Introduction

The LogiCORE™ IP 7 Series FPGAs Integrated Block for PCI Express® core is a high-bandwidth, scalable, and reliable serial interconnect building block for use with Xilinx® 7 Series FPGA families. The Integrated Block for PCI Express (PCIe®) solution supports 1-lane, 2-lane, 4-lane, and 8-lane Endpoint configurations at up to 5 Gb/s (Gen2) speeds, all of which are compliant with the *PCI Express Base Specification, rev. 2.1.* This solution supports the AMBA® AXI4-Stream interface for the customer user interface.

PCI Express offers a serial architecture that alleviates many of the limitations of parallel bus architectures by using clock data recovery (CDR) and differential signaling. Using CDR (as opposed to source synchronous clocking) lowers pin count, enables superior frequency scalability, and makes data synchronization easier. The layered architecture of PCI Express provides for future attachment to copper, optical, or emerging physical signaling media. PCI Express technology, adopted by the PCI-SIG® as the next generation PCI, is backward-compatible to the existing PCI software model.

With higher bandwidth per pin, low overhead, low latency, reduced signal integrity issues, and CDR architecture, the Integrated Block for PCIe sets the industry standard for a high-performance, cost-efficient, third-generation I/O solution.

The Integrated Block for PCI Express solution is compatible with industry-standard application form factors such as the *PCI Express Card Electromechanical (CEM) v2.0* and the *PCI Industrial Computer Manufacturers Group (PICMG) 3.4* specifications.

LogiCORE IP Facts Table	
Core Specifics	
Supported Device Family[1]	Virtex-7, Kintex-7
Minimum Device	XC7K70T-1 [2]
Supported User Interfaces	AXI4-Stream
Resources	See Table 1
Special Features	GTXE2 Transceivers, 7 Series FPGAs Integrated Block for PCI Express, Virtex-7/Kintex-7 FPGA Mixed-Mode Clock Manager (MMCM), Block RAM
Provided with Core	
Documentation	Product Specification User Guide Instantiation Template
Design Files	Verilog/VHDL[3] RTL Source and Simulation Models Verilog/VHDL Test Bench, Verilog/VHDL Example Design
Example Design	Verilog, VHDL
Test Bench	Verilog, VHDL
Constraints File	User Constraints File (UCF)
Simulation Model	Verilog, VHDL
Supported S/W Driver	N/A
Tested Design Tools	
Design Entry Tools	ISE v13.4
Simulation[4]	Cadence Incisive Enterprise Simulator (IES) Synopsys VCS and VCS MX Mentor Graphics ModelSim
Synthesis Tools	XST v13.4
Support	
Provided by Xilinx @ www.xilinx.com/support	

1. For a complete listing of supported devices, see the release notes for this core.
2. Designs needing 8-lane operation with 5 Gb/s (Gen2) speeds must use the 128-bit version of the product and a -2 or -3 speed grade device.
3. RTL source for the GTX wrapper is Verilog only. VHDL projects require mixed language mode simulators.
4. For a listing of the supported tool versions, see the ISE Design Suite 13: Release Note Guide.

Table 1: **Resources Used**

Product	Interface Width	GTXE1	LUT[1]	FF[2]	RX Buffers Size (KB)	TX Buffers Size (KB)	CMPS[2] (Bytes)	Block RAM	MMCMs	Clock Buffers
1-lane Gen1/Gen2[3]	64-bit	1	400	575	8 or 16	4-32	128-1024	2-16	1	5
2-lane Gen1/Gen2	64-bit	2	525	750						
4-lane Gen1	64-bit	4	800	1100						
4-lane Gen2	64-bit, 128-bit	4	800	1300						
8-lane, Gen1	64-bit, 128-bit	8	1350	2275						
8-lane, Gen2	128-bit	8	1450	2600						

1. Numbers are for the default core configuration. Actual LUT and FF utilization values vary based on specific configurations.
2. Capability Maximum Payload Size (CMPS).
3. Gen1 speeds are 2.5 Gb/s. Gen2 speeds are 5.0 Gb/s.

Table 2 lists the minimum device requirements for 7 series FPGAs Integrated Block for PCI Express configurations.

Table 2: **7 Series FPGAs Integrated Block for PCI Express Configurations**

		Kintex-7 FPGAs	Virtex-7 FPGAs			
		XC7K480T XC7K420 XC7K410T XC7K355T XC7K325T XCK7160T[1] XC7K70T[1]	XC7VX485T	XC7V585T	XC7V1500T[2]	XC7V2000T[2]
Number of Integrated Blocks for PCIe		1	4	3	3	4
Lanes	Gen1 (2.5 Gb/s)	1–8	1–8	1–8	1–8	1–8
	Gen2 (5.0 Gb/s)	1–8	1–8	1–8	1–8	1–8
	Gen3 (8.0 Gb/s)[3]	—	—	—	—	—
Speed Grade	x1–x4 Gen1	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -2L	-1, -2, -2L
	x8 Gen1	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -2L	-1, -2, -2L
	x1–x4 Gen2	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -3, -2L	-1, -2, -2L	-1, -2, -2L
	x8 Gen2	-2, -3, -2L (1V)	-2, -3, -2L (1V)	-2, -3, -2L (1V)	-2, -2L (1V)	-2, -2L (1V)
Maximum Payload Size MPS (Bytes)	Gen1	1024	1024	1024	1024	1024
	x1–x4 Gen2	1024	1024	1024	1024	1024
	x8 Gen2	512 (-3) 256 (-2, -2L)	512 (-3) 256 (-2, -2L)	512 (-3) 256 (-2, -2L)	512 (-3) 256 (-2, -2L)	512 (-3) 256 (-2, -2L)

Notes:
1. Kintex-7 FPGA FBG484 packages only support x1, x2, and x4 operation.
2. XC7V1500T and XC7V2000T are not available in the ISE tool flow.
3. The integrated block does not support Gen3 operation.

Features

- High-performance, highly flexible, scalable, and reliable, general-purpose I/O core
  - Compliant with the *PCI Express Base Specification, rev. 2.1*
  - Compatible with conventional PCI software model
- Incorporates Xilinx Smart-IP technology to guarantee critical timing
- Uses GTXE2 transceivers for 7 Series FPGA families
  - 2.5 GT/s and 5.0 GT/s line speed
  - Supports 1-lane, 2-lane, 4-lane, and 8-lane operation
  - Elastic buffers and clock compensation
  - Automatic clock data recovery
- Supports Endpoint configurations
- 8B/10B encode and decode
- Supports Lane Reversal and Lane Polarity Inversion per PCI Express specification requirements
- Standardized user interface
  - Supports AXI4-Stream interface
  - Easy-to-use packet-based protocol
  - Full-duplex communication
  - Back-to-back transactions enable greater link bandwidth utilization
  - Supports flow control of data and discontinuation of an in-process transaction in transmit direction
  - Supports flow control of data in receive direction
- Compliant with PCI/PCI Express power management functions
- Supports a maximum transaction payload of up to 1024 bytes
- Supports Multi-Vector MSI for up to 32 vectors and MSI-X
- Up-configure capability enables application driven bandwidth scalability
- Compliant with PCI Express transaction ordering rules

Applications

The Xilinx 7 series FPGAs Integrated Block for PCI Express architecture enables a broad range of computing and communications target applications, emphasizing performance, cost, scalability, feature extensibility and mission-critical reliability. Typical applications include:

- Data communications networks
- Telecommunications networks
- Broadband wired and wireless applications
- Cross-connects
- Network interface cards
- Chip-to-chip and backplane interconnect
- Crossbar switches
- Wireless base stations

Functional Description

For information about the internal architecture and detailed descriptions of the interfaces of the integrated block in Virtex®-7 and Kintex™-7 FPGAs, see the *7 Series FPGAs Integrated Block for PCI Express User Guide*. Figure 1 illustrates the interfaces to the core.

- System (SYS) Interface
- PCI Express (PCI EXP) Interface
- Physical Layer Control and Status (PL) Interface
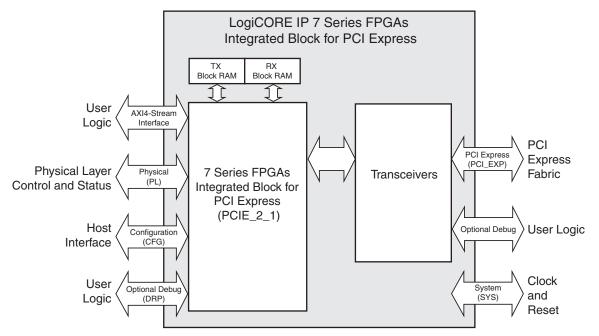- Configuration (CFG) Interface
- AXI4-Stream Interface

Figure 1: **Integrated Block for PCI Express Top-Level Functional Blocks and Interfaces**

Protocol Layers

The integrated block follows the *PCI Express Base Specification, rev. 2.1* layering model, which consists of the Physical, Data Link, and Transaction Layers. The protocol uses packets to exchange information between layers. Packets are formed in the Transaction and Data Link Layers to carry information from the transmitting component to the receiving component. Necessary information is added to the packet being transmitted, which is required to handle the packet at specific layers.

At the receiving end, each layer of the receiving element processes the incoming packet, strips the relevant information and forwards the packet to the next layer. As a result, the received packets are transformed from their Physical Layer representation to their Data Link Layer representation and Transaction Layer representation.

The functions of the protocol layers include:

- Generating and processing of TLPs
- Flow-control management
- Initialization and power management functions
- Data protection

- Error checking and retry functions
- Physical link interface initialization
- Maintenance and status tracking
- Serialization, deserialization and other circuitry for interface operation

Each of the protocol layers are defined in the sections that follow.

Physical Layer

The Physical Layer exchanges information with the Data Link Layer in an implementation-specific format. This layer is responsible for converting information received from the Data Link Layer into an appropriate serialized format and transmitting it across the PCI Express Link at a frequency and width compatible with the remote device.

Data Link Layer

The Data Link Layer acts as an intermediate stage between the Transaction Layer and the Physical Layer. Its primary responsibility is to provide a reliable mechanism for the exchange of Transaction Layer Packets (TLPs) between the two Components on a Link.

Services provided by the Data Link Layer include data exchange (TLPs), error detection and recovery, initialization services and the generation and consumption of Data Link Layer Packets (DLLPs). DLLPs are the mechanism used to transfer information between Data Link Layers of two directly connected components on the Link. DLLPs are used for conveying information such as Flow Control and TLP acknowledgments.

Transaction Layer

The upper layer of the PCI Express architecture is the Transaction Layer. The primary function of the Transaction Layer is the assembly and disassembly of Transaction Layer Packets (TLPs). Packets are formed in the Transaction and Data Link Layers to carry the information from the transmitting component to the receiving component. TLPs are used to communicate transactions, such as read and write, as well as certain types of events. To maximize the efficiency of communication between devices, the Transaction Layer implements a pipelined, full split-transaction protocol and manages credit-based flow control of TLPs.

Configuration Management

The Configuration Management Layer supports generation and reception of System Management Messages by communicating with the other layers and the user application. This layer contains the device configuration space and other system functions. The Configuration layer implements PCI and PCI Express power management capabilities, and facilitates exchange of power management messages, including support for PME event generation. Also implemented are user-triggered error message generation, and user-read access to the device configuration space.

PCI Configuration Space

The configuration space consists of three primary parts. These include the following:

- Legacy PCI v3.0 Type 0/1 Configuration Space Header
    - Type 0 Configuration Space Header, used by Endpoint applications
    - Type 1 Configuration Space Header, used by Root Port applications
- Legacy Extended Capability Items
    - PCIe Capability Item
    - Power Management Capability Item

- • Message Signaled Interrupt (MSI) Capability Item
- • MSI-X Capability Item (optional)
- • PCIe Extended Capabilities
  - • Device Serial Number Extended Capability (optional)
  - • Virtual Channel Extended Capability (optional)
  - • Vendor Specific Extended Capability (optional)
  - • Advanced Error Reporting Extended Capability (optional)
  - • Resizeable BAR Extended Capability (optional)

These capabilities, together with the standard Type 0/1 header, support software driven *Plug and Play* initialization and configuration.

Support

Xilinx provides technical 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*.

Ordering Information

The Xilinx 7 Series FPGAs Integrated Block for PCI Express is included with the CORE Generator™ software. No license key is required.

References

The following list provides supplemental information useful with this data sheet:

- • UG761, *Xilinx AXI Reference Guide*
- • *AMBA AXI4-Stream Protocol Specification*
- • UG477, *7 Series FPGAs Integrated Block for PCI Express User Guide*
- • Xilinx Solution Center for PCI Express

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
03/01/11	1.0	Initial Xilinx release. This release is for ISE 13.1 software and core release v1.1.
10/19/11	1.1	ISE 13.3 software release for core v1.2. • Updated the LogiCORE IP Facts table and added table note 3. • Updated Table 1 and added MMCM and Clock Buffer columns.
01/18/12	1.2	ISE 13.4 software release for core v1.3. • Revised the minimum device in the IP Facts table. • Added Table 2.

Notice of Disclaimer

The information disclosed to you hereunder (the "Materials") is provided solely for the selection and use of Xilinx products. To the maximum extent permitted by applicable law: (1) Materials are made available "AS IS" and with all faults, Xilinx hereby DISCLAIMS ALL WARRANTIES AND CONDITIONS, EXPRESS, IMPLIED, OR STATUTORY, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY, NON-INFRINGEMENT, OR FITNESS FOR ANY PARTICULAR PURPOSE; and (2) Xilinx shall not be liable (whether in contract or tort, including negligence, or under any other theory of liability) for any loss or damage of any kind or nature related to, arising under, or in connection with, the Materials (including your use of the Materials), including for any direct, indirect, special, incidental, or consequential loss or damage (including loss of data, profits, goodwill, or any type of loss or damage suffered as a result of any action brought by a third party) even if such damage or loss was reasonably foreseeable or Xilinx had been advised of the possibility of the same. Xilinx assumes no obligation to correct any errors contained in the Materials or to notify you of updates to the Materials or to product specifications. You may not reproduce, modify, distribute, or publicly display the Materials without prior written consent. Certain products are subject to the terms and conditions of the Limited Warranties which can be viewed at http://www.xilinx.com/warranty.htm; IP cores may be subject to warranty and support terms contained in a license issued to you by Xilinx. Xilinx products are not designed or intended to be fail-safe or for use in any application requiring fail-safe performance; you assume sole risk and liability for use of Xilinx products in Critical Applications: http://www.xilinx.com/warranty.htm#critapps.