MICROCHIP Stepper Theta Generation v4.2 Motor Control User Guide

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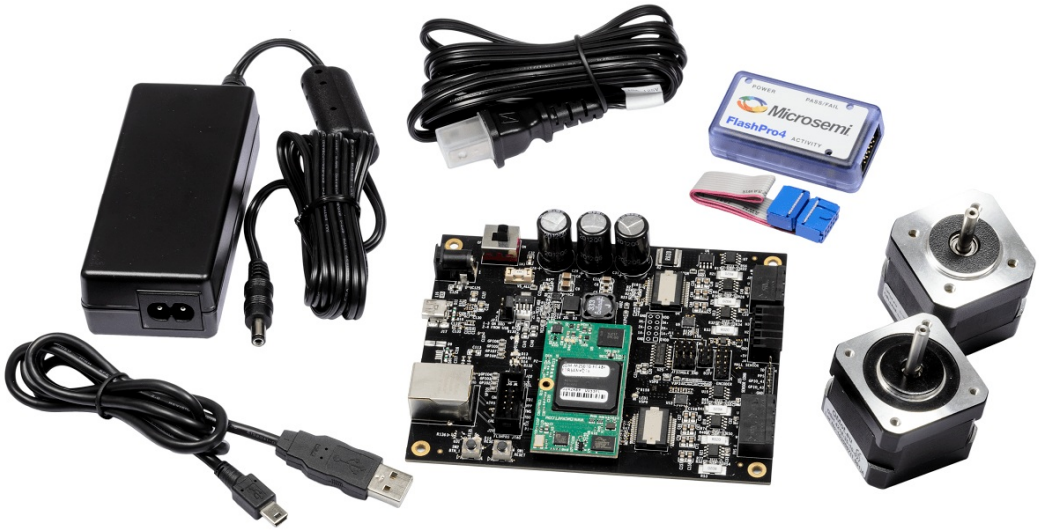
MICROCHIP Stepper Theta Generation v4.2 Motor Control



Introduction

The Stepper Theta Generation v4.2 is a device used for position control by moving through a certain number of steps. The stepper motor has a fixed number of steps per revolution, but it is possible to move through micro-steps, which improves the step resolution. The IP block generates theta that is used by the stepper motor control algorithm. This device supports microstepping up to 2048 microsteps, reducing torque ripple and power losses in the motor.

Core Version

This user guide applies to Stepper Theta Generation v4.2.

Supported Tool Flow

Libero software can be used for simulation, synthesis, and layout. Stepper Theta Generation is licensed with encrypted RTL that must be purchased separately. For more information, see Stepper Theta Generation.

Features

Stepper Theta Generation has the following key features:

- Implementation of IP Core in Libero Design Suite
- Supports microstepping up to 2048 microsteps
- Reduces torque ripple and power losses in the motor

Functional Description

The Stepper Theta Generation v4.2 device generates theta that is used by the stepper motor control algorithm. It supports microstepping up to 2048 microsteps, reducing torque ripple and power losses in the motor.

Stepper Theta Generation Parameters and Interface Signals

The device has various input and output signals, which are detailed in the user manual.

- **Input Signals**

  List of input signals is provided in the user manual.
- **Output Signals**

  List of output signals is provided in the user manual.
- **Timing Diagrams**

  The user manual provides timing diagrams for the device.
- **Testbench**

  The user manual provides information on how to run simulations using the device.
- **Revision History**

  The user manual contains a revision history for the device.
- **Microchip FPGA Support**

  The device is supported by Microchip FPGA.

Usage Instructions

To use Stepper Theta Generation v4.2, follow the instructions provided in the user manual. Ensure that you have purchased the encrypted RTL license for the device. You can use Libero software for simulation, synthesis, and layout. Connect the input and output signals as per the instructions provided in the user manual. Run simulations using the testbench provided in the user manual. Refer to the timing diagrams in the user manual to ensure proper timing of signals. Contact Microchip FPGA support for any further assistance.

Introduction

The stepper motor is used for position control by moving through a certain number of steps. While a stepper motor has a fixed number of steps per revolution, it is possible to move through micro-steps, which improves the step resolution. Micro-stepping also reduces torque ripple and power losses in the motor. The IP block generates theta that is used by the stepper motor control algorithm. It is possible to select microstepping up to 2048 microsteps.

Summary

Core Version	This document applies to Stepper Theta Generation v4.2.
Supported Device Families	• PolarFire® SoC • PolarFire
	• RTG4™
	• IGLOO® 2
	• SmartFusion® 2
Supported Tool Flow	Requires Libero® SoC v11.8 or later releases.
Licensing	Complete encrypted RTL code is provided for the core, enabling the core to be instantiated with SmartDesign. Simulation, Synthesis, and Layout can be performed with Libero software. Stepper Theta Generation is licensed with encrypted RTL that must be purchased separately. For more information, see **Stepper Theta Generation**.

Features

Stepper Theta Generation has the following key features:

- Computes the angle and step count
- Micro-stepping is possible up to 2048 microsteps
- Generates an angle in position mode and speed mode

Implementation of IP Core in Libero Design Suite

IP core must be installed to the IP Catalog of the Libero® System-on-Chip (SoC) software. This is done automatically through the IP Catalog update function in the Libero SoC software, or the IP core can be manually downloaded from the catalog. Once the IP core is installed in the Libero SoC software IP Catalog, the core can be configured, generated, and instantiated within the SmartDesign tool for inclusion in the Libero project list.

Device Utilization and Performance

The following table lists the device utilization used for Stepper Theta Generation.

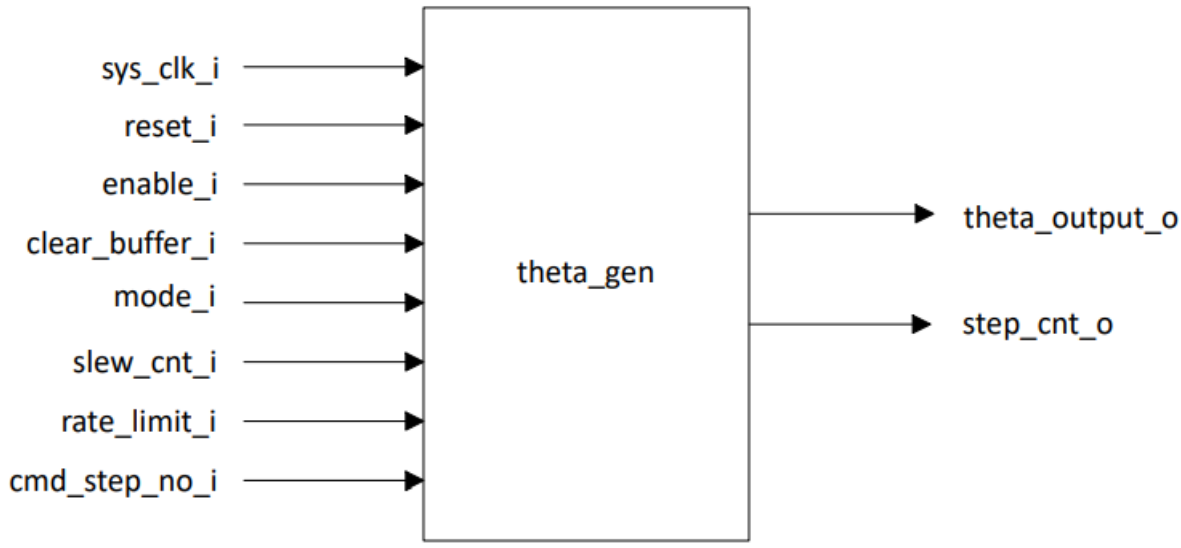
Device Details		Resources		Performance (MHz)	RAMs		Math Blocks	Chip Globals
Family	Device	LUTs	DFF		LSRAM	µSRAM		
PolarFire® SoC	MPFS250T	285	128	200	0	0	0	0
PolarFire	MPF300T	285	128	200	0	0	0	0
SmartFusion® 2	M2S150	285	128	200	0	0	0	0

Important:

1. The data in this table is captured using typical synthesis and layout settings. CDR reference clock source was set to Dedicated with other configurator values unchanged.
2. Clock is constrained to 200 MHz while running the timing analysis to achieve the performance numbers.

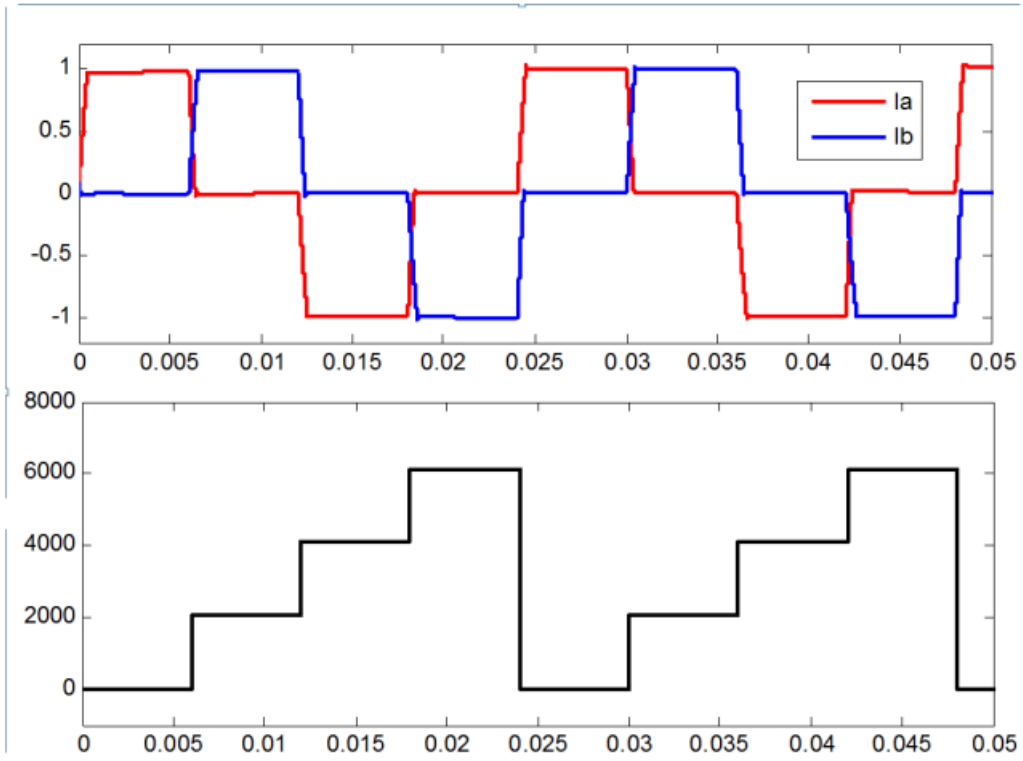
Functional Description

- This section describes the implementation details of the Stepper Theta Generation.
- The following figure shows the system-level block diagram of the Stepper Theta Generation.



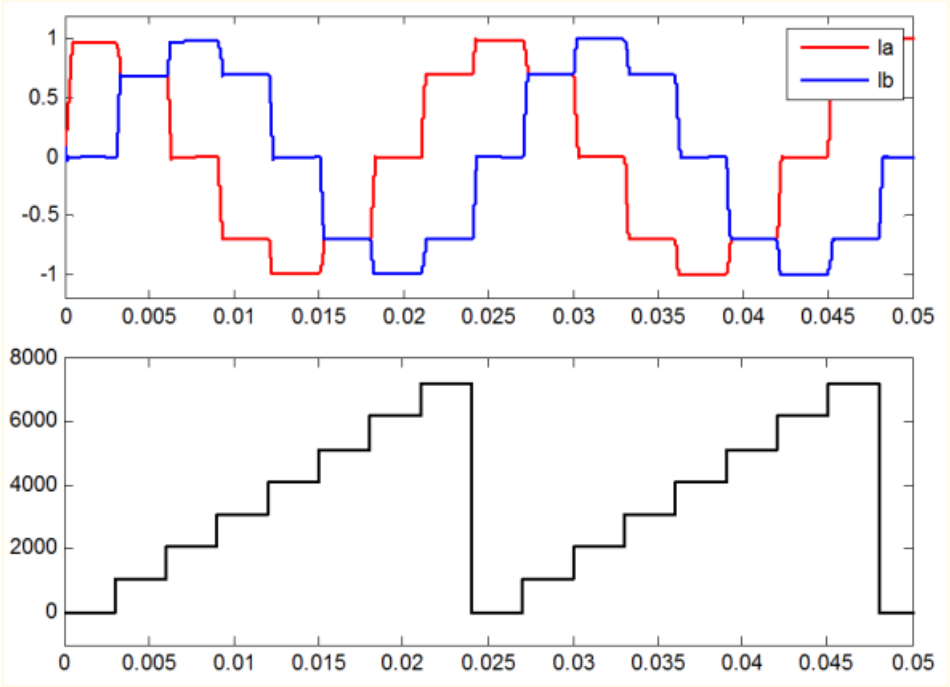
- The profile of the stepper theta output and resultant current for various micro-stepping options are shown through the following figures.

Figure 1-2. Currents and Theta in Full Step Mode



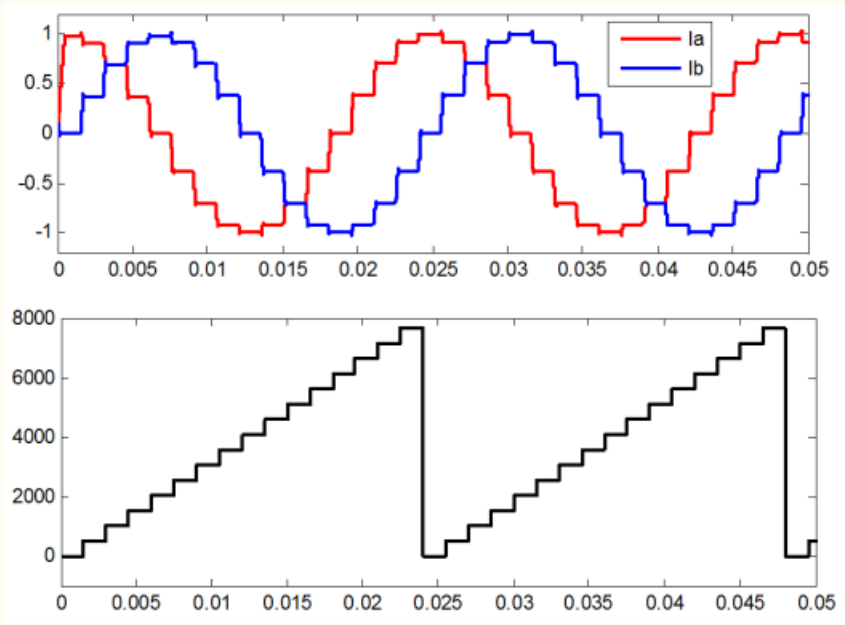
- The following figure shows the theta generation in motor phase currents for half step mode.

Figure 1-3. Currents and Theta in Half Step Mode



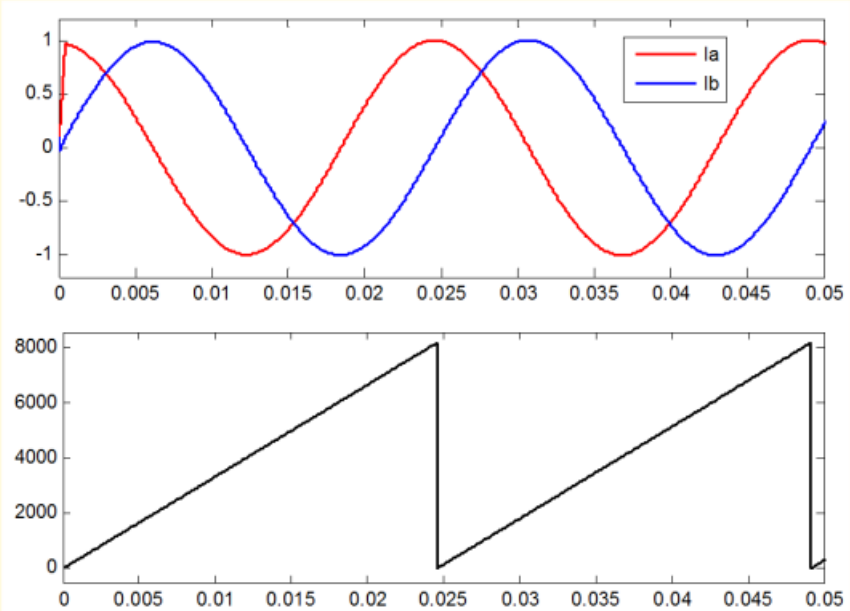
- The following figure shows the theta generation motor phase currents in quarter step mode.

Figure 1-4. Currents and Theta in Quarter step mode (micro-stepping)



- The following figure shows the theta generation motor phase currents in 1024 micro-stepping mode.

Figure 1-5. Currents and Theta in 1/1024 step mode (micro-stepping)



- The level of micro stepping is decided by the rate limit input and must be an exponent of 2. The slew count input, then decides the speed at which theta value is updated. The output theta is generated till the command number of steps are met and then theta is held at last updated value until command steps changes. However, in speed mode, the output theta is continuously updated.

Stepper Theta Generation Parameters and Interface Signals

This section discusses the parameters in the Stepper Theta Generation GUI configurator and I/O signals.

Input and Output Signals

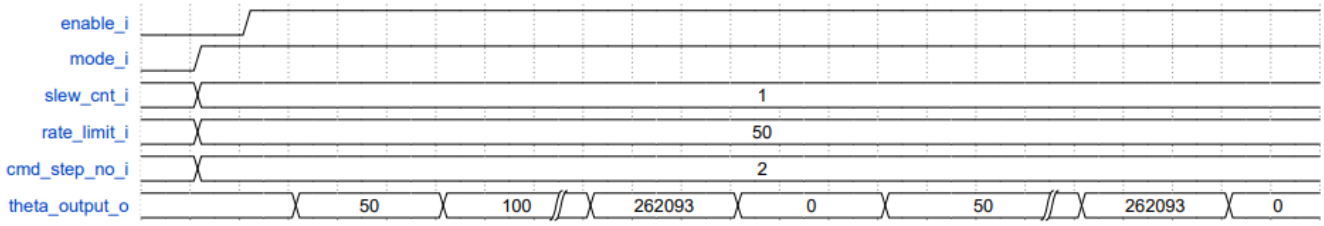
The following table lists the input and output ports of Stepper Theta Generation.

Signal Name	Direction	Description
sys_clk_i	Input	System clock.
reset_i	Input	Asynchronous active low reset signal.
enable_i	Input	Input signal enables angle generation.
mode_i	Input	When set to 0 (zero), generates angle in the Position Mode. When set to 1, generates angle in the Speed Mode (Continuous rotation mode).
slew_cnt_i	Input	Slew count input – decides the speed at which theta value is updated in terms of 1 µs.
rate_limit_i	Input	Rate limit input – decides the number of Microsteps by defining angle increment Microstep length should be exponent of 2 (for example, 1, 2, 4, 8, 16 and so on).
cmd_step_no_i	Input	Command– the number of steps/micro-steps motor must move.
theta_output_o	Output	Angle generated based on the inputs.
step_cnt_o	Output	Step count output to track the number of steps.

Timing Diagrams

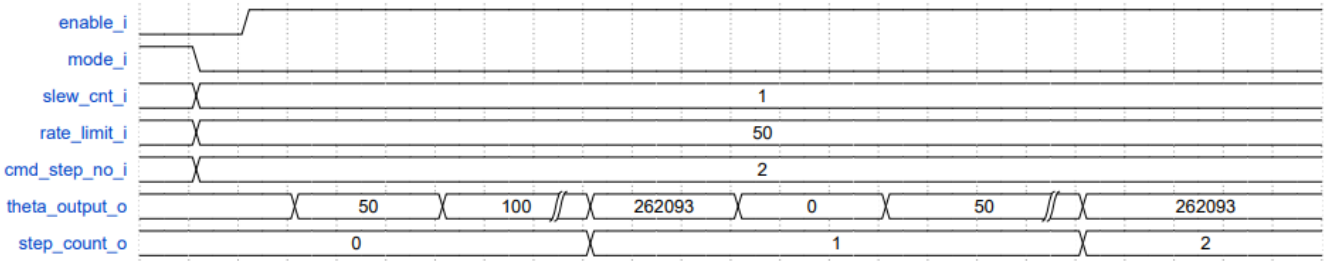
- This section discusses Stepper Theta Generation timing diagrams.
- The following figure shows the timing diagram of the Stepper Theta Generation in speed mode.

Figure 3-1. Timing Diagram of the Stepper Theta Generation in Speed Mode



The following figure shows the timing diagram of the Stepper Theta Generation in position mode.

Figure 3-2. Timing Diagram of the Stepper Theta Generation in Position Mode



Testbench

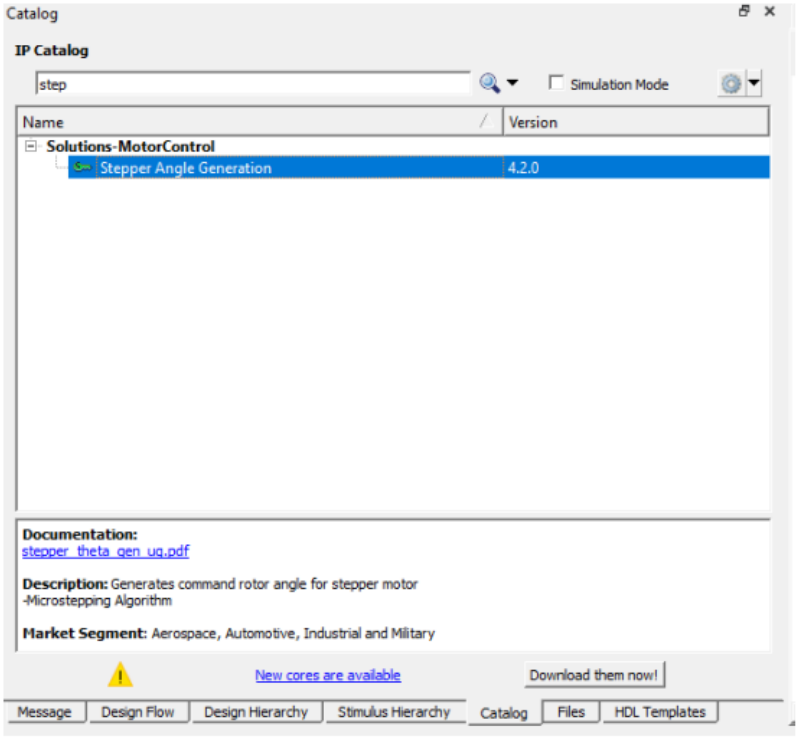
A unified testbench is used to verify and test Stepper Theta Generation called as user testbench. Testbench is provided to check the functionality of the Stepper Theta Generation IP.

Simulation

The following steps describe how to simulate the core using the testbench:

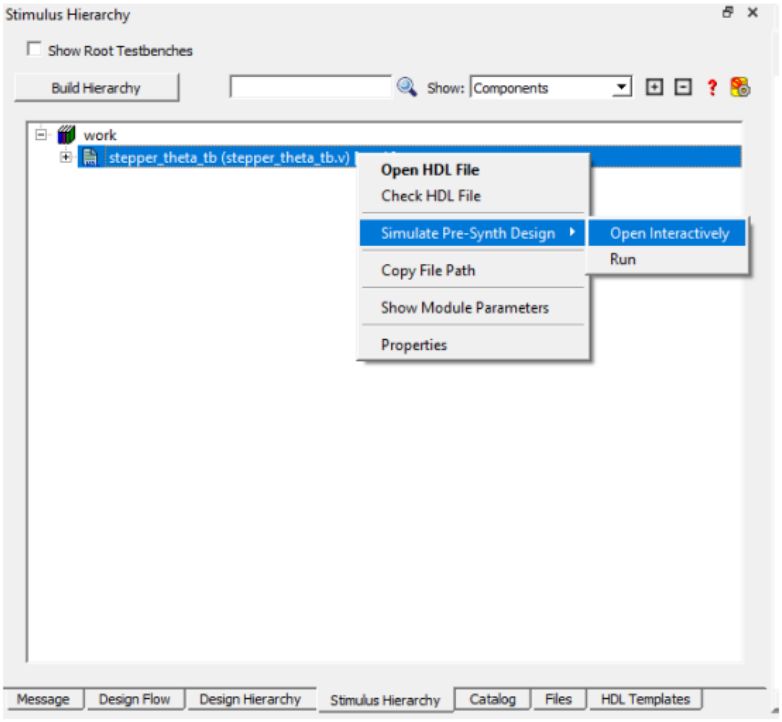
1. Go to Libero SoC Catalog tab, expand Solutions-MotorControl, double click Stepper Theta Generation, and then click OK. The documentation associated with the IP are listed under Documentation.
   Important: If you do not see the Catalog tab, navigate to View > Windows menu and click Catalog to make it visible.

Figure 4-1. Stepper Theta Generation IP Core in Libero SoC Catalog



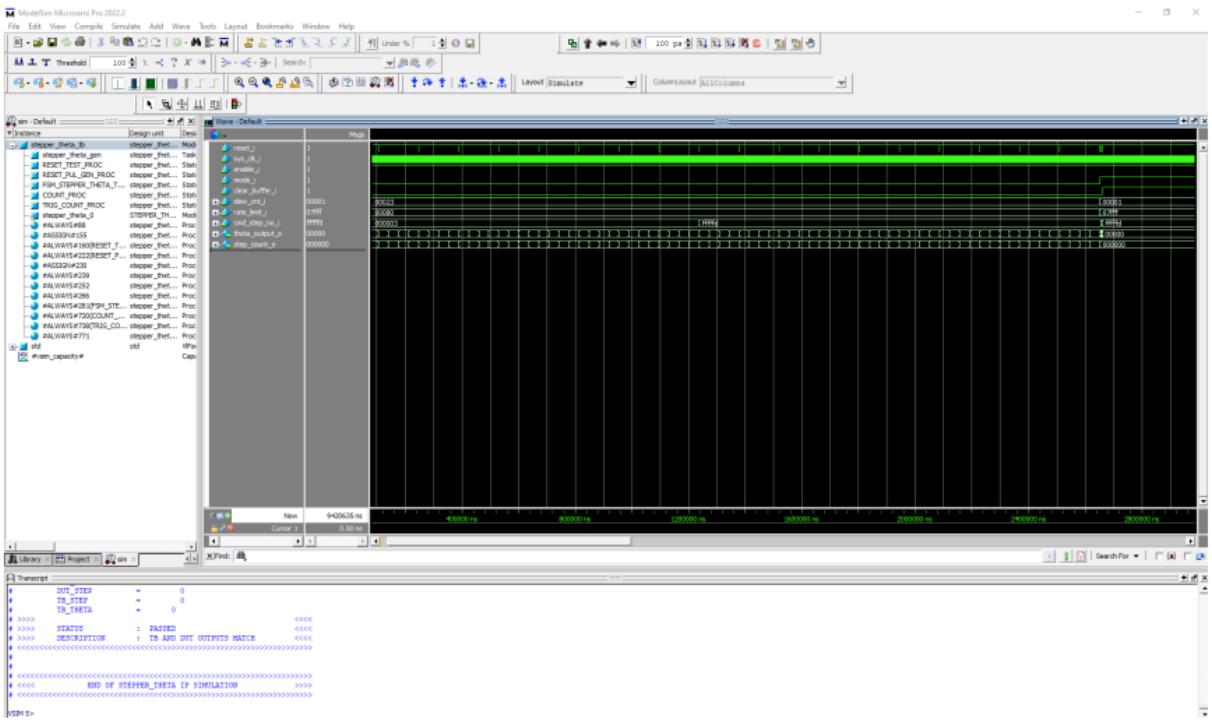
2. On the Stimulus Hierarchy tab, select the testbench (stepper_theta_tb.v), right click and then click Simulate Pre-Synth Design > Open Interactively.
   Important: If you do not see the Stimulus Hierarchy tab, navigate to View > Windows menu and click Stimulus Hierarchy to make it visible.

Figure 4-2. Simulating Pre-Synthesis Design



ModelSim opens with the testbench file, as shown in the following figure.

Figure 4-3. ModelSim Simulation Window



Important: **If** the simulation is interrupted due to the runtime limit specified in the .do file, use the run all command to complete the simulation.

Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

Revision	Date	Description
A	03/2023	The following list of changes are made in revision A of the document: • Migrated the document to the Microchip template. • Updated the document number to DS00004956A from 50200609. • Added 3. Timing Diagrams. • Added 4. Testbench.
3.0	—	The following is the list of changes in revision 3.0 of the document: • Added the IP version to the document title. • Removed Configuration Parameter section from Hardware Implementation.
2.0	—	Updated Configuration section.
1.0	—	Revision 1.0 was the first publication of this document.

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