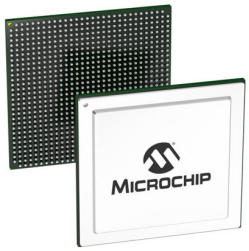


MICROCHIP v4.2 Encoder Interface User Guide

Encoder Interface v4.2
User Guide

Contents

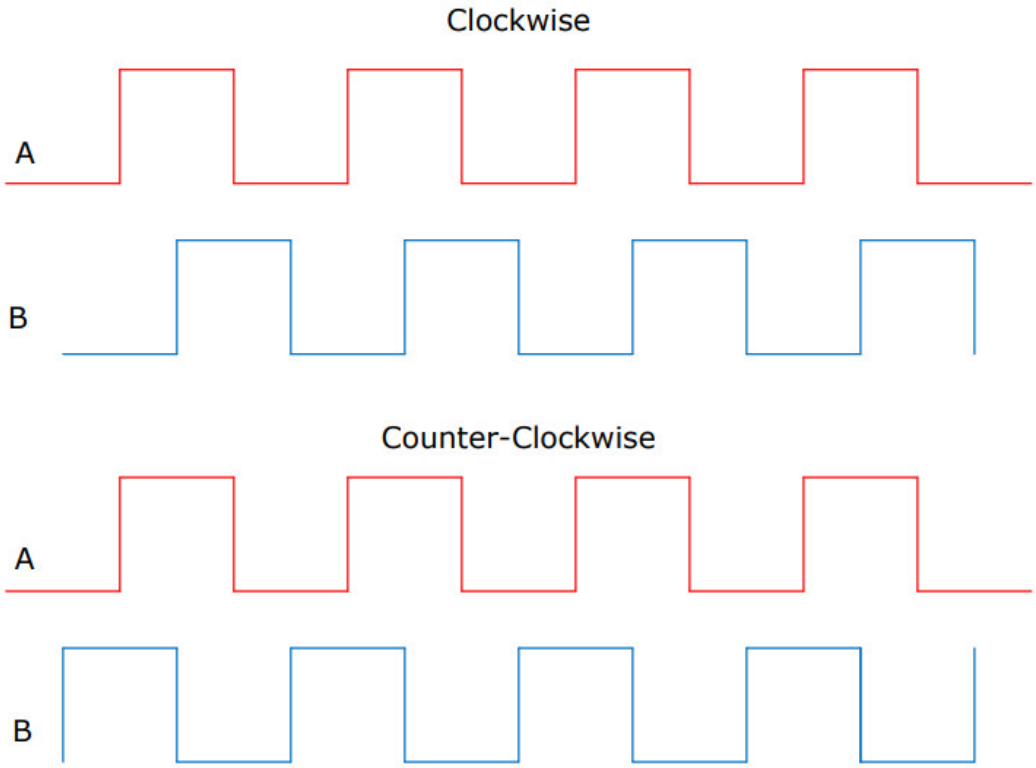
Introduction

(Ask a Question)

Incremental encoder is the most common sensor used for Field Oriented Control (FOC) of Permanent Magnet Brush Less DC (BLDC) or Permanent-Magnet Synchronous Motor (PMSM). This sensor gives relative angular position as the output in the form of pulses. A quadrature encoder, typically produces two outputs, which have pulses phase shifted by 90°, as shown in Figure 1. The phase shift between the two signals A and B represents the direction of rotation. The encoder interface logic uses edge detection on rising edge and falling edge of A and B, as shown in Figure 2. This gives a resolution that is four times the encoder resolution and produces a very high resolution from a low cost encoder.

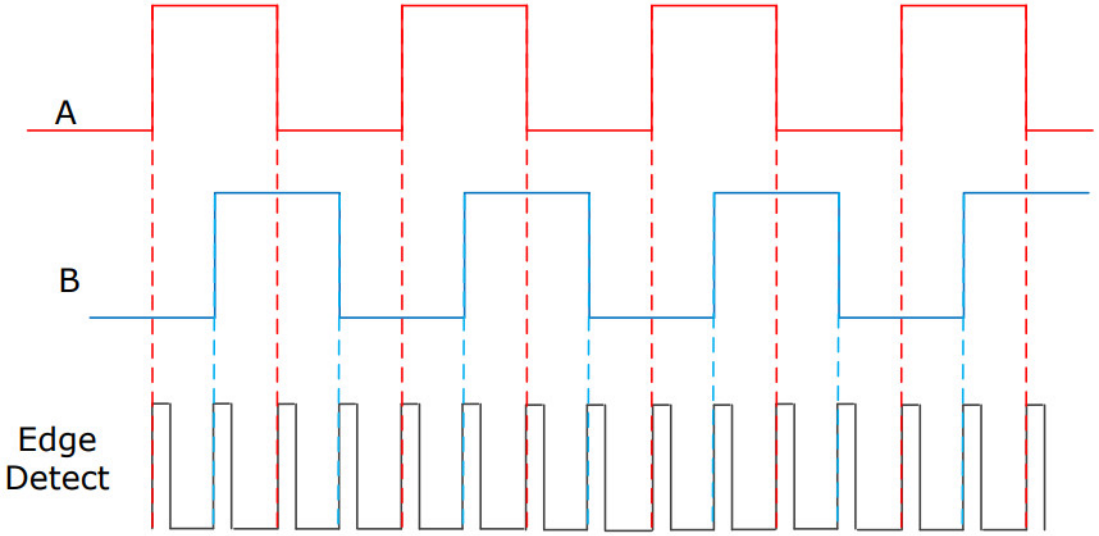
The following figure shows the encoder signals in clockwise and counter-clockwise directions.

Figure 1. Encoder Signals in Clockwise and Counter-Clockwise Directions



The following figure shows the edge detection of encoder pulses for higher resolution.

Figure 2. Edge Detection of Encoder Pulses for Higher Resolution



After the edge detection, counters are used to get a rotor angular position in terms of an electrical angle so that, it can be directly used for FOC. The Angle_count_max value represents the total number of edges that will be detected in one mechanical rotation of the rotor. The angle output ranges from 0 to 262143, where 262143 represents 360°. The variation of angle output with respect to the edges is shown in Figure 3 for positive speed and Figure 4 for negative speed. The speed output is calculated based on the rate of change of angular position.

Three parameters are used to configure the encoder interface:

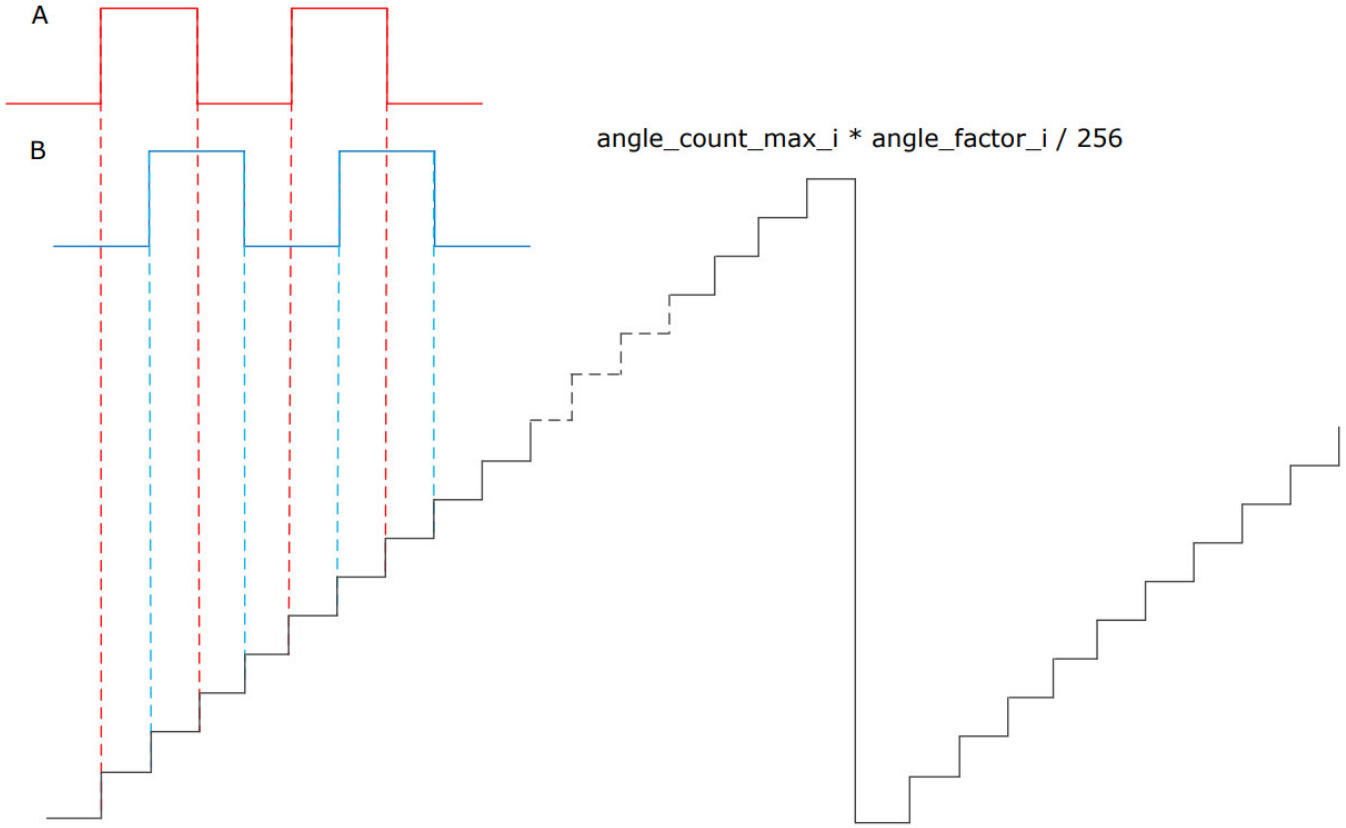
$$\text{Angle Factor} = \frac{256 \times 262144 \times \text{Number of pole pairs}}{\text{Encoder Reslution} \times 4}$$

$$\text{Speed Factor} = \frac{384000}{\text{Encoder Resolution}} \text{RPM} = \frac{384000 \times 65536}{\text{Encoder Resolution} \times \text{Rated Speed}} (p \cdot u)$$

$$\text{Angle Count Max} = 4 \times \text{Encoder Resoultion} - 1$$

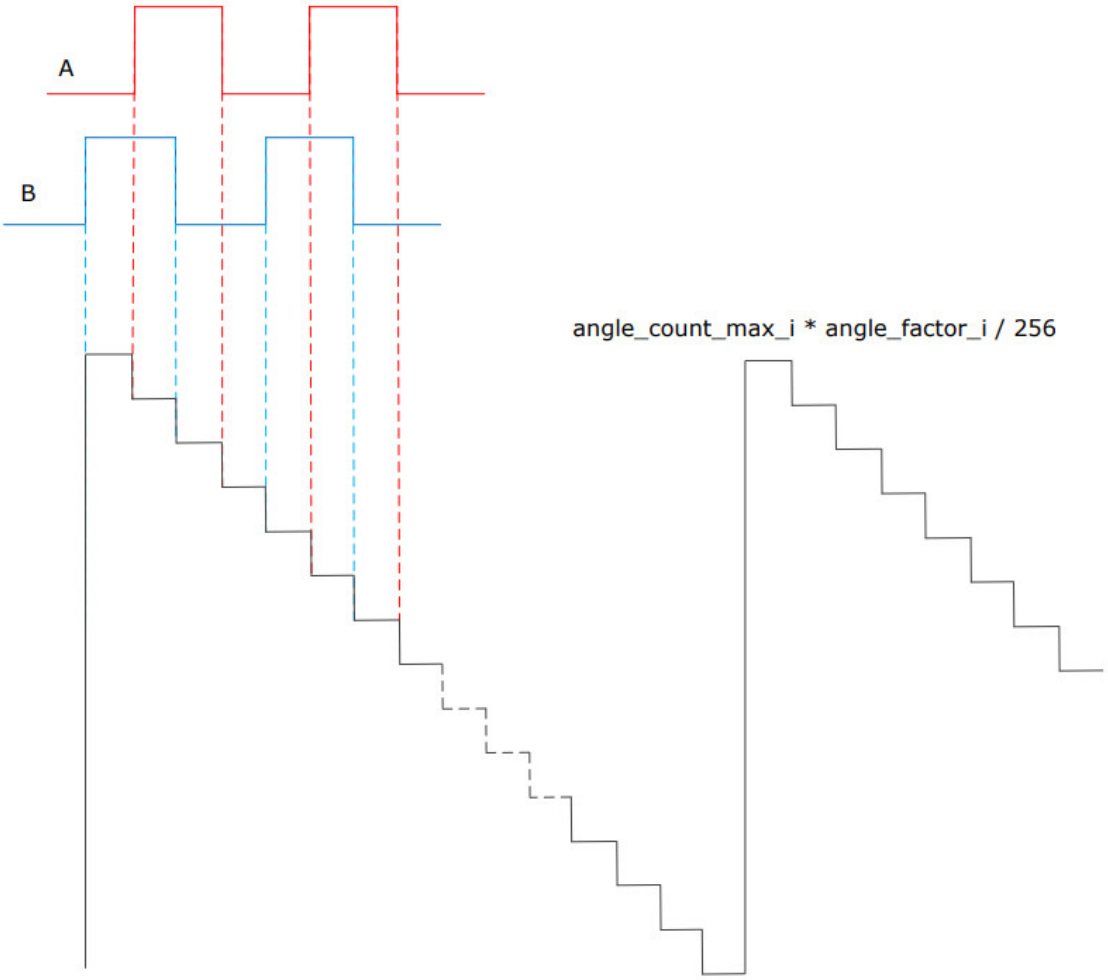
The following figure shows the Theta output for the positive direction.

Figure 3. Theta Output for Positive Direction



The following figure shows the Theta output for the negative direction.

Figure 4. Theta Output for Negative Direction



Summary (Ask a Question)
The following table provides a summary of the Encoder Interface IP characteristics.

Core Version	This document applies to Encoder Interface 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. Encoder Interface is licensed with encrypted RTL that must be purchased separately. For more information, see **Encoder Interface**.

Features (Ask a Question)
Encoder Interface has the following key features:

- Computes the relative angular position
- Computes the filtered speed output

Implementation of IP Core in Libero Design Suite (Ask a Question)
IP core must be installed to the IP Catalog of the Libero® 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 (Ask a Question)

The following table lists the device utilization used for Encoder Interface.

Table 1. Encoder Interface Utilization

Device Details		Resources		Performance (MHz)	RAMs		Math Blocks	Chip Globals
Family	Device	LUTs	DFF		LSRAM	µSRAM		
PolarFire® SoC	MPFS250T	398	285	200	0	0	2	0
PolarFire	MPF300T	387	285	200	0	0	2	0
SmartFusion® 2	M2S150	400	285	140	0	0	2	0

Important:

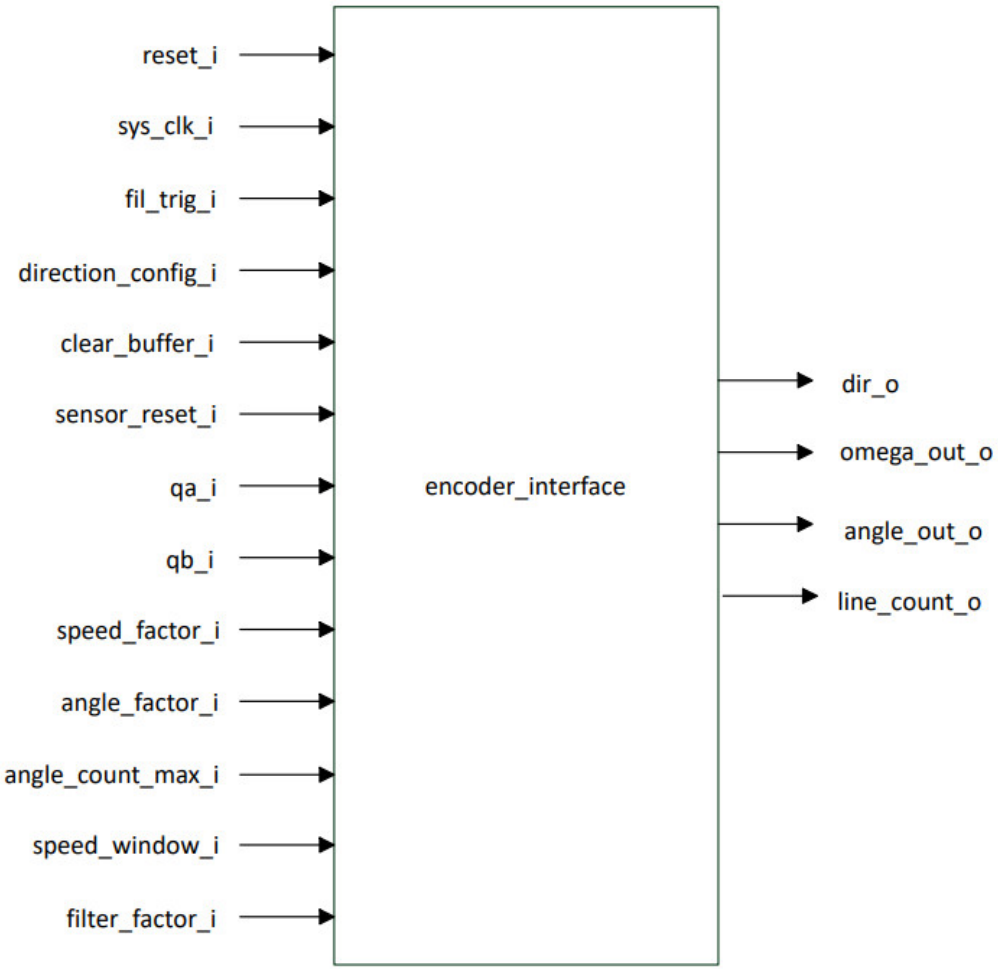
1. The data in this table is captured using typical synthesis and layout settings. CDR reference clock source was set to Dedicated with other configurator values unchanged.
2. Clock is constrained to 200 MHz while running the timing analysis to achieve the performance numbers.

Functional Description

(Ask a Question)

The following figure shows the block diagram of encoder interface.

Figure 1-1. System-Level Block Diagram of Encoder Interface



The encoder interface block converts signals received from QA, QB into its corresponding angle and speed. The block counts encoder edges till the angle_count_max_i value is attained and then starts counting from zero again. The angle generated is scaled to 262144 by multiplying it with the angle_factor_i. Speed is measured by counting the number of encoder events in a constant time period defined by speed_window_i input. A filter is used to filter the quantization noise from speed measurement. The filter time constant can be configured using the filter_factor_i value using the following equation:
Filter time constant = Time period between successive pulses of pwm midmatch _ i × 2 filter_factor_i

The sensor_reset_i input is used to find motor electrical angle by injecting constant current for a small duration. When the motor has aligned to the injected angle, the encoder output is initialized with 90° or 270° based on initial direction of rotation. The encoder edge counting is expected to start after the falling edge of the sensor_reset_i input is detected.
The clear_buffer_i input can be used to reset the filter buffer, as the filter buffer is expected to be reset when the motor stops.
The direction_config_i input is used to initially detect the motor direction. Once the motor starts running, the motor direction is detected from the encoder signals and used in generating the angle.

Encoder Interface Parameters and Interface Signals

(Ask a Question)
This section discusses the parameters in the Encoder Interface GUI configurator and I/O signals.

2.1 Inputs and Outputs Signals (Ask a Question)
The following table lists the input and output ports of Encoder Interface.

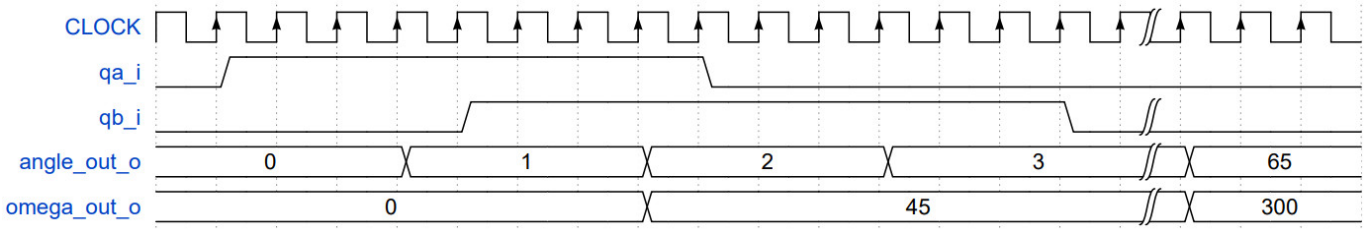
Signal Name	Direction	Description
reset_i	Input	Active Low Asynchronous Reset Signal
sys_clk_i	Input	System Clock
fil_trig_i	Input	Filter trigger input. A timing pulse of one clock cycle width must be provided at this input. The periodicity of the pulse determines the sampling time.
direction_config_i	Input	Direction configuration bit – used at calibration time to align the rotor. When 1, aligns rotor for counter clockwise starting or when 0, aligns rotor for clockwise starting.
clear_buffer_i	Input	Clears the filter buffer generally when the motor is stopped. A pulse of one clock cycle width must be input each time the motor stops.
sensor_reset_i	Input	Sensor Reset signal: When set to 1, rotor angle is reset to the equivalent of 90° or 270° as determined by the direction_config_i input. When set to 0 (zero), normal operation.
qa_i	Input	Encoder input A
qb_i	Input	Encoder input B
speed_factor_i	Input	Speed output scaling multiplier
angle_factor_i	Input	Angle output scaling multiplier
angle_count_max_i	Input	Maximum angle count value in terms of encoder pulse events.
speed_window_i	Input	The time window for speed computation, specified in multiples of 10 µs. Larger time window gives better speed resolution but has higher latency. Smaller time window must be used for high dynamic speed response.
filter_factor_i	Input	Filter factor value for filter – if value is n, the filter time constant is 2^n times the sampling time of the filter defined by filt_trig_i.
dir_o	Output	Direction signal generated based on encoder input signals.
speed_done_o	Output	Indicates speed computation is ready for filtering (at the end of speed window). A pulse of one sys_clk_i cycle width is generated.
speed_filter_done_o	Output	Indicates speed output after filtering is valid (at omega_out_o output port). A pulse of one sys_clk_i cycle width is generated.
omega_out_o	Output	Rotor speed output after filtering – suitable for use as speed feedback in speed control operation.

angle_out_o	Output	Electrical angle output suitable for FOC.
line_count_o	Output	Specifies the rotor position in terms of number of encoder lines (increments) since the last sensor reset. Suitable for use with position control operations.

Timing Diagrams

(Ask a Question)
This section discusses encoder interface timing diagram.
The following figure shows the timing diagram of encoder interface.

Figure 3-1. Encoder Interface Timing Diagram



Testbench

(Ask a Question)
A unified testbench is used to verify and test Encoder Interface called as user testbench. Testbench is provided to check the functionality of the Encoder Interface IP.

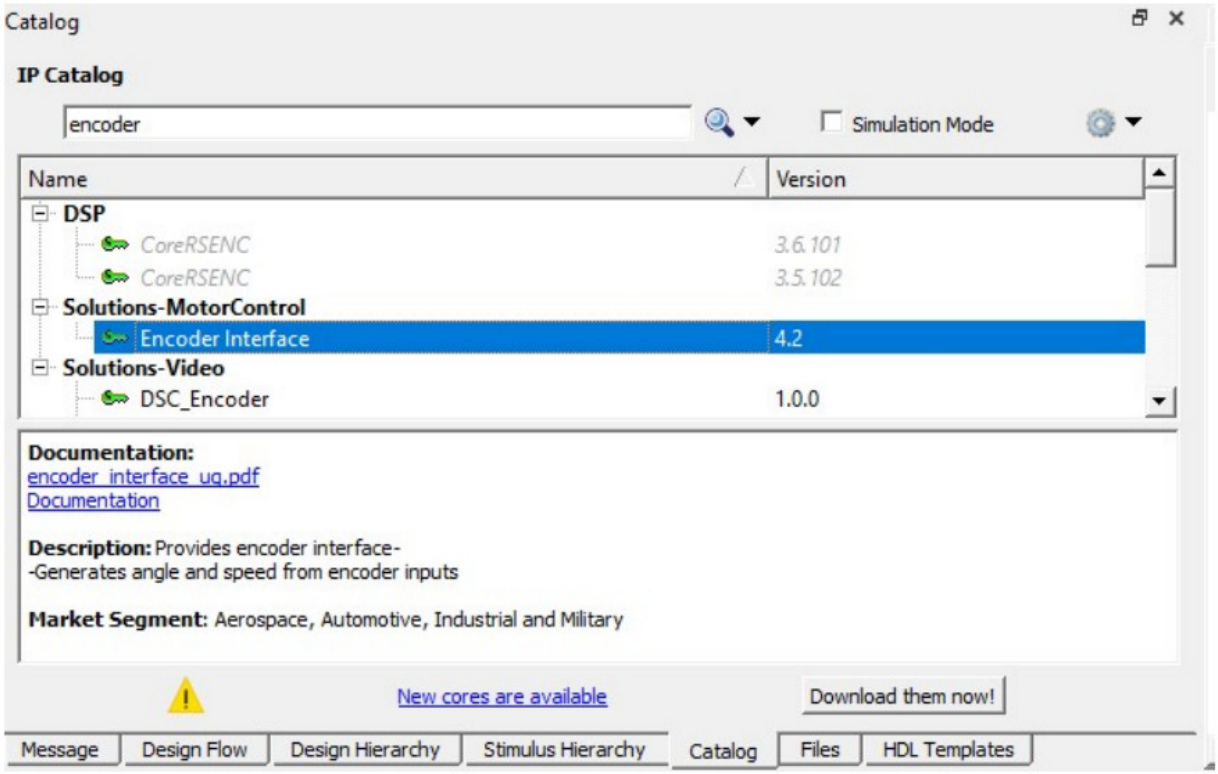
4.1 Simulation (Ask a Question)

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

1. Open Libero SoC, click Catalog tab, and then click Solutions-MotorControl.
2. Double-click Encoder Interface and then click OK. The documentation associated with the IP are listed under Documentation.

   Important: If you do not see the Catalog tab, click View, open Windows menu, and then click Catalog to make it visible.

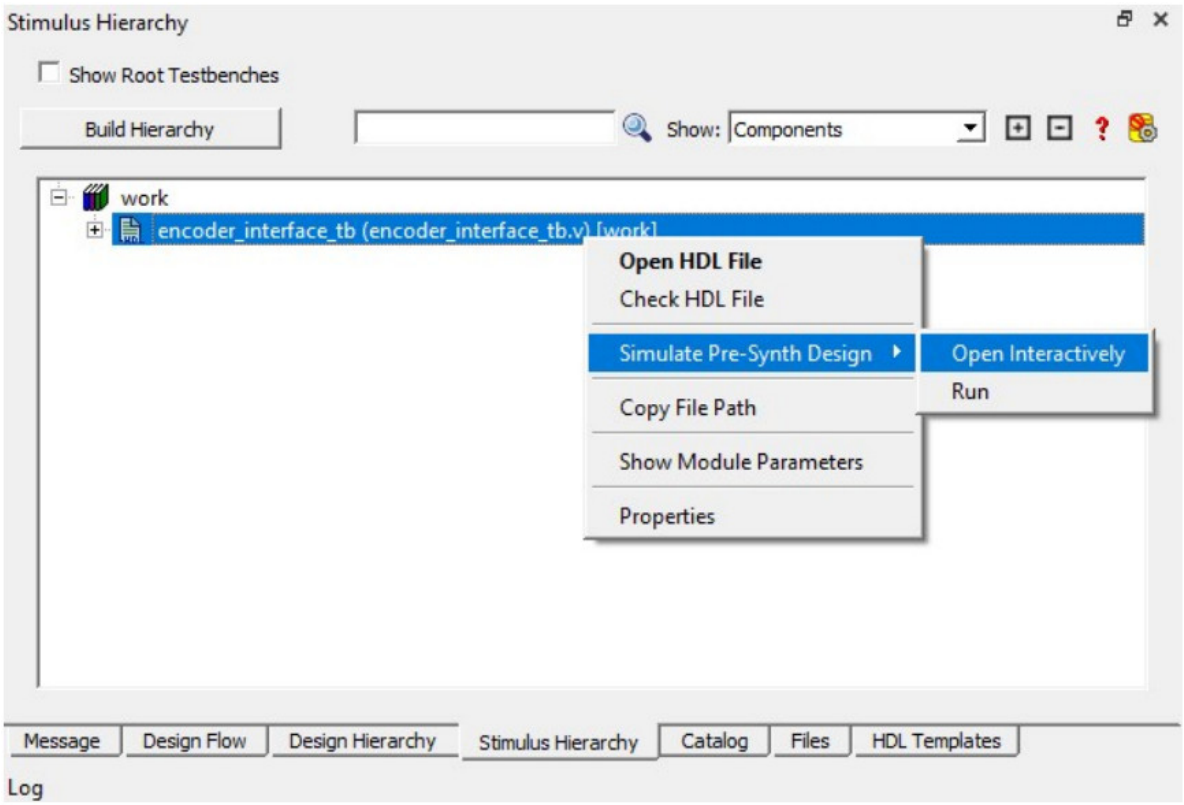
   Figure 4-1. Encoder Interface IP Core in Libero SoC Catalog



3. On the Stimulus Hierarchy tab, click the testbench (encoder_interface_tb.v), point to Simulate PreSynth Design, and then click Open Interactively.

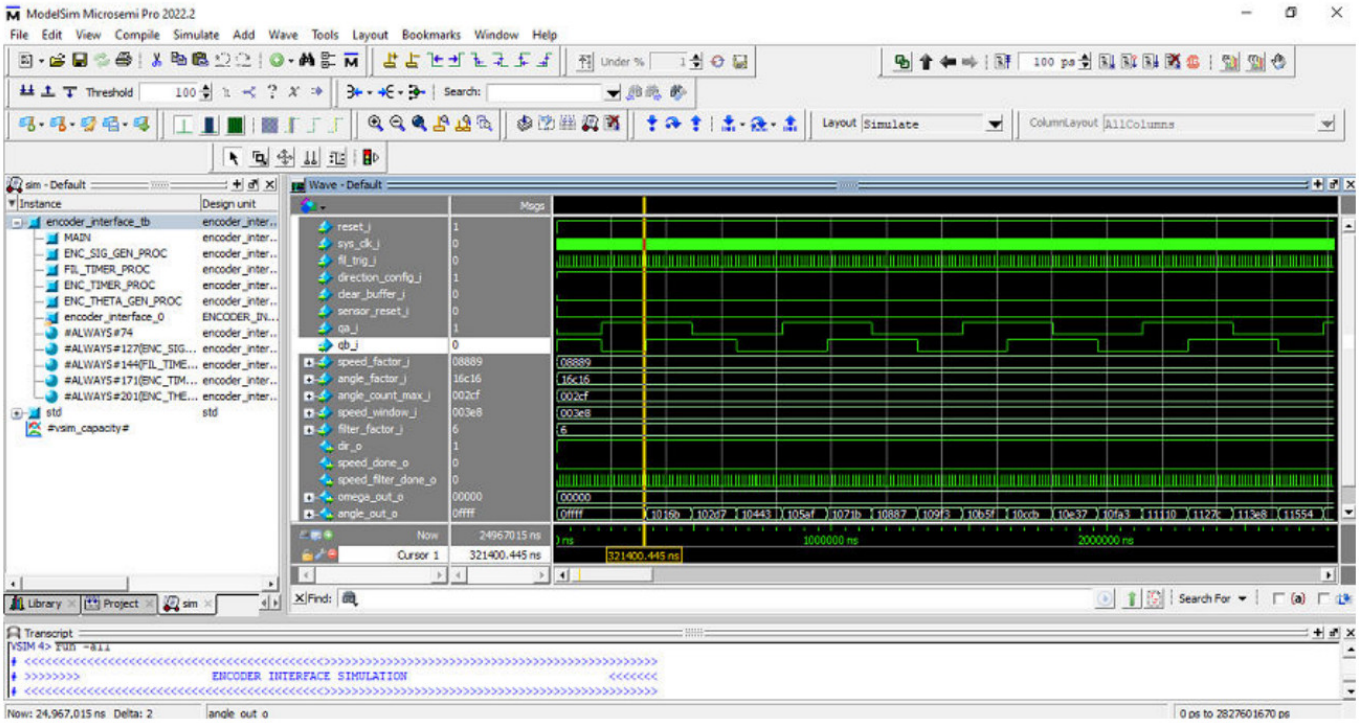
Important: If you do not see the Stimulus Hierarchy tab, click View, open Windows menu, and then click Stimulus Hierarchy to make it visible.

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

(Ask a Question)

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

Table 5-1. Revision History

Revision	Date	Description
A	03/2023	The following are the list of changes in revision A of the document: • Migrated the document to the Microchip template. • Updated the document number to DS00004913A from 50200659. • Added 3. Timing Diagrams. • Added 4. Testbench.
3.0	—	The following is a summary of changes made in this revision: • Added the IP version to the document title. • Added speed_done_o and speed_filter_done_o output signals. • Removed Configuration Parameter section from Hardware Implementation.
2.0	—	Updated the document with the new output signals.
1.0	—	Revision 1.0 was the first publication of this document.

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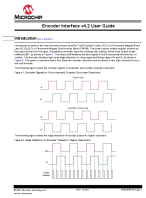	MICROCHIP v4.2 Encoder Interface [pdf] User Guide v4.2 Encoder Interface, v4.2, Encoder Interface, Interface

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