

AXIS Switch v1.0

IP User Guide (Beta Release)



November 21, 2023

Contents

IP Summary	2
Overview	3
AXIS Switch	3
Licensing	4
IP Specification	5
Standards	5
IP Support Details	6
Resource Utilization	6
Port List	7
Parameters	8
Design Flow	9
IP Customization and Generation	9
Example Design	11
Overview	11
Simulating the Example Design	11
Synthesis and PnR	11
Test Bench	12
Release	14
Revision History	14

IP Summary

Introduction

The AXIS Switch core is an AXI4-Streaming compliant customizable switch that is designed to be used in applications that require configurable routing between masters and slaves with multiple arbitration options.

The TDEST based routing uses RTL parameters configured before synthesis to control the routing by assigning a base TDEST pair to each master interface that is then used to generate a decode table which is then decoded by the respective slave interface based on the valid TDEST value. This transfer routes a request to an arbiter of one of the master interfaces.

The arbiter responds with a grant based on input from a priority encoder, and then the slave proceeds with the transfer. Arbitration can be performed at either transfer level or the transaction level. The TDEST based routing requires that the signal has at least \log_2 number of bits.

Features

- Supports 1-16 slaves.
- Supports 1-16 masters.
- Supports Round-Robin and LSB High Priority arbitration choices.
- Supports routing based on TDEST base/high pairs.
- Configurable data width.
- Configurable slave/master register types.
- Configurable offset in address arbitration.

Overview

AXIS Switch

AXIS Switch is configured via its AXI-streaming slave interface. It captures the number of slaves and masters and their respective addressing offsets and generate address configuration for each master-slave pair. The arbitration occurs via an embedded priority encoder. The Figure 1 shows the AXIS Switch core connected with multiple masters and slaves routing data in between them.

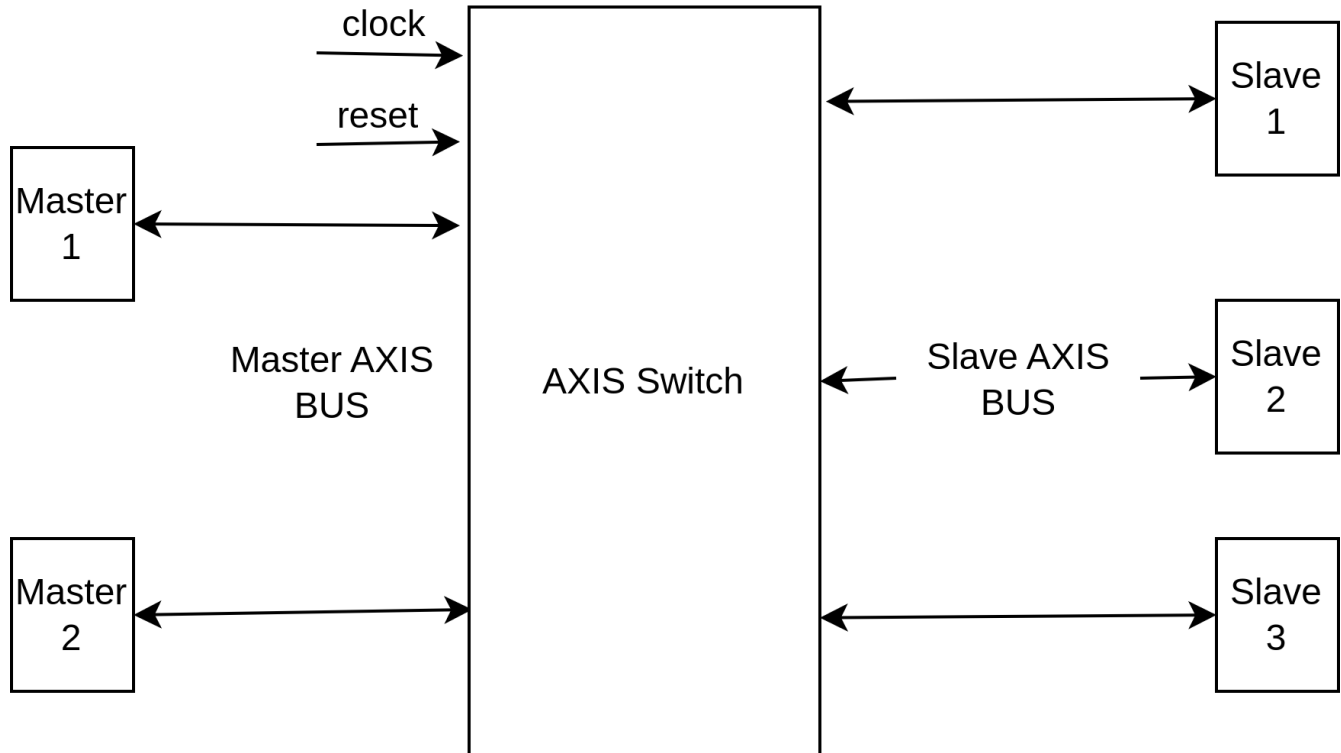


Figure 1. AXIS Switch

Licensing

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IP Specification

The Figure 2 shows the internal block diagram of AXIS Switch. It consists of a priority encoder, an arbiter and an axis register module to be used on both slave and master sides.

The AXIS Switch is configured from the AXI interface on the rising edge of the AXI bus clock. All the modules interfaced with this AXIS switch run on the same AXI bus clock and hence follow a pipelined structure. The Switch generates the address configuration based on the configuration and then the arbitration module routes the traffic between the slave-master pairs. This Switch forms the base for an AXIS Interconnect.

The whole module combines sequential and combinational logic to make sure it operates effectively without breaking.

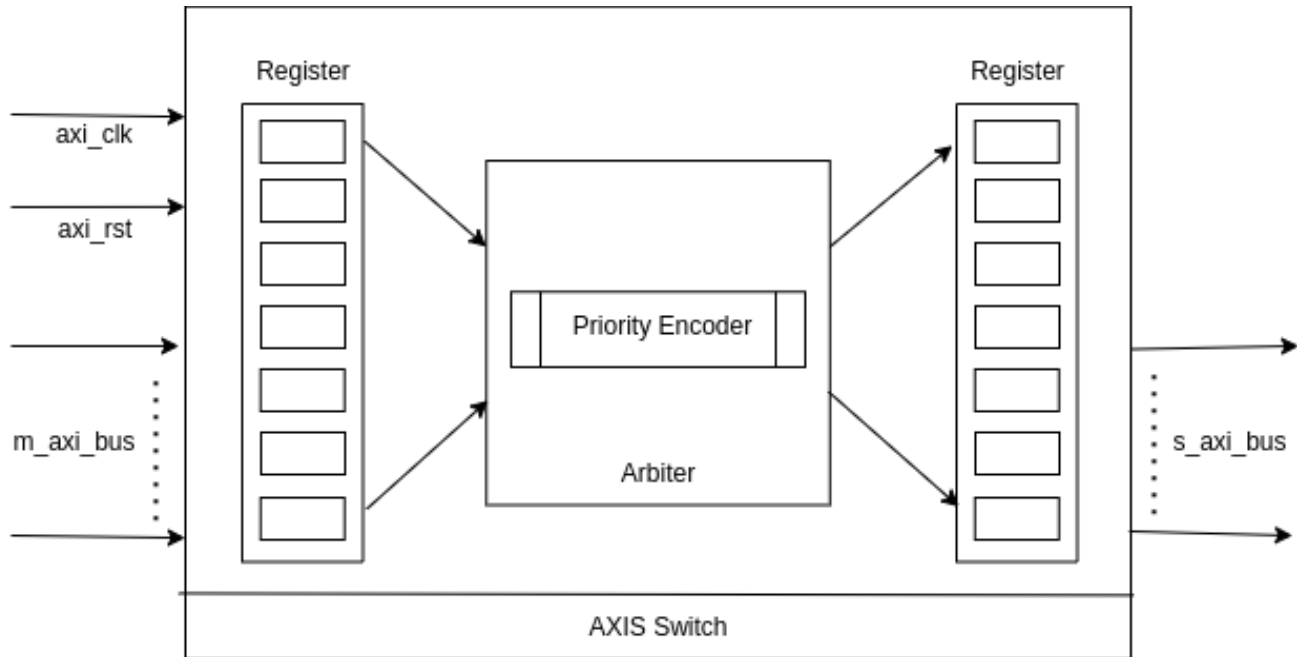


Figure 2. Top Module

Standards

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

IP Support Details

The Table 1 gives the support details for AXIS Switch.

Compliance		IP Resources					Tool Flow		
Device	Interface	Source Files	Constraint File	Testbench	Simulation Model	Software Driver	Analyze and Elaboration	Simulation	Synthesis
GEMINI	AXI4-Stream	Verilog	SDC	Python	Cocotb	Verilator	Raptor	Raptor	Raptor

Table 1. IP Details

Resource Utilization

The parameters for computing the maximum and minimum resource utilization are given in Table 2, remaining parameters have been kept at their default values.

Tool	Raptor Design Suite			
FPGA Device	GEMINI			
Configuration			Resource Utilization	
Minimum Resource	Options	Configuration	Resources	Utilized
	Master Interfaces	1	LUT	5
	Slave Interfaces	1	Registers	2
	S ID Width	1	-	-
	M Reg Type	0	-	-
	LSB High Priority	0	-	-
	Type Round Robin	0	-	-
	Data Width	8	-	-
Maximum Resource	Options	Configuration	Resources	Utilized
	Master Interfaces	3	LUT	521
	Slave Interfaces	8	Registers	200
	ID En	ON	DSP	3
	TID En	ON	-	-

Table 2. AXIS Switch Resource Utilization

Ports

Table 3 lists the top interface ports of the AXIS Switch.

Signal Name	I/O	Description
AXI Clock and Reset		
clk	I	AXI4-Stream Clock
rst	I	AXI4-Stream RESET
AXI Slave Interface		
s_axis_tdata	I	AXI4-Stream data
s_axis_tkeep	I	AXI4-Stream keep data qualifier
s_axis_tvalid	I	AXI4-Stream valid transfer
s_axis_tready	O	AXI4-Stream transfer ready
s_axis_tlast	I	AXI4-Stream boundary of transfer packet
s_axis_tid	I	AXI4-Stream data stream identifier
s_axis_tdest	I	AXI4-Stream data routing information
s_axis_tuser	I	AXI4-Stream user defined sideband information
AXI Master Interface		
m_axis_tdata	O	AXI4-Stream data
m_axis_tkeep	O	AXI4-Stream keep data qualifier
m_axis_tvalid	O	AXI4-Stream valid transfer
m_axis_tready	I	AXI4-Stream transfer ready
m_axis_tlast	O	AXI4-Stream boundary of transfer packet
m_axis_tid	O	AXI4-Stream data stream identifier
m_axis_tdest	O	AXI4-Stream data routing information
m_axis_tuser	O	AXI4-Stream user defined sideband information

Table 3. AXIS Switch Interface

Parameters

Table 4 lists the parameters of the AXIS Switch.

Parameter	Values	Default Value	Description
S COUNT	1 - 16	4	Number of Slave Interfaces
M COUNT	1 - 16	4	Number of Master Interfaces
DATA WIDTH	1 - 1024	8	Data Width for each transfer
USER WIDTH	1 - 1024	1	Data Width for user defined sideband information
S ID WIDTH	1 - 16	8	Slave side ID Width
M DEST WIDTH	1 - 8	1	Master side Destination Width
M REG TYPE	Bypass, Simple Buffer, Skid Buffer	Skid Buffer	Master side Register Type
S REG TYPE	Bypass, Simple Buffer, Skid Buffer	Bypass	Slave side Register Type
M BASE	0 - 15	0	Address configuration for Master Interface from Base
M TOP	0 - 15	0	Address configuration for Master Interface from Top
ID EN	0 / 1	0	ID Enable
USER EN	0 / 1	1	User Data Enable
LSB HIGH PRIORITY	0 / 1	1	LSB Priority Selection
TYPE ROUND ROBIN	0 / 1	1	Round Robin Architecture
TID	0 / 1	0	Enable update of Transfer ID

Table 4. Parameters

Design Flow

IP Customization and Generation

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

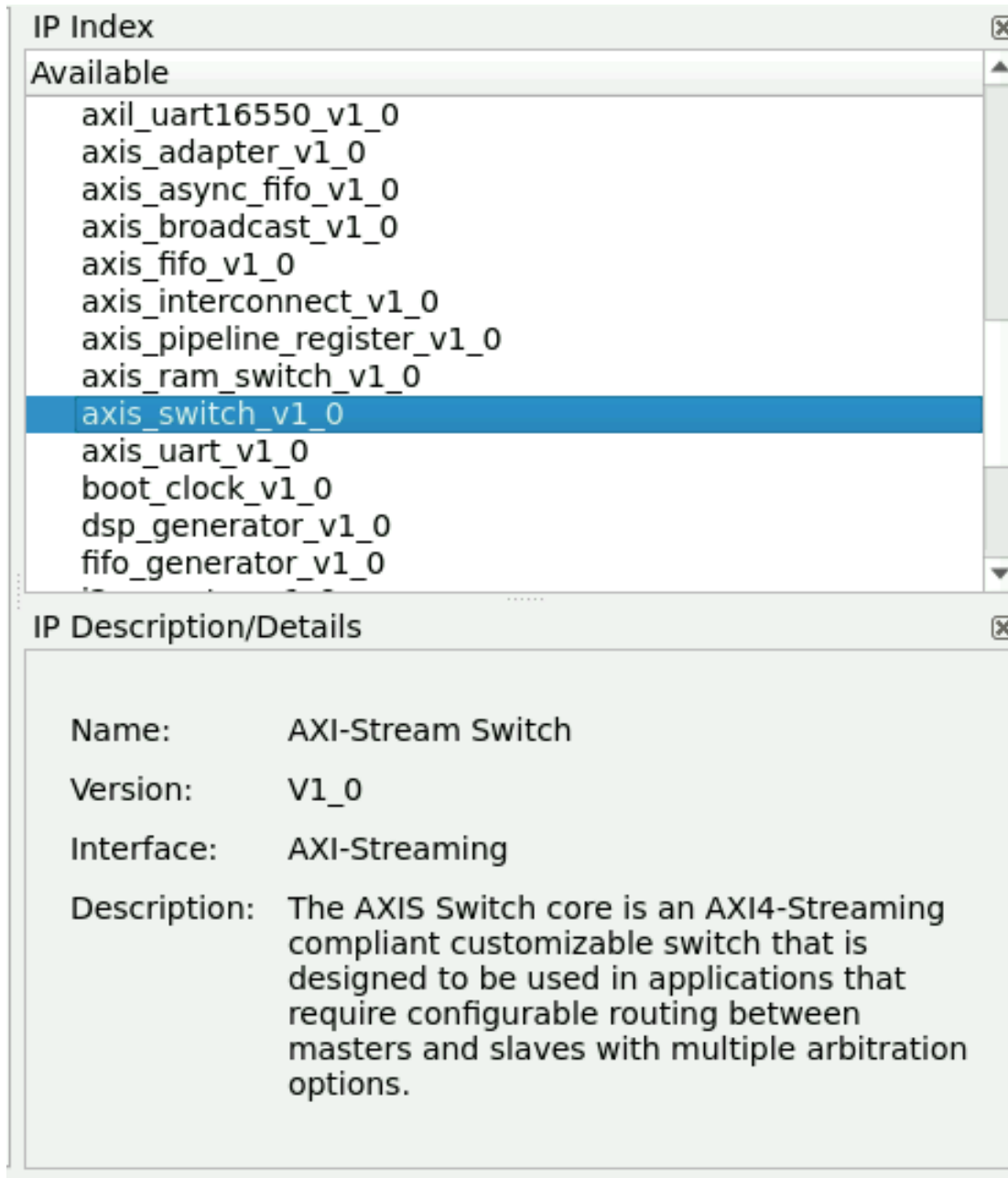
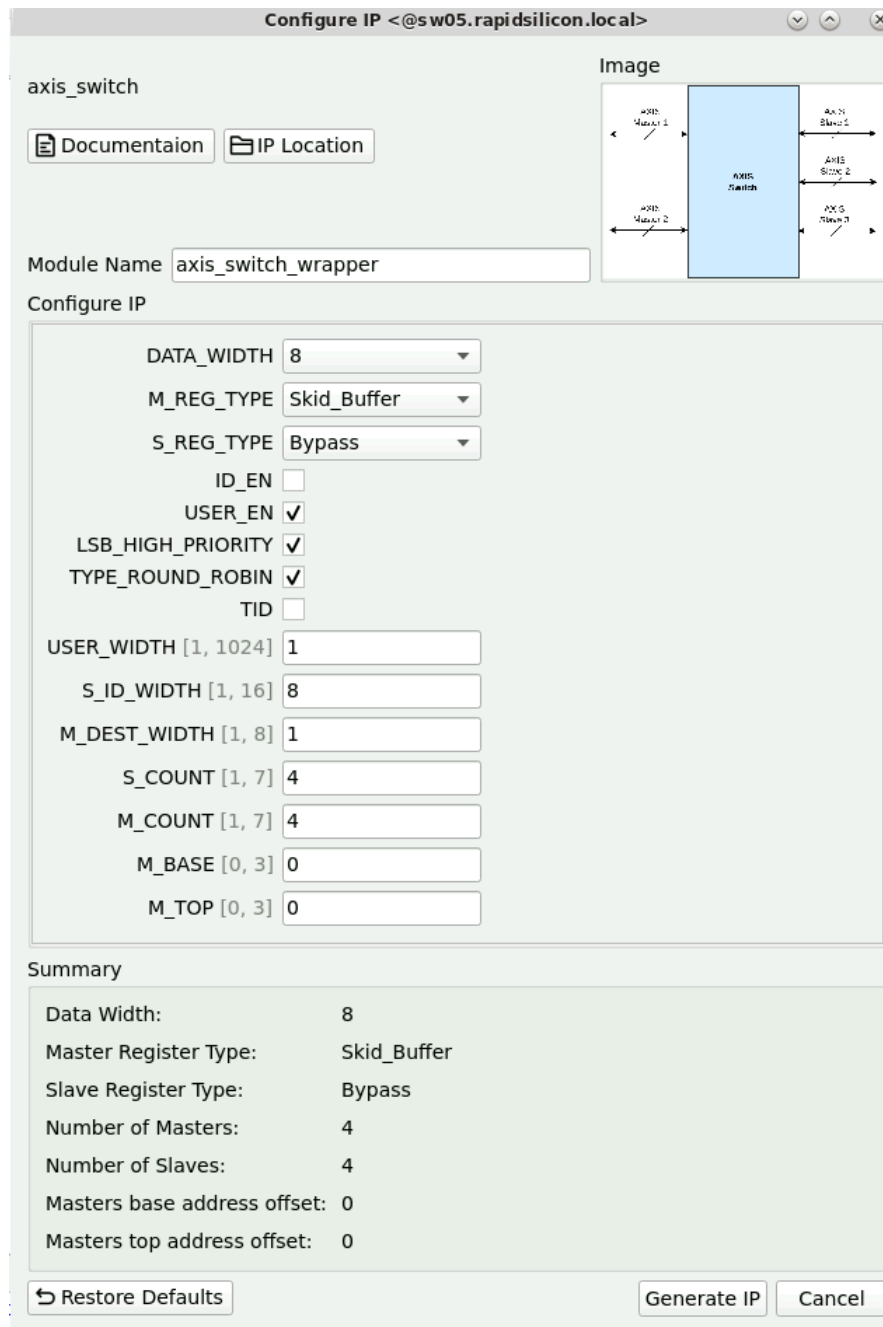




Figure 3. IP list

Parameters Customization: From the IP configuration window, the parameters of the Switch can be configured and Switch features can be enabled for generating a customized Switch 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 Switch.



Configure IP <@sw05.rapidsilicon.local>

axis_switch

 Documentaion  IP Location

Module Name

Configure IP

DATA_WIDTH

M_REG_TYPE

S_REG_TYPE

ID_EN ☐

USER_EN ☒

LSB_HIGH_PRIORITY ☒

TYPE_ROUND_ROBIN ☒

TID ☐

USER_WIDTH [1, 1024]

S_ID_WIDTH [1, 16]

M_DEST_WIDTH [1, 8]

S_COUNT [1, 7]

M_COUNT [1, 7]

M_BASE [0, 3]

M_TOP [0, 3]

Summary

Data Width:	8
Master Register Type:	Skid_Buffer
Slave Register Type:	Bypass
Number of Masters:	4
Number of Slaves:	4
Masters base address offset:	0
Masters top address offset:	0


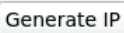

 Restore Defaults  Generate IP  Cancel

Figure 4. IP Configuration

Example Design

Overview

This AXIS RAM Switch can be utilized in any system that has multiple master and slave pairs and there is a need to route the traffic between them. This RAM Switch can also be utilized to make an Interconnect by adding several required FIFOs and data width adapters. In its native form, it acts as a minimalist data routing switch with the smallest footprint. One such interpretation of this AXIS Switch utilized in the AXIS Interconnect can be visualized in Figure 5.

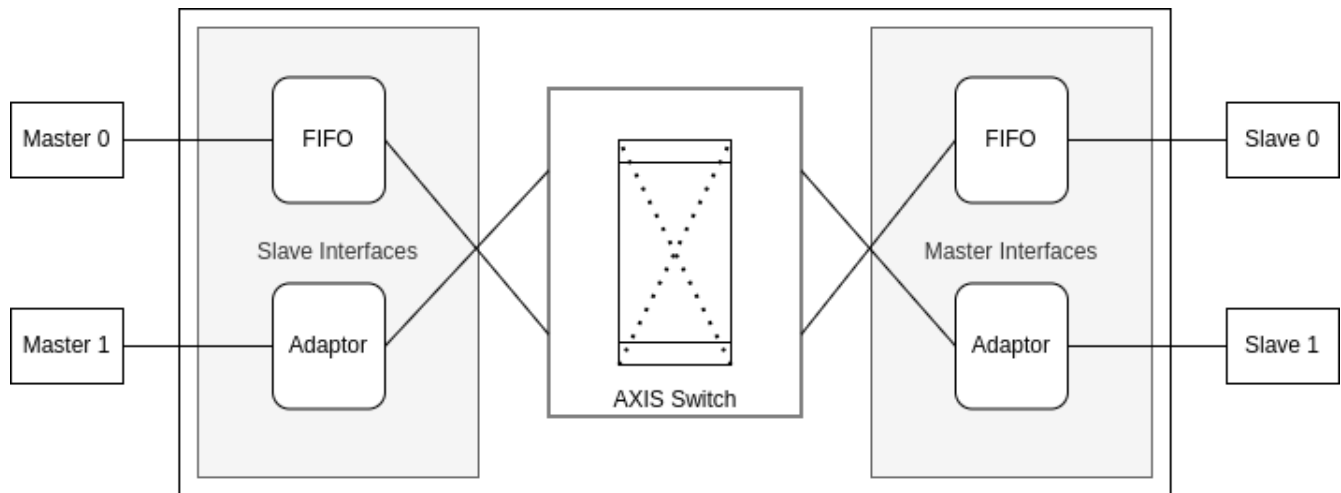


Figure 5. AXIS Switch in Interconnect

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 RAM Switch. The bundled example design is stimulated via a Coco-tb based environment that iteratively stimulates all the master/slave pairs while also stress testing the data routing between them.

Synthesis and PnR

Raptor Suite is armed with tools for **Synthesis** along with **Post and Route** capabilities and the generated post-synthesis 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

A Coco-tb based test bench can be found in the `/sim` repository formed after the generation of the IP. It generates a Switch IP with the following parameters: -

- ID EN = 1
- TID = 1
- S ID WIDTH = 16
- M DEST WIDTH = 8
- S COUNT = 4
- M COUNT = 4

This test environment can be simulated with any Verilog HDL simulator of choice e.g., Verilator or Icarus. This simulates the generated IP under various test conditions including stimulating all master and slave interfaces individually and then some stress test cases where all the interfaces are stimulated together. This makes up for a total of 25 tests upon passing of which the IP can be verified functionally. The simulation can be easily run by clicking the "Simulate IP" button as shown in figure 6a. The waveform can also be viewed via the built-in wave-veiwer by clicking the "View waveform" button as shown in figure 6b.

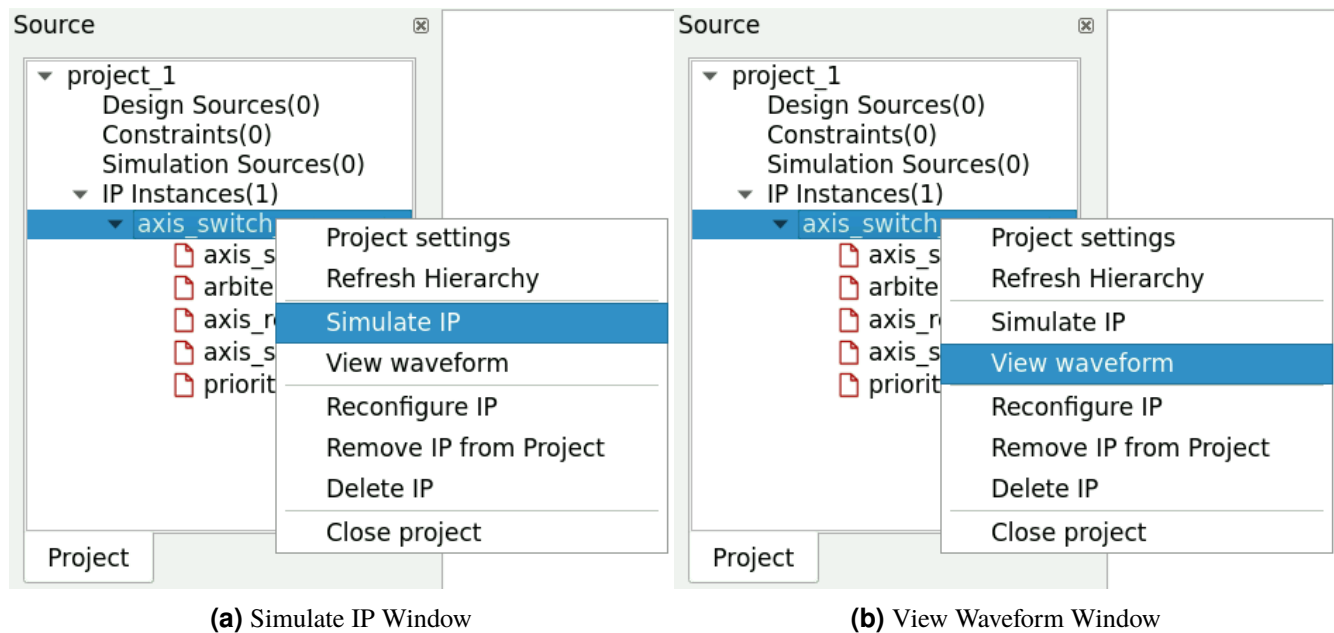


Figure 6. IP Source Window

The simulation results are also displayed in the console window a glimpse of which can be seen in figure 7.

```

*****
** TEST                                STATUS  SIM TIME (ns)
*****
** test_axis_switch.run_test_001      PASS      7320.00
** test_axis_switch.run_test_002      PASS      7330.00
** test_axis_switch.run_test_003      PASS      7330.00
** test_axis_switch.run_test_004      PASS      7330.00
** test_axis_switch.run_test_005      PASS     23530.00
** test_axis_switch.run_test_006      PASS     23530.00
** test_axis_switch.run_test_007      PASS     23530.00
** test_axis_switch.run_test_008      PASS     23530.00
** test_axis_switch.run_test_009      PASS     23520.00
** test_axis_switch.run_test_010      PASS     23520.00
** test_axis_switch.run_test_011      PASS     23520.00
** test_axis_switch.run_test_012      PASS     23520.00
** test_axis_switch.run_test_013      PASS     23530.00
** test_axis_switch.run_test_014      PASS     23530.00
** test_axis_switch.run_test_015      PASS     23530.00
** test_axis_switch.run_test_016      PASS     23530.00
** test_axis_switch.run_test_tuser_assert_001 PASS      430.00
** test_axis_switch.run_test_tuser_assert_002 PASS      430.00
** test_axis_switch.run_test_tuser_assert_003 PASS      430.00
** test_axis_switch.run_test_tuser_assert_004 PASS      430.00
** test_axis_switch.run_arb_test_001  PASS      930.00
** test_axis_switch.run_stress_test_001 PASS     20380.00
** test_axis_switch.run_stress_test_002 PASS     72370.00
** test_axis_switch.run_stress_test_003 PASS     67260.00
** test_axis_switch.run_stress_test_004 PASS     69970.00
*****
** TESTS=25 PASS=25 FAIL=0 SKIP=0      544260.03
*****

```

Figure 7. Simulation Results

Revision History

Date	Version	Revisions
November 21, 2023	0.01	Initial version AXIS Switch User Guide Document