LogiCORE IP AXI4-Stream Protocol Checker v1.0

Product Guide for Vivado Design Suite

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Introduction

The AXI4-Stream Protocol Checker core monitors AXI4-Stream interfaces for protocol violations and provides an indication of which violation occurred.

The checks are synthesizable versions of the System Verilog protocol assertions provided by ARM in the *AMBA 4 AXI4, AXI4-Lite, and AXI4-Stream Protocol Assertion User Guide*[Ref 2].

Features

- Supports checking for AXI4-Stream protocol.
- Supports interface widths:
  - TDATA width: 1 to 512 bytes
  - TUSER width: 0 to 4096 bits
  - TID width: 0 to 32 bits
  - TDEST width: 0 to 32 bits
- Supports optional signals:
  - TREADY
  - TSTRB
  - TLAST
  - TKEEP
- Programmable messaging levels for simulation operation.
- Instrumented to support Vivado Debug Nets and connections to Vivado Logic Analyzer monitoring.

LogiCORE IP Facts Table	
Core Specifics	
Supported Device Family(1)	Virtex®-7, Kintex™-7, Artix™-7
Supported User Interfaces	AXI4-Stream
Resources	See Table 2-1.
Provided with Core	
Design Files	RTL
Example Design	Not Provided
Test Bench	Not Provided
Constraints File	Not Provided
Simulation Model	Not Provided
Supported S/W Driver	N/A
Tested Design Flows(2)	
Design Entry	Vivado Design Suite
Simulation	Mentor Graphics Questa SIM Vivado Simulator
Synthesis	Vivado Synthesis.
Support	
Provided by Xilinx @ www.xilinx.com/support	

Notes:

1. For a complete list of supported devices, see Vivado IP catalog.
2. For the supported versions of the tools, see the Xilinx Design Tools: Release Notes Guide.

Overview

The AXI4-Stream Protocol Checker is used to debug interface signals in systems using the AXI4-Stream protocol. When placed in an AXI4-Stream system, the connection of the AXI4-Stream Protocol Checker monitors the traffic between the AXI4-Stream Master and AXI4-Stream Slave core.

The interface is checked against the rules outlined in the AXI Specification to determine if a violation has occurred [Ref 2]. These violations are reported in a simulation log file message and as a debug net in the Vivado Logic Analyzer. In addition, the violations appear on the status vector output port from the core, as shown in Figure 1-1.

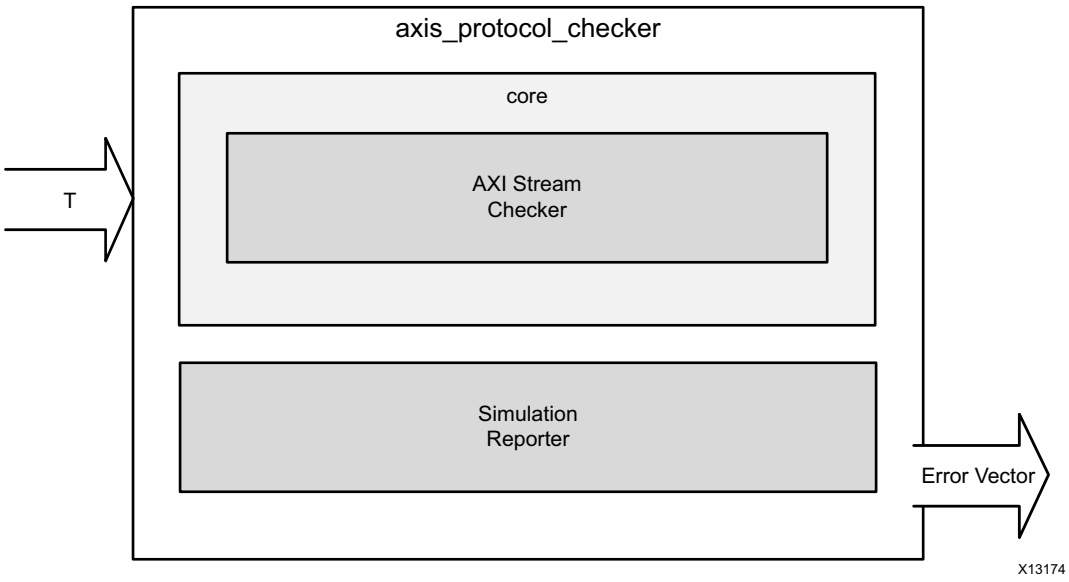

Figure 1-1: **AXI4-Stream Protocol Checker**

Applications

The AXI4-Stream Protocol Checker is typically used to ensure that traffic on a given AXI4-Stream connection complies with the AXI4-Stream protocol.

Licensing and Ordering Information

This Xilinx LogiCORE IP module is provided at no additional cost with the Xilinx Vivado Design Suite under the terms of the Xilinx End User License.

Information about this and other Xilinx LogiCORE IP modules is available at the Xilinx Intellectual Property page. For information on pricing and availability of other Xilinx LogiCORE IP modules and tools, contact your local Xilinx sales representative.

Product Specification

The AXI4-Stream Protocol Checker monitors the connection for AXI4-Stream protocol violations. The AXI4-Stream Protocol Checker is designed around the ARM System Verilog assertions that have been converted into synthesizable HDL. When a protocol violation occurs, the AXI4-Stream Protocol Checker asserts the corresponding bit on the `pc_status` output vector. The output vector bit mapping can be found in Table 2-4.

Bits of the `pc_status` vector are synchronously set when a protocol violation occurs. Multiple bits can be triggered on the same or different cycles. When the bit within the `pc_status` vector has been set, it remains asserted until either the connection has been reset with `aresetn` or the core has been reset with `system_resetn`.

Standards

The AXI interfaces conform to the Advanced Microcontroller Bus Architecture (AMBA®) AXI version 4 specification from Advanced RISC Machine (ARM®), including the AXI4-Lite control register interface subset [Ref 2].

Performance

This section details the performance information for various core configurations.

Maximum Frequencies

The maximum frequency for largest configuration listed in Table 2-1 is 225MHz.

Resource Utilization

The resources listed in Table 2-1 have been estimated for the Virtex-7 XC7VX485T FPGA. These values were generated using the Vivado IP Catalog. They were derived from post-synthesis reports, and might change during the implementation stages.

Table 2-1: **Virtex-7 Resource Utilization (XC7VX485T)**

Range	HAS_TKEEP	HAS_TLAST	HAS_TREADY	HAS_TSTRB	MAXWAITS	TDATA BYTES	TDEST_WIDTH	TID_WIDTH	TUSER_WIDTH	LUTs	FFs
Largest	1	1	1	1	128	512	32	32	1024	0	14362
-	1	1	1	1	16	16	4	0	16	0	467
-	1	1	1	0	32	8	4	0	0	0	212
-	1	1	1	0	32	8	4	0	0	0	212
Smallest	0	0	0	0	0	0	0	0	1	0	22

Port Descriptions

Table 2-2 lists the common interface signals. Table 2-3 lists the AXI4-Stream ports.

IMPORTANT: *Due to the flexible nature of the AXI4-Stream protocol definition, all ports except ACLK, ARESETn and TVALID are optional ports.*

Table 2-2: **Protocol Independent Ports**

Signal Name	Direction	Default	Width	Description
aclk	Input	Required	1	Interface clock input
aresetn	Input	Required	1	Interface reset input (active-Low)
aclken	Input	1	1	Interface clock enable input (active-High)
system_resetn	Input	Optional	1	System reset (active-Low). This signal can be enabled through the configuration GUI.
pc_status	Output		11	Active-High vector of protocol violations or warnings.
pc_asserted	Output		1	Active-High signal is asserted when any bit of the pc_status vector is asserted.

Table 2-3: **AXI4-Stream Protocol Ports**

Signal Name	Direction	Default	Width	Description
pc_axis_tlast	Input	1'b1	1	Stream Channel Last Data Beat
pc_axis_tdata	Input		DATA_WIDTH	Stream Channel Data
pc_axis_tstrb	Input	All Ones	DATA_WIDTH/8	Stream Channel Byte Strobes
pc_axis_tkeep	Input	All Ones	DATA_WIDTH/8	Stream Channel Byte Keeps
pc_axis_tuser	Input		USER_WIDTH	Stream Channel user-defined signal
pc_axis_tvalid	Input	Required	1	Stream Channel Valid
pc_axis_tready	Input	1'b1	1	Stream Channel Ready

Table 2-3: **AXI4-Stream Protocol Ports *(Cont'd)***

Signal Name	Direction	Default	Width	Description
pc_axis_tid	Input		ID_WIDTH	Stream Channel Transaction ID
pc_axis_tdest	Input		DEST_WIDTH	Stream Channel Transaction DEST

Checks and Descriptions

The AXI4-Stream Protocol checks and descriptions listed in Table 2-4 are the same as the assertions that are found in the ARM AXI Assertions [Ref 2] with minor differences. Table 2-4 details the bits contained in the `pc_status` vector.

Table 2-4: **Checks and Descriptions**

Name of Protocol Check	Bit	Description
AXI4STREAM_ERRM_TVALID_RESET	0	TVALID is Low for the first cycle after aresetn goes High. This assertion is not available when the system_resetn port is not enabled.
AXI4STREAM_ERRM_TID_STABLE	1	TID remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if both TREADY and TID are enabled on the interface.
AXI4STREAM_ERRM_TDEST_STABLE	2	TDEST remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if both TREADY and TDEST are enabled on the interface.
AXI4STREAM_ERRM_TKEEP_STABLE	3	TKEEP remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if TDATA, TREADY and TKEEP are enabled on the interface.
AXI4STREAM_ERRM_TDATA_STABLE	4	TDATA remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if both TREADY and TDATA are enabled on the interface.
AXI4STREAM_ERRM_TLAST_STABLE	5	TLAST remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if both TREADY and TLAST are enabled on the interface.
AXI4STREAM_ERRM_TSTRB_STABLE	6	TSTRB remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if TDATA, TREADY and TSTRB are enabled on the interface.
AXI4STREAM_ERRM_TVALID_STABLE	7	When TVALID is asserted, it must remain asserted until TREADY is High. This assertion is only valid if TREADY is enabled on the interface.
AXI4STREAM_RECS_TREADY_MAX_WAIT	8	It is recommended that TREADY is asserted within MAXWAITS cycles of TVALID being asserted. This assertion is only valid if TREADY is enabled on the interface.

Table 2-4: **Checks and Descriptions *(Cont'd)***

Name of Protocol Check	Bit	Description
AXI4STREAM_ERRM_TUSER_STABLE	9	TUSER remains stable when TVALID is asserted, and TREADY is Low. This assertion is only valid if both TREADY and TUSER are enabled on the interface.
AXI4STREAM_ERRM_TKEEP_TSTRB	10	If TKEEP is de-asserted, then TSTRB must also be de-asserted. This assertion is only valid it TDATA, TSTRB and TKEEP are enabled on the interface.

Designing with the Core

This chapter includes guidelines and additional information to facilitate designing with the core.

General Design Guidelines

The AXI4-Stream Protocol Checker should be inserted into a system as shown in Figure 3-1.

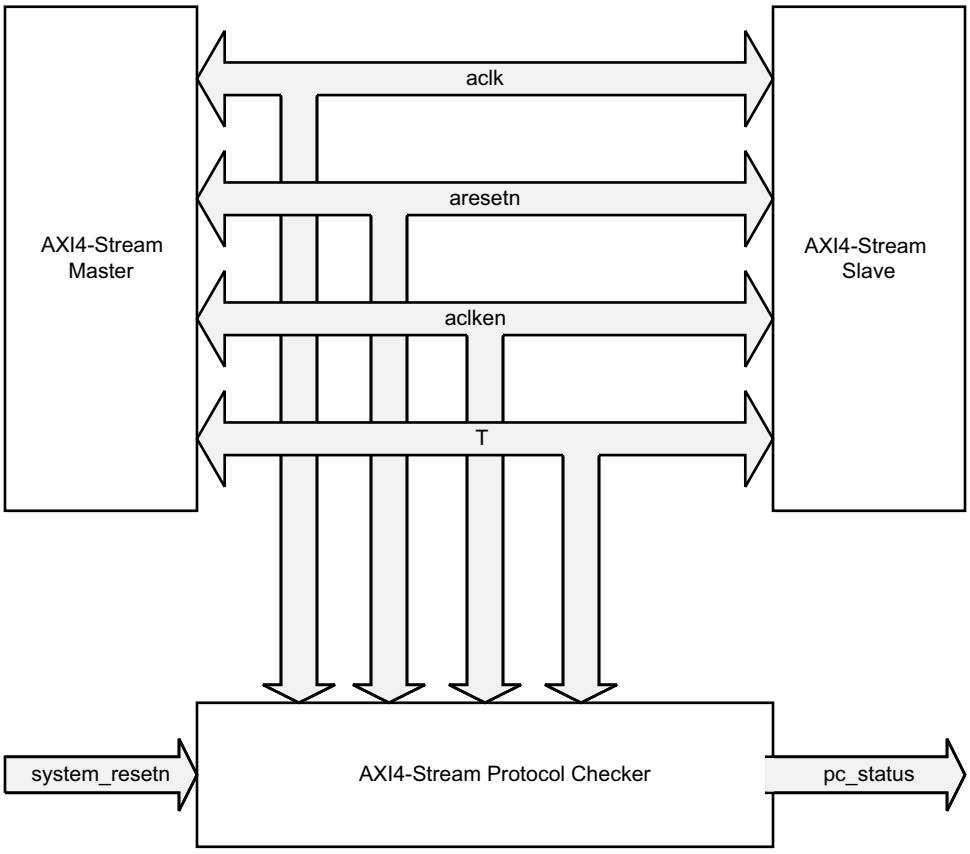

Figure 3-1: **AXi4-Stream Connections**

It is typically easier to find protocol violations during simulation. In simulation, it is possible to instantiate protocol checkers on all AXI4-Stream interfaces.

TIP: *It is highly recommended to debug a system in simulation rather than in hardware. A processor can be used to monitor the pc_status port connecting the signals to an axi_gpio core.*

Simulation

When simulating, the AXI4-Stream Protocol Checker can be configured to print display messages as follows:

```
<time>ns : <instance_path> : BIT( <bit_number>) : <log_level> : <violation_message>
```

The fields shown are defined as:

- **instance_path**: The simulation hierarchy of the protocol checker instance that is issuing the message.
- **bit_number**: Indicates which bit in the `pc_status` vector is asserted. This bit can be used to look up the violation in Table 2-4.
- **log_level**: Messaging-level text that can be one of the following values: INFO, WARNING, or ERROR with the ability to stop or finish the simulation. This value is set via the configuration GUI.
- **violation_message**: Descriptive message indicating the name of the violation (for example, AXI4STREAM_ERRM_TVALID_RESET) and violation. In most cases, the location of the full violation description in the AXI specification is included. The violation message name can be used to look up the violation in Table 2-4.

For example:

```
73717.00ns : tb.top.AXI4STREAM_0.REP : BIT(0) : ERROR :
AXI4STREAM_ERRM_TVALID_RESET. TVALID must be low for the first clock edge that
ARESETn goes high. Spec: section 2.7.2, and figure 2-4 on page 2-11.
```

The core provides a debugging capability for simulation. Based on the messaging-level configuration, the AXI4-Stream Protocol Checker can either, continue, finish, or stop the simulation at the point of detecting the violation.

Clocking

The same `aclk` that is connected to both the AXI4-Stream Master and AXI4-Stream Slave should also be connected to the AXI4-Stream Protocol Checker.

Resets

At a minimum, the AXI4-Stream Protocol Checker requires the `aresetn` signal. A `system_resetn` can be configured to clear the pc_status vector without resetting the AXI4-Stream interface. Both reset inputs are synchronous to `aclk`. The assertion of either reset clears the `pc_status` vector.

TIP: *Xilinx recommends asserting `aresetn` for a minimum of 16 clock cycles.*

If system_resetn is enabled, the AXI4-Stream Protocol Checker cab check the AXI4-Stream Protocol specification that defines the state of the interface following the de-assertion of `aresetn`. This check Protocol violation notifications related to the required behavior of the interface with respect to `aresetn` are cleared using `system_resetn`. When a system reset is not available, `system_resetn` should be disabled. When this is done, the AXI4STREAM_ERRM_TVALID_RESET check is not possible.

Customizing and Generating the Core

This chapter includes information about using Xilinx tools to customize and generate the core in the Vivado™ Design Suite environment.

GUI

Locate the IP core in the Vivado IP Catalog and click it once to select it. Details regarding the solution are displayed in the Details window. To configure the IP, double-click the IP name in the IP catalog.

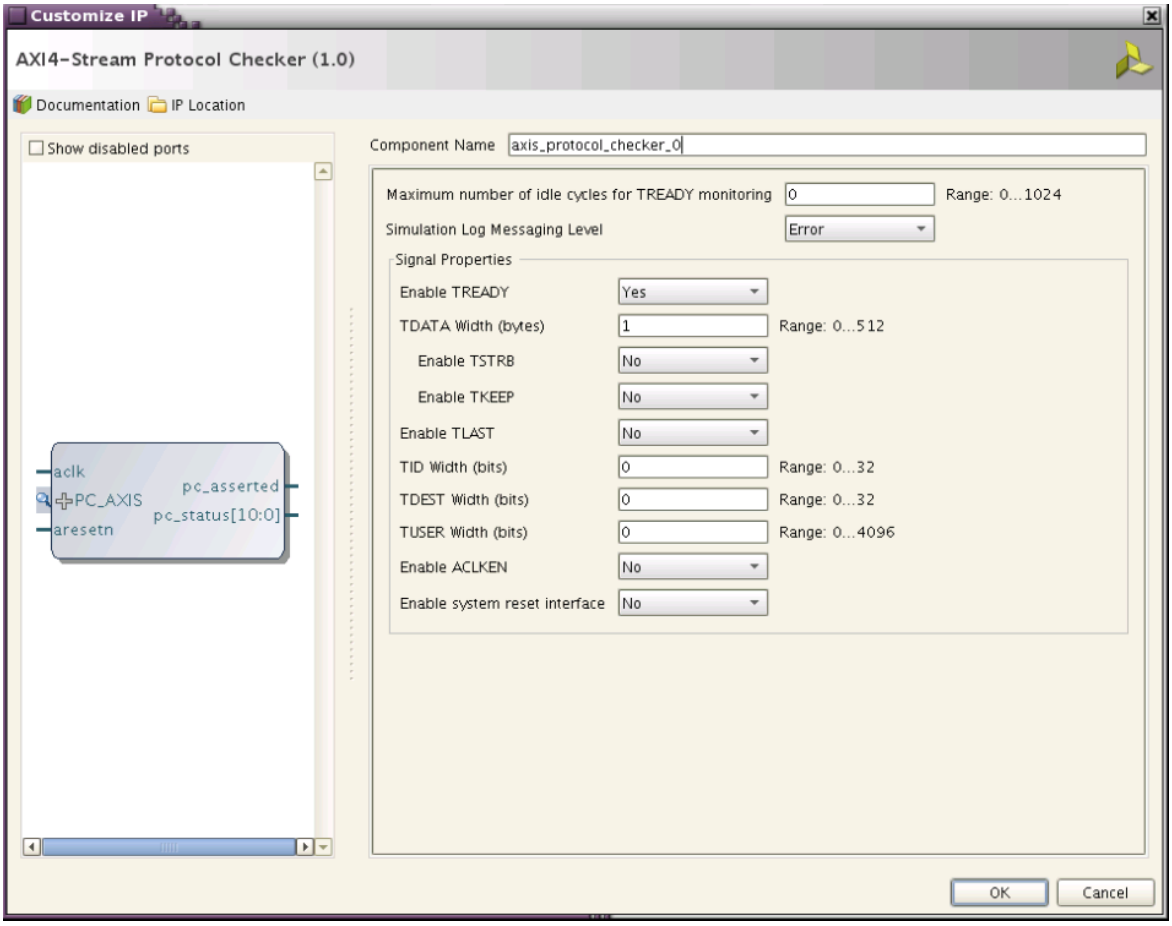

Figure 4-1: **Vivado IP Catalog GUI**

Modify the parameters to meet the requirements of the larger project into which the core is integrated. The following subsections detail the options.

Global Parameters

- **Component Name**: The base name of the output files generated for the core. Names must begin with a letter and can be composed of any of the following characters: a to z, 0 to 9, and "_".
- **TDATA Width**: Specifies the width of the TDATA data path and its companion signals if enabled to be monitored by the protocol checker. If set to 0, the signal is omitted.
- **TID Width**: Specifies the width of the TID signal (if any) to be monitored by the protocol checker. If set to 0, the signal is omitted.
- **TDEST Width**: Specifies the width of the TDEST signal (if any) to be monitored by the protocol checker. If set to 0, the signal is omitted.
- **TUSER Width**: Specifies the width of the TUSER signal (if any) to be monitored by the protocol checker. If set to 0, the signal is omitted.
- **TREADY Enabled**: When checked, the TREADY signal is monitored by the protocol checker. If unchecked, the signal is omitted.
- **TSTRB Enabled**: When checked, the TSTRB signal is monitored by the protocol checker. If unchecked, the signal is omitted. This box is not available when the TDATA width is 0.
- **TKEEP Enabled**: When checked, the TKEEP signal is monitored by the protocol checker. If unchecked, the signal is omitted. This box is not available when the TDATA width is 0.
- **TLAST Enabled**: When checked, the TLAST signal will be monitored by the protocol checker. If unchecked the signal is omitted.

Parameter Checker Options

- **Maximum number of idle cycles for TREADY monitoring**: Specifies the maximum number of cycles between the assertion of TVALID to the assertion of TREADY before an ERROR is generated. When the value is set to 0, this check is disabled.
- **Simulation Log Messaging Level**: When a violation is triggered this parameter allows the core to indicate to the simulation log file different error levels or to disable all messaging entirely. It is also possible via this parameter, to stop or finish the simulation upon a protocol violation occurrence.
- **Enable system reset interface**: Enables the system_resetn port. When disabled the port is tied High.

Output Generation

The AXI4-Stream Protocol Checker deliverables are organized in the directory `<project_name>/<project_name>.srcs/sources_1/ip/<component_name>` and is designed as the primary source directory (`<ip_source_dir>`). The relevant contents or the directories are described in the following sections.

<ip_source_dir>

The Vivado Design Suite project files are located in the root of the <ip_source_dir> directory.

Table 4-1: **ip_source_dir Directory**

Name	Description
`<ip_source_dir>`	
`<component_name>.xci`	Vivado tools IP configuration options file. This file can be imported into any Vivado tools design and be used to generate all other IP source files.
`<component_name>.{veo|vho}`	AXI4-Stream Protocol Checker instantiation template.
`hdl/verilog/*.v`	AXI4-Stream Protocol Checker source files.
`synth/<component_name>.v`	AXI4-Stream Protocol Checker generated top-level file for synthesis. This file is optional and is only generated if synthesis target selected.
`sim/<component_name>.v`	AXI4-Stream Protocol Checker generated top-level file for simulation. This file is optional and is only generated if simulation target selected.

<project directory>

The project directory contains all the Vivado IP catalog project files.

Table 4-2: **project directory Directory**

Name	Description
`<project_directory>`	
`<component_name>_xmdf.tcl`	Xilinx standard IP core information file used by Xilinx design tools.

Constraining the Core

This chapter contains information about constraining the core in the Vivado™ Design Suite environment.

Required Constraints

There are no required constraints for this core.

Device, Package, and Speed Grade Selections

See IP Facts for details on device support.

Clock Frequencies

There are no clock frequency constraints for this core.

Clock Management

There are no clock management constraints for this core.

Clock Placement

There are no clock placement constraints for this core.

Banking

There are no banking constraints for this core.

Transceiver Placement

There are no transceiver placement constraints for this core.

I/O Standard and Placement

There are no I/O constraints for this core.

Debugging

This appendix includes details about resources available on the Xilinx Support website and debugging tools. The following topics are included in this appendix:

- Finding Help on Xilinx.com
- General Checks
- Debug Tools
- Clocks and Resets
- Core Size and Optimization
- Flags

Finding Help on Xilinx.com

To help in the design and debug process when using the AXI4-Stream Protocol Checker, the Xilinx Support web page (www.xilinx.com/support) contains key resources such as product documentation, release notes, answer records, information about known issues, and links for opening a Technical Support WebCase.

Documentation

This product guide is the main document associated with the AXI4-Stream Protocol Checker. This guide, along with documentation related to all products that aid in the design process, can be found on the Xilinx Support web page (www.xilinx.com/support) or by using the Xilinx Documentation Navigator.

Download the Xilinx Documentation Navigator from the Design Tools tab on the Downloads page (www.xilinx.com/download). For more information about this tool and the features available, open the online help after installation.

Contacting Technical Support

Xilinx provides technical support at www.xilinx.com/support for this LogiCORE™ IP product when used as described in the product documentation. Xilinx cannot guarantee timing, functionality, or support of product if implemented in devices that are not defined in the

documentation, if customized beyond that allowed in the product documentation, or if changes are made to any section of the design labeled DO NOT MODIFY.

To contact Xilinx Technical Support:

1. Navigate to www.xilinx.com/support.
2. Open a WebCase by selecting the WebCase link located under Support Quick Links.

When opening a WebCase, include:

- Target FPGA including package and speed grade.
- All applicable Xilinx Design Tools and simulator software versions.
- Additional files based on the specific issue might also be required. See the relevant sections in this debug guide for guidelines about which file(s) to include with the WebCase.

Answer Records

All answer records for this core are linked off the AXI4-Stream Protocol Checker Master Answer Record.

General Checks

The AXI4-Stream Protocol Checker design limits the types of problems one may encounter when using the core. In the case where the interface is not fully specified, the system designer must ensure that any unused inputs to the AXI4-Stream Protocol Checker have been correctly tied off based on the AXI4-Stream Protocol. See Table 2-3 for the correct tie-off values.

Debug Tools

Vivado Lab Tools

Vivado inserts logic analyzer and virtual I/O cores directly into your design. Vivado Lab Tools allows you to set trigger conditions to capture application and integrated block port signals in hardware. Captured signals can then be analyzed. This feature represents the functionality in the Vivado IDE that is used for logic debugging and validation of a design running in Xilinx FPGA devices in hardware.

The AXI4-Stream Protocol Checker core supports probing using the Vivado ILA 2.0 core and the Vivado Logic Analyzer. All of the protocol checks named in Table 2-4 are available as Unassigned Debug Nets in the synthesized design. See UG936, Vivado Design Suite Tutorial: Programming and Debugging on the Vivado Design Suite on the Vivado documentation page.

It is also possible to monitor all or one bit of the `pc_status` vector via any method of the designer's choosing.

Clocks and Resets

To resolve clocking and reset issues, verify these items:

- Check that `aclk` is connected to the same clock that is driving both the Master and Slave interfaces.
- Check that `aresetn` is connected to the same reset that is driving both the Master and Slave interfaces.
- Check that `aclken` is connected to the same reset that is driving both the Master and Slave interfaces.
- Ensure that both `aresetn` and `system_resetn` (if enabled) are connected to active-Low polarity.
- Ensure that `aresetn` is both synchronously asserted and released on `aclk`.

Core Size and Optimization

In some cases the size of the core can become very large. The following tips can reduce the size of the core:

- Set the maximum number of idle cycles for READY monitoring to 0. This disables a recommended *VALID to *READY wait checks.
- Each bit of the pc_status vector consumes some amount of resources; therefore, fewer bits observed reduces the overall foot print of the design.

Flags

- **No Flags Asserted**: One simple test to check to see if the AXI4-Stream Protocol Checker is correctly connected to the interface is to not connect the `pc_axis_tready`

input into the protocol checker and to tie that port to 0. This causes multiple bits in the pc_status vector to be asserted when AXI4-Stream traffic begins because this will violate all the AXI4STREAM_ERRM_T*_STABLE protocol checks (bits [1:7] and 9). See Table 2-4 for the descriptions of these checks.

- **Flags Asserted**: If there are bits asserted in the pc_status vector and the source/reason of the violation using Table 2-4 is not clear, move the AXI4-Stream Protocol Checker "upstream" toward the AXI4-Stream Master generating the transactions.

Additional Resources

Xilinx Resources

For support resources such as Answers, Documentation, Downloads, and Forums, see the Xilinx Support website at:

www.xilinx.com/support.

For a glossary of technical terms used in Xilinx documentation, see:

www.xilinx.com/company/terms.htm.

References

These documents provide supplemental material useful with this product guide:

1. *AMBA AXI4-Stream Protocol Specification*
2. *AMBA 4 AXI4, AXI4-Lite, and AXI4-Stream Protocol Assertion User Guide*
3. *Xilinx AXI Reference Guide* (UG761)
4. Vivado™ Design Suite User Documentation

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
03/20/2013	1.0	Initial Xilinx release.

Notice of Disclaimer