



Gowin CORDIC IP User Guide

IPUG522-2.01E, 04/23/2021

Copyright © 2021 Guangdong Gowin Semiconductor Corporation. All Rights Reserved.

GOWIN, Gowin and GOWINSEMI are trademarks of Guangdong Gowin Semiconductor Corporation and are registered in China, the U.S. Patent and Trademark Office, and other countries. All other words and logos identified as trademarks or service marks are the property of their respective holders. No part of this document may be reproduced or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written consent of GOWINSEMI.

Disclaimer

GOWINSEMI assumes no liability and provides no warranty (either expressed or implied) and is not responsible for any damage incurred to your hardware, software, data, or property resulting from usage of the materials or intellectual property except as outlined in the GOWINSEMI Terms and Conditions of Sale. All information in this document should be treated as preliminary. GOWINSEMI may make changes to this document at any time without prior notice. Anyone relying on this documentation should contact GOWINSEMI for the current documentation and errata.

Revision History

Date	Version	Description
09/18/2018	1.0E	Initial version published.
03/28/2019	1.1E	IP supported products updated.
09/06/2019	1.2E	ITERATE mode and timing description added.
03/26/2020	1.3E	CORDIC description updated.
06/01/2020	2.0E	● Data bit width can be adjusted. ● Number of iterations can be adjusted. ● Some descriptions added and amended. ● The figures updated.
04/23/2021	2.01E	Minor typos corrected.

Contents

Contents	i
List of Figures.....	ii
List of Tables.....	iii
1 About This Guide	1
1.1 Purpose	1
1.2 Related Documents	1
1.3 Terminology and Abbreviations.....	2
1.4 Support and Feedback	2
2 Overview	3
2.1 Gowin CORDIC IP Introduction	3
2.2 CORDIC Algorithm Introduction.....	3
3 Features and Performance	4
3.1 Features.....	4
3.2 Max. Frequency	4
3.3 Latency	5
3.4 Resource Utilization.....	5
4 Functional Description	6
4.1 CORDIC Architecture.....	6
4.2 Basic Calculations and Mode Descriptions	7
4.3 Port Description	9
4.4 Timing Description	10
5 CORDIC Generation and Configuration	12
6 Reference Design	14

List of Figures

Figure 4-1 CORDIC Diagram.....	6
Figure 4-2 CORDIC IP Port Diagram.....	9
Figure 4-3 CORDIC PIPELINE Mode Timing Diagram.....	10
Figure 4-4 CORDIC ITERATE Mode Timing Diagram	11
Figure 5-1 CORDIC Configuration Interface.....	12

List of Tables

Table 1-1 Terminology and Abbreviations	2
Table 2-1 Gowin CORDIC IP Overview	3
Table 3-1 CORDIC Resource Utilization	5
Table 4-1 CORDIC IO Description	9

1 About This Guide

1.1 Purpose

Gowin CORDIC IP User Guide mainly covers functional features, port descriptions, timing descriptions, a configuration generation, and a reference design. It mainly helps you quickly understand the features, characteristics and usage of the Gowin CORDIC IP product.

1.2 Related Documents

The latest user guides are available on the GOWINSEMI Website. You can find related documents at www.gowinsemi.com.cn/en/

- [DS100](#), GW1N series of FPGA Products Data Sheet
- [DS117](#), GW1NR series of FPGA Products Data Sheet
- [DS821](#), GW1NS series of FPGA Products Data Sheet
- [DS841](#), GW1NZ series of FPGA Products Data Sheet
- [DS861](#), GW1NSR series of FPGA Products Data Sheet
- [DS871](#), GW1NSE series of SecureFPGA Products Data Sheet
- [DS881](#), GW1NSER series of SecureFPGA Products Data Sheet
- [DS891](#), GW1NRF series of Bluetooth FPGA Products Data Sheet
- [DS102](#), GW2A series of FPGA Products Data Sheet
- [DS226](#), GW2AR series of FPGA Products Data Sheet
- [DS961](#), GW2ANR series of FPGA Products Data Sheet
- [DS971](#), GW2AN series of FPGA Products Data Sheet

- [SUG100](#), Gowin Software User Guide

1.3 Terminology and Abbreviations

The terminology and abbreviations used in this manual are as shown in Table 1-1.

Table 1-1 Terminology and Abbreviations

Terminology and Abbreviations	Meaning
IP	Intellectual Property
LUT	Look-up Table
CORDIC	Coordinate Rotation Digital Computer

1.4 Support and Feedback

Gowin Semiconductor provides customers with comprehensive technical support. If you have any questions, comments, or suggestions, please feel free to contact us directly by the following ways.

Website: www.gowinsemi.com/en

E-mail: support@gowinsemi.com

2 Overview

2.1 Gowin CORDIC IP Introduction

Gowin CORDIC IP can perform sin, cos, arctan calculations, conversion between polar and Cartesian coordinates, and vector rotation.

Table 2-1 Gowin CORDIC IP Overview

Gowin CORDIC IP	
IP Core Application	
Logic Resource	-
Delivered Doc.	
Design Files	Verilog (encrypted)
Reference Design	Verilog
TestBench	Verilog
Test and Design Flow	
Synthesis Software	Synplify Pro
Application Software	Gowin Software

2.2 CORDIC Algorithm Introduction

Coordinate Rotated Number Calculation (CORDIC) is an algorithm for calculating transcendental functions such as sin (sine), cos (cosine), and arctan (arc tangent). The algorithm works by simplifying the calculation of the transcendental function into a number of micro-rotations where the arctangent value is precomputed and loaded into the table. This approach simplifies the calculation of the transcendental function into a combination of addition, subtraction, comparison, and shift. Gowin CORDICIP can perform sin, cos, arctan calculations, conversion between polar and Cartesian coordinates, and vector rotation.

3 Features and Performance

3.1 Features

- Supports sin, cos, arctan calculation;
- Supports conversion between polar and Cartesian coordinates, and vector rotation;
- Supports two angle types, including RADIAN and DEGREE, with radian range ($-\pi/2$, $\pi/2$) and degree range (-90° , 90°).
- Supports synchronous reset
- Supports adjustable data bit width
- Supports adjustable number of iterations
- Supports three implementation methods: COMBINATORIAL, ITERATE, and PIPELINE.

3.2 Max. Frequency

The maximum frequency of Gowin CORDIC IP is primarily determined by the devices used and the speed grade of the devices. For instance, GW2A-55 series of FPGA can be up to 95M.

3.3 Latency

The Latency of Gowin CORDIC IP refers to the time delay period between data input and data output.

Gowin CORDIC IP has different delays between input and output in different modes, and the actual delay is related to Iteration Accuracy (Iterations).

- PIPELINE mode delays clock period of Iterations;
- ITERATE mode delays clock period of Iterations;
- COMBINATORIAL mode is pure combinatorial logic with a delay period of 1.

3.4 Resource Utilization

Gowin CORDIC IP can be implemented by Verilog language. Its performance and resource utilization may vary when the design is employed in different devices, or at different density, speed, grade or the different modes of IP configuration.

Gowin CORDIC IP takes ROTATE, ITERATE and RADIANT mode for instances to introduce utilization of CORDIC of Gowin GW2N-55 series of FPGA. The resource utilization of CORDIC is shown in Table 3-1. For application verification on other Gowin FPGA, please pay attention to later release information.

Table 3-1 CORDIC Resource Utilization

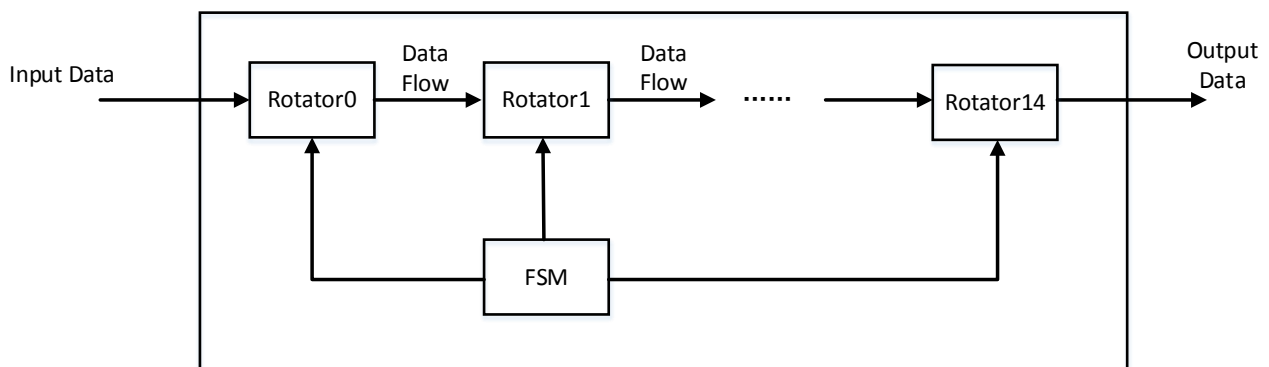
Device Series	Speed Grade	Name	Resource Utilization	Notes
GW2A-55	C8/I7	LUT	329	-
		ALU	54	
		REG	55	

4 Functional Description

4.1 CORDIC Architecture

In the FPGA, the state machine controls the rotator and the shifter to iterate, and finally implements CORDIC. Figure 4-1 shows CORDIC Implementation Block Diagram.

Figure 4-1 CORDIC Diagram



4.2 Basic Calculations and Mode Descriptions

The input and output data of the Gowin CORDIC IP are calculated in a fixed-point manner (complementary code). The calculation of the relevant functions is described below.

Calculation of sin and cos

When performing radian sin and cos calculations, select ROTATE mode and input “ $x_i=0.607253$, $y_i=0$, $\theta_i=\theta$ ”, then the final output is “ $x_o=\cos\theta$ and $y_o=\sin\theta$ ”.

Note!

- The $\cos\theta/\sin\theta/0.607253$, etc., expressed in the text, are described in terms of floating-point values for ease of description. However, the actual calculation should be converted to the fixed point value of the corresponding bit width before calculation.
- The $\cos\theta/\sin\theta$ ranges into $[-1,1]$ and the θ ranges into $(-\pi/2, \pi/2)$.
- 0.607253 is the gain constant set by the algorithm, i.e., the Cordic Gain, and the same below.

Calculation of arctan

When performing the radian arctan calculation, select VECTOR mode and input “ $x_i=\cos\theta$, $y_i=\sin\theta$, $\theta_i=0$ ”, then the final output is “ $\theta_o=\arctan\theta$ ”.

Note!

$\cos\theta$ and $\sin\theta$ cannot exceed 0.858.

Rectangular Coordinates to Polar Coordinates

When performing the radian rectangular coordinate (x,y) to polar coordinate (ρ , θ) conversion, select VECTOR mode and input “ $x_i=0.607253*x$, $y_i=0.607253*y$ ” when the rectangular coordinate is (x,y), then the final output is “ $x_o=\rho$, $\theta_o=\theta$ ”.

Note!

The value of x and y cannot exceed 0.858.

Polar Coordinate to Rectangular Coordinate

When performing the polar coordinate (ρ , θ) to rectangular coordinate (x,y) conversion, select ROTATE mode and input “ $x_i=\rho*0.607253$, $y_i=0$, $\theta_i=\theta$ ” when the polar coordinate is (ρ , θ), then the final output is “ $x_o=x$, $y_o=y$ ”.

Note!

The value of ρ cannot exceed 1.214.

Rotating Coordinate

When (x0, y0) rotating θ angle and then calculating the coordinates (x1, y1) after the rotation, you can select the ROTATE mode and input “x_i=0.607253*x0, y_i=0.607253*y0, theta_i= θ ”, and the final output is “x_o=x1, y_o=y1”.

Note!

x0 and y0 cannot exceed 0.858.

Angle Type

Angle Type is classified as RADIAN and DEGREE. The radian ranges into $(-\pi/2, \pi/2)$ and the degree ranges into $(-90^\circ, 90^\circ)$.

The fixed-point representation of the input/output angle values varies according to the angle type.

- Fixed-point bit width representation of radians: Theta Bits = 1(Sign Bit) + 1(Whole Number Bit) + Fractional Number Bits. For example, “Theta Bits=17”, then “Fractional Number Bits=15”.
- Fixed-point bit width representation of angles Theta Bits = 1(Sign Bit) + 8(Whole Number Bits) + Fractional Number Bits. For example, “Theta Bits=17”, then “Fractional Number Bits=8”.

ITERATE Mode

When calculating in ITERATE mode, the “init” signal needs to be kept high for one clock cycle at the beginning of each calculation. And enter the data to be calculated while the “init” signal is high, then the output result is obtained after clock cycles of iterations. After that, give the input value and the “init” signal again and perform a new calculation. Please refer to 4.4 Timing Description for the specific timing.

Data Interpretation

The x/y fixed-point width indicates: XY Bits = 1(Sign Bit) + 1(Whole Number Bit) + Fractional Number Bits; For example, XY Bits = 17, then Fractional Number Bits=15.

Taking the gain constant 0.607253 as an example and converting it to a fixed-point value, then the input IP is “x_i=17'd19898” (Fractional Number Bits=15).

If the output is “x_o=17'd19898”, then convert it to a floating point value (Fractional Number Bits=15) of approximately 0.607239.

Note!

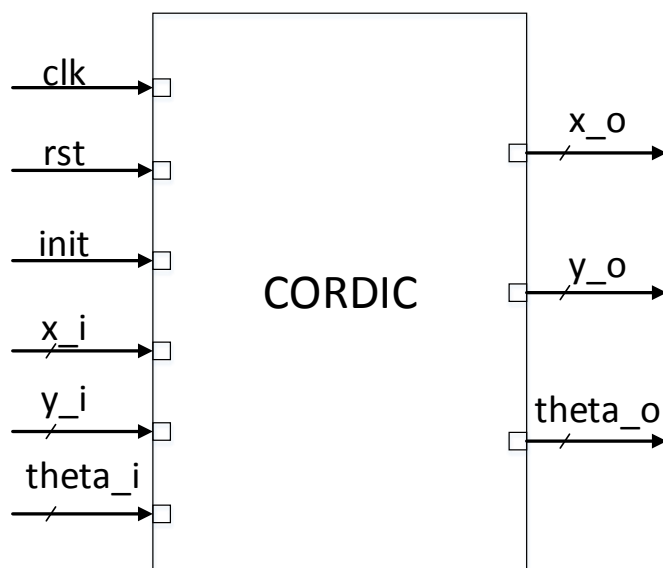
- “Floating-point value*(2[^] Fractional Number Bits)” represents the fixed-point value

- of the input.
- “Fixed-point value/(2[^] Fractional Number Bits) represents the floating-point value of the output.

4.3 Port Description

The IO ports of the Gowin CORDIC IP are shown in Figure 4-2 below.

Figure 4-2 CORDIC IP Port Diagram



The CORDIC IP Core interface may vary slightly depending on the mode chosen.

For the details of IO ports description of Gowin CORDIC IP, please refer to Table 4-1.

Table 4-1 CORDIC IO Description

Signal	I/O	Description
clk	input	Clock
rst	input	Reset, active high
init	input	When ITERATE mode is selected, the port exists; when init=1, load input value.
x_i	input	x input, bit width 17~32, signed
y_i	input	y input, bit width 17~32, signed
theta_i	input	theta input, bit width 17~32, signed
x_o	output	x output, bit width 17~32, signed
y_o	output	y output, bit width 17~32, signed
theta_o	output	theta output, bit width 17~32, signed

Note!

- “x_i, y_i, x_o, y_o” have the same bit width, which is determined by the value of the

configuration parameter "XY Bits".

- θ_i , θ_o have the same bit width, which is determined by the value of the configuration parameter "Theta Bits".

4.4 Timing Description

Taking the "XY Bits=17", "Theta Bits=17", "Iteration Accuracy=16" configuration as an example, the timing of the Gowin CORDIC IP is as described below.

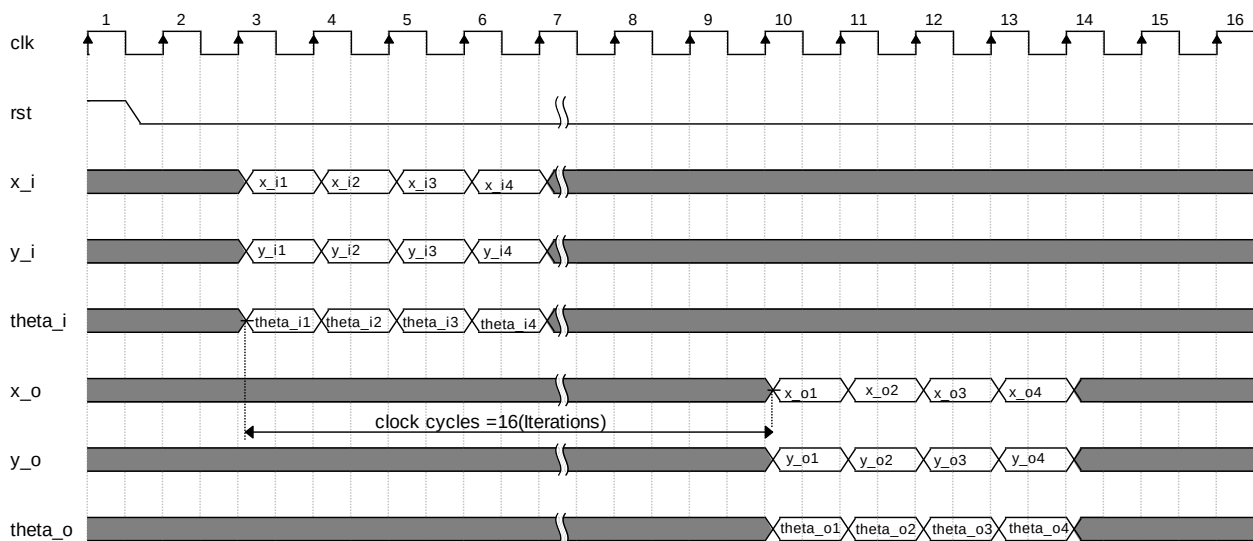
In PIPELINE mode, there is an input in every clock cycle and there is an output in every clock cycle after 16 (Iterations) clock cycles.

COMBINATORIAL mode uses combination logic to iterate, and produces input and output in a single clock cycle.

In ITERATE mode, the output is delayed by 16 (Iterations) clock cycles after one clock cycle input. And the next input can only be done after the previous output is completed.

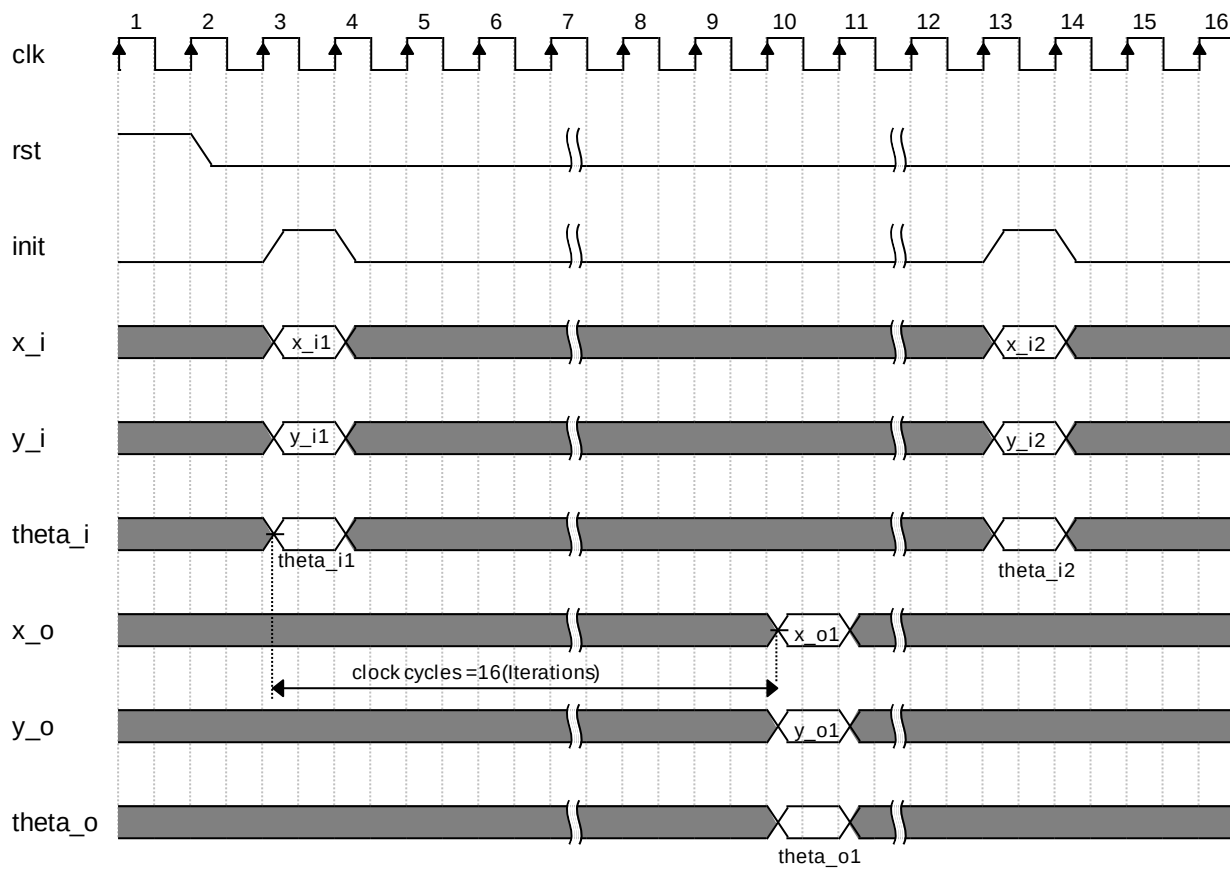
The timing diagram of the PIPELINE mode is shown in Figure 4-3.

Figure 4-3 CORDIC PIPELINE Mode Timing Diagram



The timing diagram of ITERATE mode is shown in Figure 4-4.

Figure 4-4 CORDIC ITERATE Mode Timing Diagram

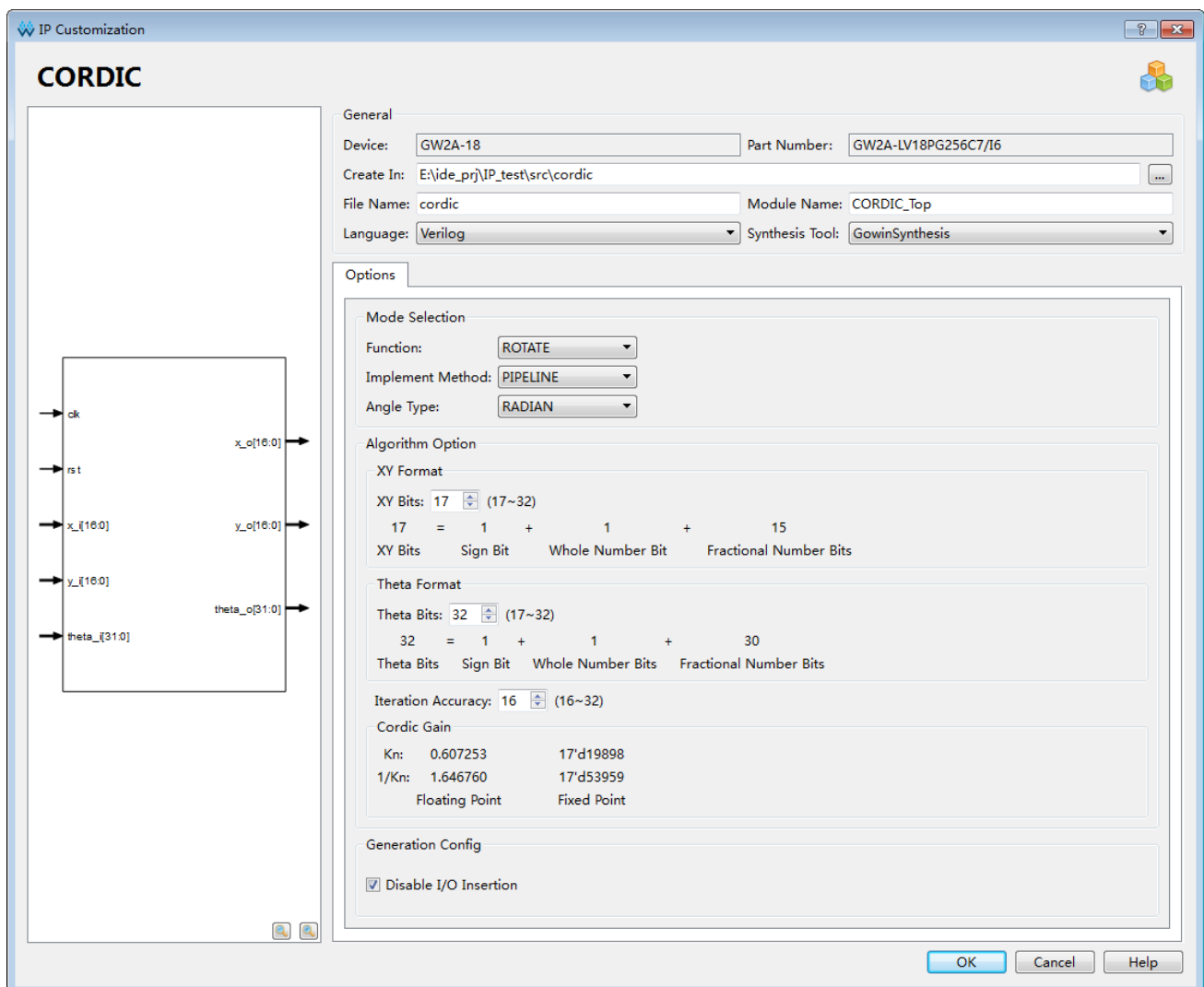


5 CORDIC Generation and Configuration

Start "IP Core Generator" from the "Tools" menu in the Gowin software and then complete the generation and configure Gowin CORDIC IP.

The Gowin CORDIC IP configuration interface is shown in Figure 5-1.

Figure 5-1 CORDIC Configuration Interface



The mode selection for Gowin CORDIC IP has three option groups: Function, Implementation Method, and Angle Type.

- Function has two options, VECTOR and ROTATE, which can be selected according to the function to be completed.
- Implement Method has three options: PIPELINE、ITERATE and COMBINATORIAL. When ITERATE mode selected, then the "init" input signal is added to the left module diagram. There is no "init" input in PIPELINE and COMBINATORIAL modes.

Angle Type is available in RADIAN and DEGREE options, and you can select either of them as required. The algorithm configuration options for Gowin CORDIC IP are as follows.

- XY Format: Set the bit width (XY Bits) of "x_i, x_o, y_i, y_o", ranging from 17 to 32.
- Theta Format: Set the bit width (Theta Bits) of "theta_i, theta_o", ranging from 17 to 32.
- Iteration Accuracy: Set the number of iterations, ranging from 16 to 32;
- Cordic Gain: Read only, the gain constant of the CORDIC algorithm.

6 Reference Design

This chapter focuses on the usage and structure of the reference design instance of Gowin CORDIC IP. The Gowin CORDIC IP design example has only one module. Please refer to [reference design](#) in IP for details.

In the design instance, the steps are as follows:

1. We input a string of data stored in the document into the CORDIC IP;
2. The output is calculated by CORDIC IP and compared to the correct data.

CORDIC functions can be verified quickly using this design. When the reference design is applied to board level test, you need to provide appropriate stimulus to the reference design and use an on-line logic analyzer or oscilloscope to observe the signals.

