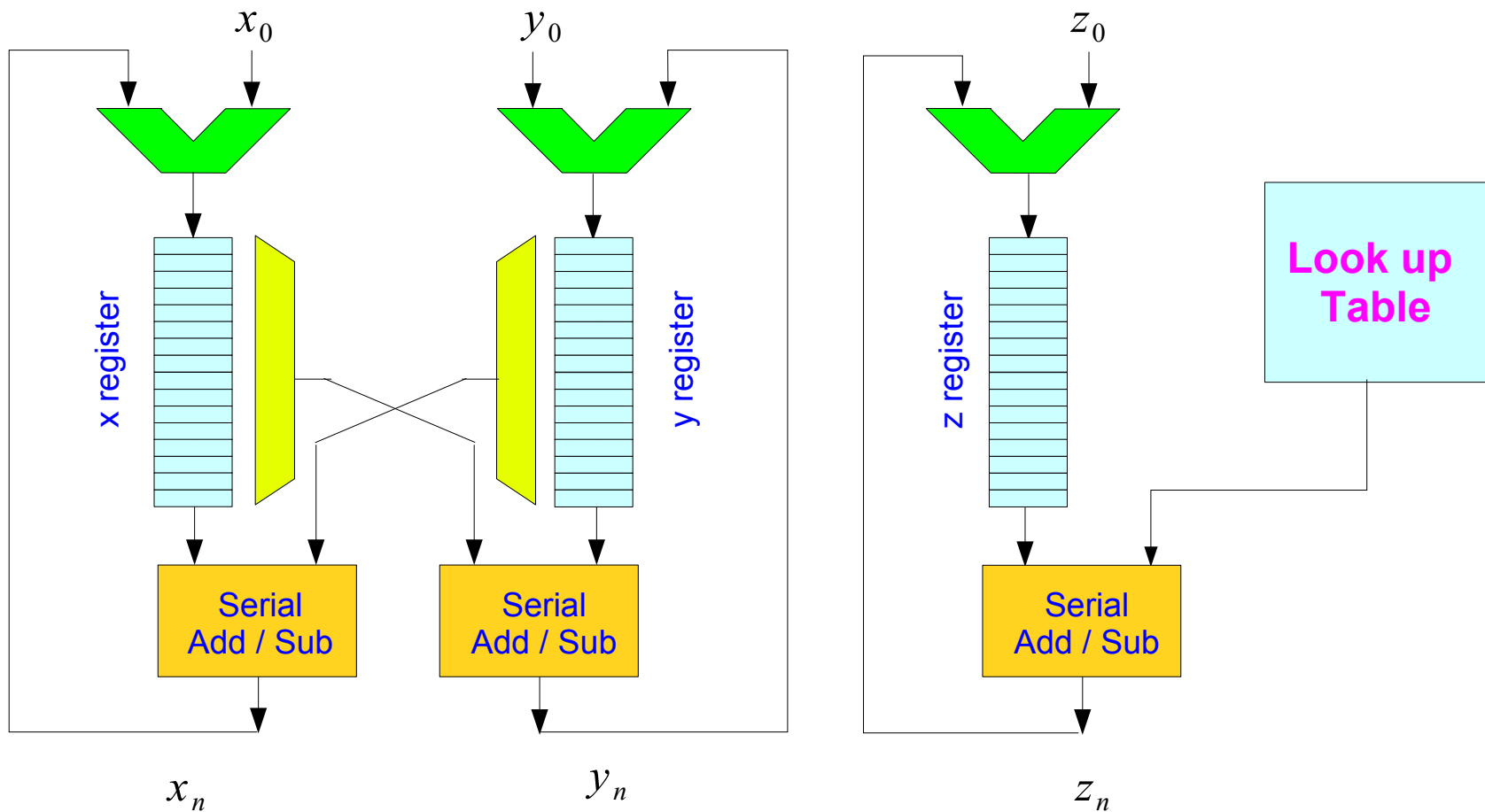
High Fan-in

→ several layers of logic

→ many cells to be traversed

- Slow design
- Large Area

# Bit-Serial Iterative CORDIC Structure



# Unified CORDIC Iteration Eq

$$x_{i+1} = x_i - m \cdot y_i \cdot d_i \cdot 2^{-i}$$

$$y_{i+1} = y_i + x_i \cdot d_i \cdot 2^{-i}$$

$$z_{i+1} = z_i - d_i \cdot e_i$$

$$m = 1 \Rightarrow e_i = \tan^{-1}(2^{-i})$$

$$m = 0 \Rightarrow e_i = (2^{-i})$$

$$m = -1 \Rightarrow e_i = \mathbf{\tanh}^{-1}(2^{-i})$$

$$\mathbf{\cosh} i x = \frac{1}{2}(e^{ix} + e^{-ix}) = \cos x$$

$$\mathbf{\sinh} i x = \frac{1}{2}(e^{ix} - e^{-ix}) = i \sin x$$

$$\mathbf{\tanh} i x = \frac{(e^{ix} + e^{-ix})}{(e^{ix} - e^{-ix})} = i \tan x$$

$$\mathbf{\cosh} x = \frac{1}{2}(e^x + e^{-x}) = \cos i x$$

$$\mathbf{\sinh} x = \frac{1}{2}(e^x - e^{-x}) = -i \sin i x$$

$$\mathbf{\tanh} x = \frac{(e^x + e^{-x})}{(e^x - e^{-x})} = -i \tan i x$$



# Unified CORDIC Iteration Eq

---

## References

- [1] <http://en.wikipedia.org/>
- [2] CORDIC FAQ, [www.dspguru.com](http://www.dspguru.com)
- [3] R. Andraka, A survey of CORDIC algorithms for FPGA based computers
- [4] J. S. Walther, A Unified Algorithm for Elementary Functions