AXI4-Stream UART (Beta Release)

Version 0.1

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IP Summary

Introduction

The AXIS UART is designed to be used with the AXIS bus, which provides a high-speed, low-latency data path between the UART and other components in the system. The AXIS UART is often used to interface with other peripherals such as memory or other processors, or to provide a serial communication link to external devices such as a PC or another microcontroller. UARTs typically include a transmitter and receiver and can be used for a wide range of applications. This is an AXI-Stream compliant UART IP that can be integrated in a number of systems.

Features

- Configurable data width for the AXIL bus.
- Independent transmission and reception modules.
- Supports the AXI4-Stream interface specification.

Overview

AXIS UART

AXI Stream UART is a type of Universal Asynchronous Receiver-Transmitter (UART) interface that is designed to work with the Advanced Microcontroller Bus Architecture (AMBA) AXI Stream protocol. It is commonly used in FPGA (Field-Programmable Gate Array) designs to provide a simple and efficient way to communicate with other components in the system. The AXI Stream UART is a serial communication interface that enables the transfer of data between two devices in a streaming fashion, where data is sent continuously without any start or stop bits. This makes it ideal for applications that require a high throughput of data, such as video or audio streaming.
The AXI Stream UART interface is designed to work with the AXI Stream protocol, which is a high-speed, packet-based protocol used to transfer data between components in an FPGA. The AXI Stream protocol uses a simple, unidirectional interface that allows data to be transmitted in a continuous stream, without any handshaking signals.
One of the key benefits of using AXI Stream UART is that it simplifies the design process by eliminating the need for additional components, such as a serializer or deserializer. This can help reduce the overall complexity of the FPGA design and improve system performance.
In summary, the AXI Stream UART is a high-speed, streaming interface that allows for efficient transfer of data between components in an FPGA design. It is commonly used in applications that require a high throughput of data, such as video or audio streaming. A block diagram for the UART IP is shown in Figure 1.

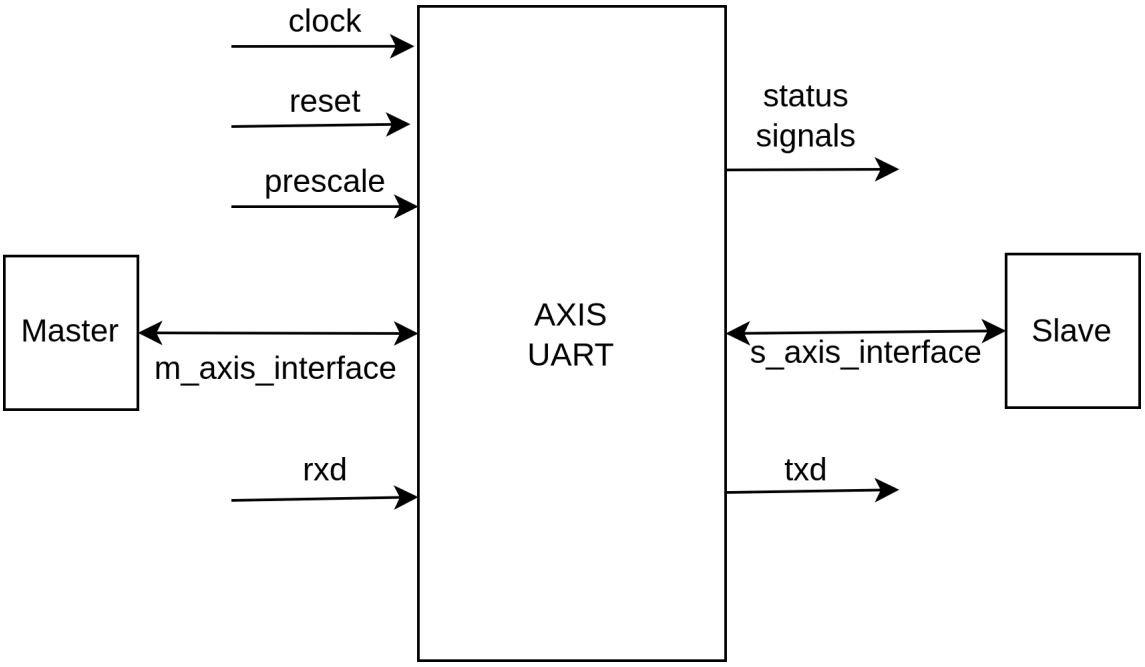

Figure 1: AXIS UART Block Diagram

IP Specification

The UART transmitter and receiver both use a single transmit or receive pin. The modules take one parameter, DATA_WIDTH, that specifies the width of both the data bus and the length of the actual data words communicated. The default value is 8 for an 8 bit interface. The prescale input determines the data rate - it should be set to Fclk / (baud * 8). This is an input instead of a parameter so it can be changed at run time, though it is not buffered internally so care should be used to avoid corrupt data. The main interface to the user design is an AXI4-Stream interface that consists of the tdata, tvalid, and tready signals. tready flows in the opposite direction. tdata is considered valid when tvalid is high. The destination will accept data only when tready is high. Data is transferred from the source to the destination only when both tvalid and tready are high, otherwise the bus is stalled.
Both interfaces also present a 'busy' signal that is high when an operation is taking place. The receiver also presents overrun error and frame error strobe outputs. If the data word currently in the tdata output register is not read before another word is received, then a single cycle pulse will be emitted from overrun_error and the word is discarded. If the receiver does not get a stop bit of the right level, then a single pulse will be emitted from the frame_error output and the received word will be discarded. The internal block diagram can be seen in Figure 2.

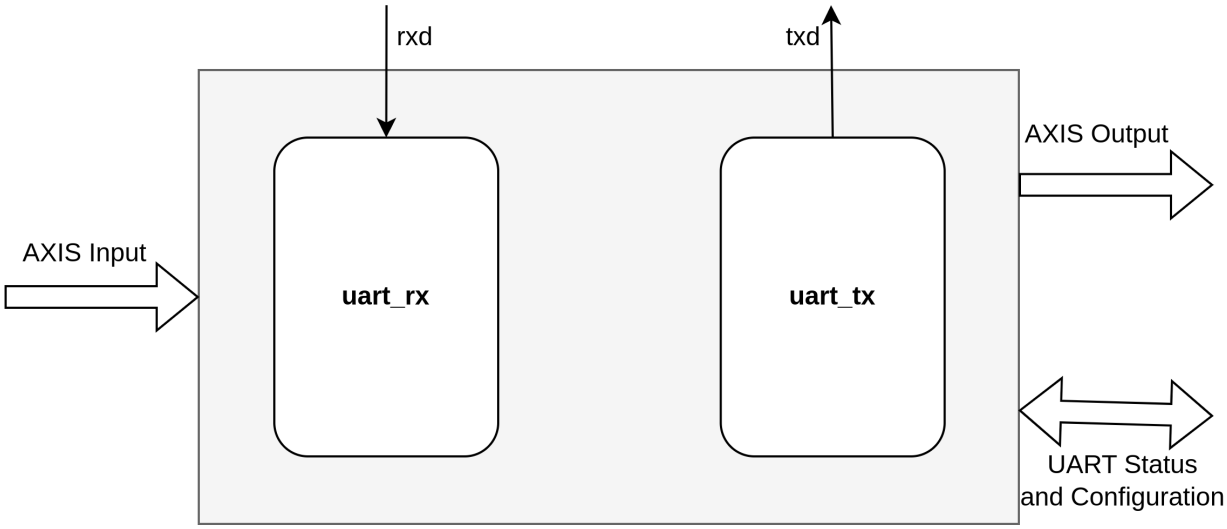

Figure 2: AXIS UART Internal Diagram

Standards

The AXI4-Stream interface is compliant with the AMBA® AXI Protocol Specification.

IP Support Details

The Table 1 gives the support details for AXIS UART.

Compliance		IP Resources				Tool Flow		
Device	Interface	Source Files	Constraint Files	Testbench	Simulation Model	Analyze and Elaboration	Simualtion	Synthesis
Gemini	AXI4-Stream	Verilog	-	Python / Verilog	MyHDL	Verific (Raptor)	Icarus (Raptor)	Raptor

Table 1: IP Details

Port List

Table 2 lists the top interface ports of the AXIS UART.

Signal Name	I/O	Description
AXI Clock and Reset		
clk	I	AXI4-Stream Clock
rst	I	AXI4-Stream Active High Reset
AXI Slave Interface		
s_axis_tdata	I	AXI4-Stream data
s_axis_tvalid	I	AXI4-Stream valid transfer
s_axis_tready	O	AXI4-Stream transfer ready
AXI Master Interface		
m_axis_tdata	O	AXI4-Stream data
m_axis_tvalid	O	AXI4-Stream valid transfer
m_axis_tready	I	AXI4-Stream transfer ready
UART Interface		
rxd	I	UART reception
txd	O	UART transmission
Status Signals		
tx_busy	O	UART transmission busy
rx_busy	O	UART reception busy
rx_overrun_error	O	UART overrun of data reception
rx_frame_error	O	UART reception of non-integral units
Configuration		
prescale	I	UART prescaler configuration

Table 2: AXIS UART Interface

Parameters

Table 3 lists the parameters of the AXIS UART.

Parameter	Values	Default Value	Description
DATA WIDTH	8, 16, 32, 64, 128, 256, 512, 1024	8	Data Width for each transfer

Table 3: Parameters

Resource Utilization

The parameters for computing the maximum and minimum resource utilization are given in Table 4, remaining parameters have been kept at their default values.

Tool	Raptor Design Suite			
FPGA Device	GEMINI			
Configuration			**Resource Utilized**	
Minimum Resource	**Options**	**Configuration**	**Resources**	**Utilized**
	DATA WIDTH	8	LUTs	165
			Registers	79
Maximum Resource	**Options**	**Configuration**	**Resources**	**Utilized**
	DATA WIDTH	1024	LUTs	3193
			Registers	3121

Table 4: Resource Utilization

Design Flow

IP Customization and Generation

AXIS UART IP core is a part of the Raptor Design Suite Software. A customized AXIS UART can be generated from the Raptor's IP configurator window as shown in Figure 3.

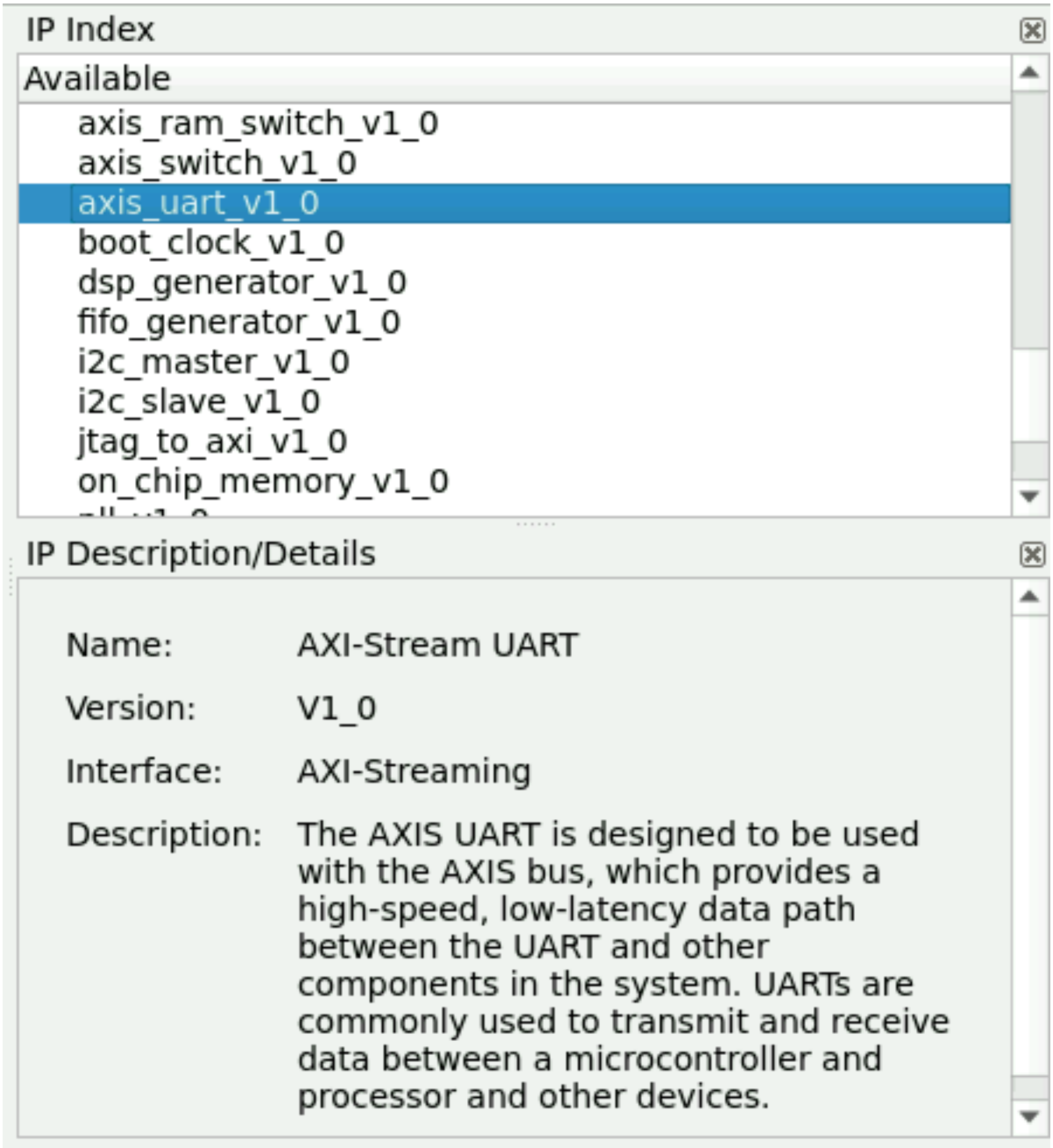

Figure 3: IP list

Parameters Customization

From the IP configuration window, the parameters of the UART can be configured and UART features can be enabled for generating a customized UART IP core that suits the user application requirement as shown in Figure 4. After IP Customization, all the source files are made available to the user with a top wrapper that instantiates a parameterized instance of the AXIS UART.

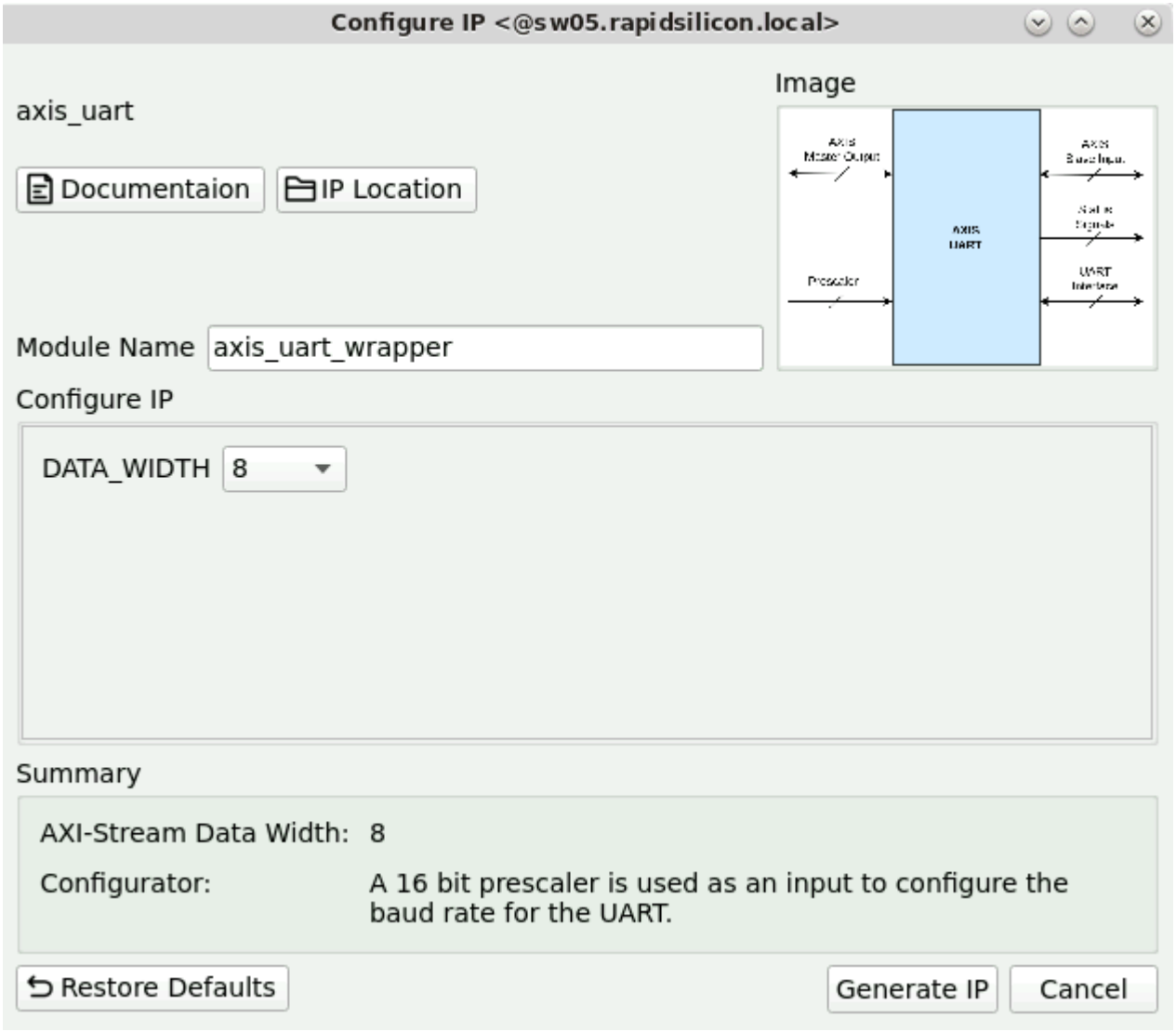

Figure 4: IP Configuration

Example Design

Overview

This AXIL UART IP can be utilized in a system that requires sequential transmission and reception of data from the outside world. UART is a crucial component in many electronic systems, enabling communication between the system and external devices through a serial interface. It can be embedded inside SoCs to enable two-way communication via the SoC in a streaming interface to maximize the throughput. One such example design of this AXIS UART can be visualized in Figure 5.

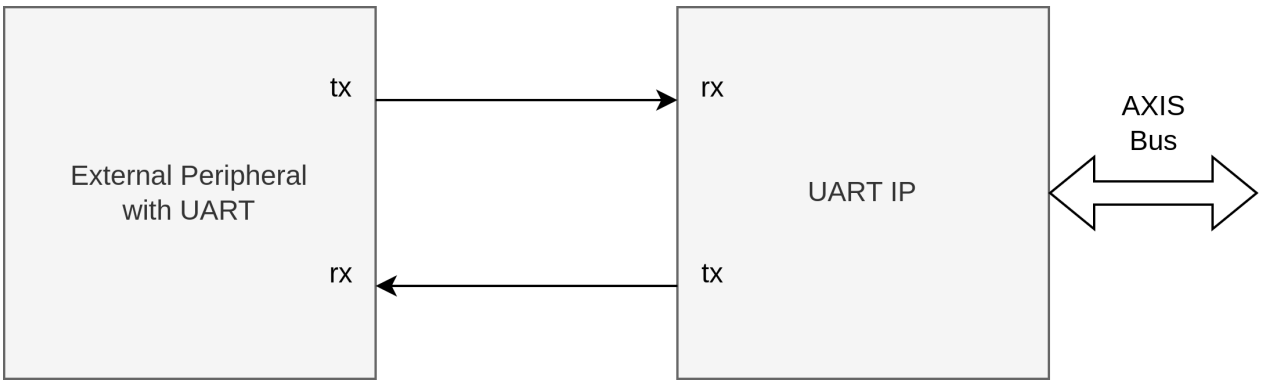

Figure 5: AXIS UART replicating connected with a Peripheral

Simulating the Example Design

The IP being Verilog HDL, can be simulated via a bunch of industry standard stimulus. For instance, it could be simulated via writing a Verilog Test-bench, or incorporating a soft processor that can stimulate this UART IP. The bundled example design is stimulated via a MyHDL based environment that iteratively stimulates the soft IP with the help of a Verilog testbench by performing various transmission and reception operations on the UART interface while also stimulating the AXI-Stream interface.

Synthesis and PR

Raptor Suite is armed with tools for Synthesis along with Post and Route capabilities and the generated postsynthesis and post-route and place netlists can be viewed and analyzed from within the Raptor. The generated bitstream can then be uploaded on an FPGA device to be utilized in hardware applications.

Test Bench

The included testbench for the AXIS UART IP is a MyHDL based Python testbench that performs various transmission and reception operations on the IP core with the help of pre-defined Verilog testbenches. Python is used to simulate the Verilog testbenches under the influence of MyHDL for this purpose and a total of 2 tests are performed, one for the transmission and the other for reception of the data by the UART IP from the Verilog testbenches. The waveforms are also dumped in the format of .lxt for in-depth analysis of the whole operation. Being written in simple Verilog and Python, the testbenches are easily modifiable to provide maximum coverage of the UART IP. The simulation can be easily run by clicking the "Simulate IP" button as shown in figure 6.

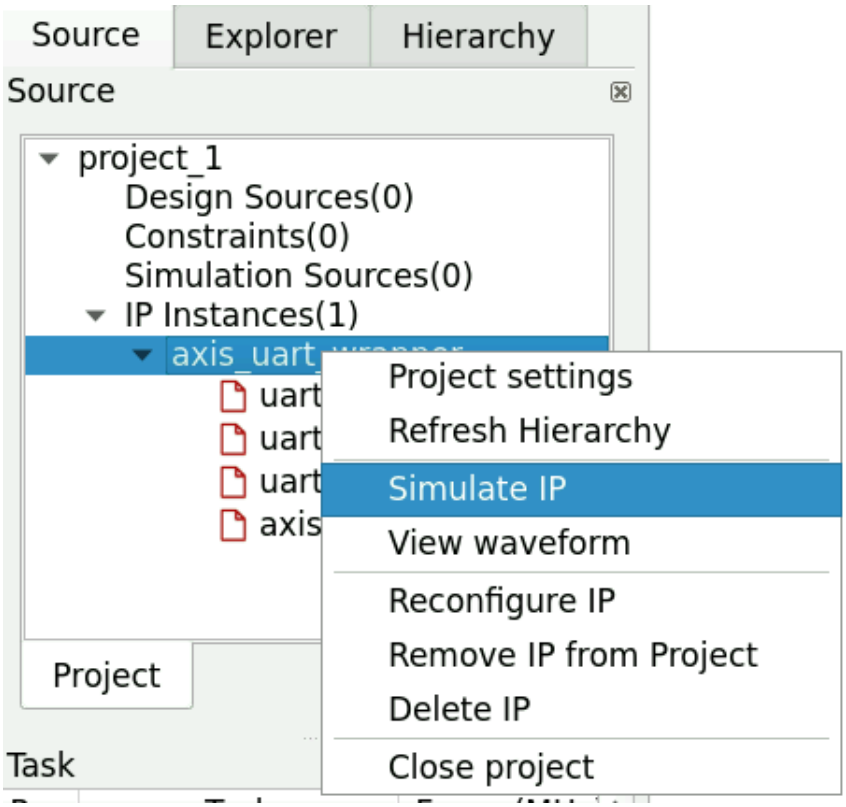

Figure 6: Simulate IP Window

The waveforms are also dumped in-depth analysis of the whole operation which can be seen by clicking the "View Waveform" button as shown in 7.

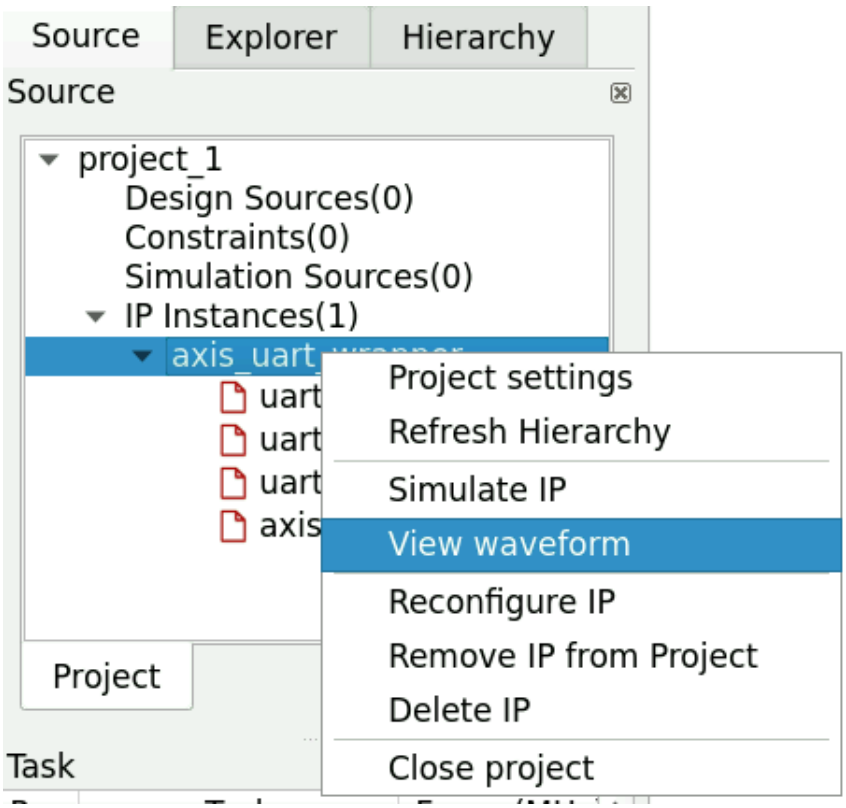

Figure 7: View Waveform Window

The simulation results are also displayed in the console window a glimpse of which can be seen in figure 8.

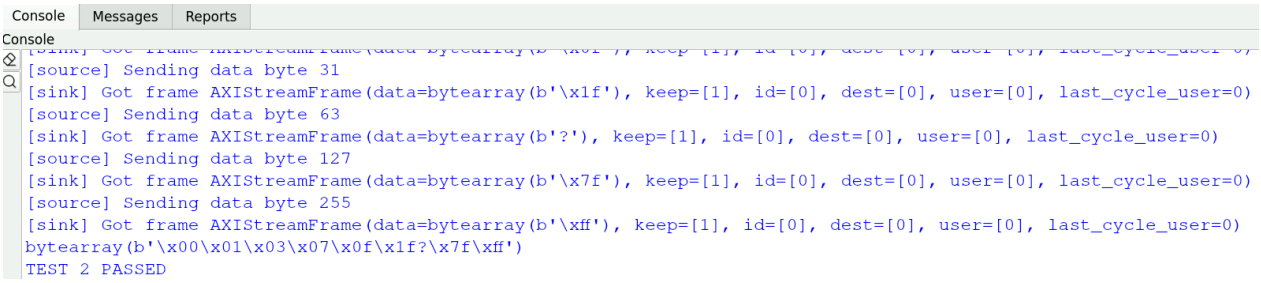

Figure 8: Simulation Results

Release

Release History

Date	Version	Revisions
November 21, 2023	0.1	Initial version AXI4-Stream UART User Guide Document